Some Environmental Effects of Flooding in the Niger Delta Region of Nigeria

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Abstract: Some environmental effects of flooding in the Niger Delta region of Nigeria was reviewed to provide the desired knowledge needed for the effective management of flooding. Floods are caused by many factors: Heavy rainfall, highly accelerated snowmelt, severe winds over water, unusual high tide, tsunamis, or failure of dams, levees, retention ponds, or other structures that retained the water. Flooding can be exacerbated by increased amounts of impervious surface or by other natural hazards such as wildfires, which reduce the supply of vegetation that can absorb rainfall. The effects of flooding from the sources outlined above are felt by various 'receptors'. These include, people, buildings, infrastructure, agriculture, open recreational space and the natural world. Flood warning is the provision of advance warning of conditions that are likely to cause flooding to property and a potential risk to life. The main purpose of flood warning is to save life by allowing people, support and emergency services time to prepare for flooding. The secondary purpose is to reduce the effects and damage of flooding. Floods renew wetland areas which in turn host a wide range of flora and fauna. Preventing flood waters from entering such wetland areas will create imbalance to the natural state of things resulting to destruction of natural habitats and even extinction of various species of animals and plants. Floods play an important part in various ecosystems. Humans, therefore, should be careful when they try to prevent or control floods. Oftentimes, human intervention causes more harm than good. The study discuses the meaning of flooding, basic background of the Niger Delta causes of flooding, types of flooding, factors determining the effect of flooding, the effects of flooding, benefits of flooding and control of flooding with emphasis on some countries to provide the desired knowledge needed for the effective management of flooding in the Niger Delta region of Nigeria.

Keywords: Affecting factors, causes, economic benefits and control, flooding, types

INTRODUCTION

Flooding is one of the major environmental crises one has to contend of within the century. This is especially the case in most wetlands of the world. The reason of this is the general rise in sea level globally, due to global warming as well as the saturated nature of the wetlands in the Niger Delta. Periodic floods occur on many rivers, forming a surrounding region known as flood plain. Rivers overflow for reasons like excess rainfall. The good thing about river overflows is the fact that as flood waters flow into the banks, sand, silt and debris are deposited into the surrounding land. After the river water subsided and go back to its normal flow, the deposited materials will help make the land richer or more fertile. The organic materials and minerals deposited by the river water keep the soil fertile and productive (Abowei and Sikoki, 2005).

During times of rain or snow, some of the water is retained in ponds or soil. Some is absorbed by grass and vegetation, some evaporates and rest travels over the land as surface runoff. Flood occurs when ponds, lakes, riverbeds, soil and vegetation cannot absorb all the water. Water the runs off the land in quantities that cannot be carried within stream channels or retained in natural ponds, lakes and manmade reservoirs. About 30% of all precipitation becomes runoff and that amount might be increased by water from melting snow. A flood that raises rapidly, with little or no relatively small area, or if, the area was already saturated from previous precipitation (Henry, 2006).

During flooding water supplies that result in contamination of water (water pollution). Clean drinking water becomes scarce. Unhygienic conditions and Spread of water-borne diseases result. People, buildings, infrastructure, agriculture, open recreational space and the natural world. In extreme cases flooding may cause a loss of life. Torrential rains pushed rivers over their banks, collapsed mud houses and washed away livestock (Adelye and Rustum, 2011). Damage
bridges and caused a dam to overflow, submerging buildings, displacement from homes, the loss of personal valuables and the ongoing fear and insecurity caused by the experience. Potable water supplies may be lost or contaminated in a flood and this can have immediate health effects upon people and animals.

The economy can also be severely affected by flooding. Businesses may lose stock, patronage, data and productivity and disruption to utilities and transport infrastructure can have knock-on effects to a wider area. Tourism, farming and livestock can equally be affected. Vital infrastructure may also be damaged or disrupted. Electricity and gas supplies can be interrupted to individual properties but also to wider communities if sub stations and transformers themselves are flooded. Road links, railways, canals etc., may be blocked causing disruption to the wider transport network and accessibility severely disrupted for local inhabitants, especially amongst those considered most vulnerable and loss of communications networks (Adelye and Rustum, 2011).

Although flooding, generally, is a bane to most people, floods can be quite beneficial. Actually, believe it or not, nature benefits more from natural floods than from not having them at all. The thing that makes natural floods a disaster is when flood waters occur in areas populated by humans and in areas of significant human development. Otherwise, when left in its natural state, the benefits of floods outweigh the adverse effects (Bradshaw et al., 2007).

However, too much sand deposit will do the opposite. For farmers that maintain their crops along rivers, they should not feel threatened by yearly flooding. This gives their farm lands better soil consistencies and keeps their land fertile resulting to better harvests each year. Instead of preventing the natural flow of river floods, it might be beneficial in the long run to allow the flood waters to encroach into their lands (Hill, 1976). It was how nature intended it to be in the first place. However, there may be limits to how much farmers can tolerate such natural occurrences. One has to increase production to feed the demands of the human populace. Great examples of how river overflows benefit humans are in the Nile River and the Mississippi delta. Farmers in Egypt have long equated river floods to high harvest rates. The higher the flood waters from the river, the better the harvest for that year. However, the case of the Mississippi delta is a little different (O’Connor and John, 2004).

The Mississippi River naturally overflows and leaving behind huge deposits of sediments. In time these sediments created lands which are now identified as part of the Mississippi delta. But when humans began settling in along the river banks, they constructed complicated and elaborate systems to prevent or control the flood waters from the Mississippi river. Without the regular sediment deposits that the land along the area of the Mississippi delta receives from the river, the land begins to sink. Each year the Mississippi delta becomes dryer and sinks more and more (Rosenberg and Snor, 1975). The two primary causes are climate change, resulting in increased severity and intensity of rainfall and new developments on floodplains, which are they at risk of flooding and which increase the risk of flooding down stream. A review of some environmental effects of flooding in the Niger Delta region of Nigeria provides the desired knowledge needed for the effective management of flooding. The meaning of flooding, basic background of the Niger Delta causes of flooding, types of flooding, factors determining the effect of flooding, the effects of flooding, benefits of flooding and control of flooding with emphasis on some countries to provide the desired knowledge needed for the effective management of flooding in the Niger Delta region of Nigeria.

### LITRATURE REVIEW

**Meaning of flooding:** The word "flood" comes from the Old English "/flod/, a word common to Germanic languages (compare German /Flut/, Dutch /vloed/ from the same root as is seen in /flow, float/; also compare with Latin /fluctus/, /flumen/). Deluge myths are mythical stories of a great flood sent by a deity or deities to destroy civilization as an act of divine retribution and are featured in the mythology of many cultures. Floods (Fig. 1) can also occur in rivers, when flow exceeds the capacity of the river channel, particularly at bends or meanders. Floods often cause damage to homes and businesses if they are placed in natural flood plains of rivers. While flood damage can be virtually eliminated by moving away from rivers and other bodies of water, since time out of mind, people have lived and worked by the water to seek sustenance and capitalize on the gains of cheap and easy travel and commerce by being near water. That humans continue to inhabit areas threatened by flood damage is evidence that the perceived value of living near the water exceeds the cost of repeated periodic flooding (David et al., 1981).
Floods are also known to renew wetland areas which in turn host a wide range of flora and fauna. Preventing flood waters from entering such wetland areas will create imbalance to the natural state of things resulting to destruction of natural habitats and even extinction of various species of animals and plants. Floods play an important part in various ecosystems. Humans, therefore, should be careful when they try to prevent or control floods. Oftentimes, human intervention causes more harm than good (Esu, 1999).

Table 1 shows a list of some deadliest floods worldwide, showing events with death tolls at or above 100,000 individuals.

**Basic background of Niger Delta:** The Niger Delta (Fig. 2) covers 20,000 km² within wetlands of 70,000 km² formed primarily by sediment deposition. Home to 20 million people and 40 different ethnic groups, this floodplain makes up 7.5% of Nigeria's total land mass. It is the largest wetland and maintains the third-largest drainage basin in Africa. The Delta's environment can be broken down into four ecological zones: coastal barrier islands, mangrove swamp forests, freshwater swamps and lowland rainforests (Welch et al., 1977). This incredibly well-endowed ecosystem contains one of the highest concentrations of biodiversity on the planet, in addition to supporting abundant flora and fauna, arable terrain that can sustain a wide variety of crops, lumber or agricultural trees and more species of freshwater fish than any ecosystem in West Africa (Thompson, 1964). The region could experience a loss of 40% of its habitable terrain in the next thirty years as a result of extensive dam construction in the region. The carelessness of the oil industry has also precipitated this situation, which can
perhaps be best encapsulated by a 1983 report issued by the NNPC, long before popular unrest surfaced:

There has been the slow poisoning of the waters of this country and the destruction of vegetation and agricultural land by oil spills which occur during petroleum operations. But since the inception of the oil industry in Nigeria, more than 25 years ago, there has been no concerned and effective effort on the part of the government, let alone the oil operators, to control environmental problems associated with the industry (Powell, 2009)

It is estimated that:

- 1.5% of the country is at risk from direct flooding from the sea
- About 7% of the country is likely to flood at least once every 100 years from rivers
- 1.7 m homes and 130,000 commercial properties, worth more than £200 billion, are at risk from river or coastal flooding in England

Many more properties are also at risk from flash floods. The effects of flooding and managing flood risk, cost the UK around £2.2 billion each year: we currently spend around £800 million/annum on flood and coastal defenses; and, even with the present flood defenses in place, we experience an average of £1,400 million of damages.

Causes of flooding:

Floods are caused by many factors: Heavy rainfall, highly accelerated snowmelt, severe winds over water, unusual high tide, tsunamis, or failure of dams, levees, retention ponds, or other structures that retained the water. Flooding can be exacerbated by increased amounts of impervious surface or by other natural hazards such as wildfires, which reduce the supply of vegetation that can absorb rainfall (Welch et al., 1977)

Slow kinds: Runoff from sustained rainfall or rapid snow melts exceeding the capacity of a river's channel. Causes include heavy rains from monsoons, hurricanes and tropical depressions, foreign winds and warm rain affecting snow pack. Unexpected drainage obstructions such as landslides, ice, or debris can cause slow flooding upstream of the obstruction (USEPA, 2002).

Fast kinds: Include flash floods resulting from convective precipitation (intense thunderstorms) or sudden release from an upstream impoundment created behind a dam, landslide, or glacier (Thompson, 1964).

Floods commonly caused by a combination of sea tidal surges caused by storm-force winds. A storm surge, from either a tropical cyclone or an extra-tropical cyclone, falls within this category (Rosenberg and Snor, 1975).

Floods caused by severe sea storms, or as a result of another hazard (e.g., Tsunami or hurricane).

A storm surge, from either a tropical cyclone or an extra-tropical cyclone, falls within this category (Powell, 2009).

Floods caused by a significant and unexpected event e.g., dam breakage, or as a result of another hazard (e.g., earthquake or volcanic eruption).

Floods caused by accidental damage by workmen to tunnels or pipes.

Floods caused by a series of storms moving over the same area.

Floods caused by sea storms, or as a result of another hazard (e.g., earthquake or volcanic eruption).

Floods caused by accidental damage by workmen to tunnels or pipes.

A muddy flood is produced by an accumulation of runoff generated on cropland. Sediments are then detached by runoff and carried as suspended matter or bed load. Muddy runoff is more likely detected when it reaches inhabited areas. Muddy floods are therefore a hill slope process and confusion with mudflows produced by mass movements should be avoided (Esu, 1999).

Floods can occur if water accumulates across an impermeable surface (e.g., from rainfall) and cannot rapidly dissipate (i.e., gentle orientation or low evaporation).

Floods caused by a series of storms moving over the same area.

Floods caused by a series of storms moving over the same area.

Dam can flood low-lying urban and rural areas, often causing significant damage.

Severe winds over water: Even when rainfall is relatively light, the shoreline of lakes and bays can be flooded by severe winds such as during hurricanes that blow water into the shore areas.

Unusual high tides: Coastal areas are sometimes flooded by unusually high tides, such as spring tides, especially when compounded by high winds and storm surges.

Tsunamis: Tsunamis are high, large waves, typically caused by undersea earthquakes, volcanic eruptions or massive explosions.

Climate change: Climate Change is an attributed cause of flooding because when the climate is warmer it results to:

- Heavy rains
- Relative sea level will continue to rise around most shoreline
- Extreme sea levels will be experienced more frequently
Climate change is therefore likely to increase flood risk significantly and progressively over time. At particularly increased risk will be low-lying coastal areas, as sea levels rise and areas not currently prone to fluvial or tidal flooding as more intense rainfall leads to significantly higher risk of flooding from surface runoff and overwhelmed drainage systems.

Flaring and venting of natural gas from oil and gas wells contribution to greenhouse gases has declined by three-quarters in absolute terms since a peak in the 1970s of approximately 110 million metric tons/year and now accounts for 0.5% of all anthropogenic carbon dioxide emissions. Recently, under the Kyoto Protocol, garbage collecting companies in some developing nations have received a carbon bonus for installing combustion devices for the methane gas produced at their landfills, preventing methane from reaching the atmosphere. After the burning, this gas is converted to heat, water and CO2 and according to the IPCC Third Assessment Report of the IPCC, as Methane is 23 times more powerful a greenhouse gas than CO2 the greenhouse effect is reduced in the same order (David et al., 1981).

The greenhouse effect is a phenomenon whereby greenhouse gases create a condition in the upper atmosphere causing a trapping of heat and leading to increased surface and lower tropospheric temperatures. Carbon dioxide emissions from combustion of fossil fuels are a source of greenhouse gas emissions. Other greenhouse gases include methane, hydro fluorocarbons, per fluorocarbons, chlorofluorocarbons, nitrogen oxides and ozone. This effect has been understood by scientists for about a century and technological advancements during this period have helped increase the breadth and depth of data relating to the phenomenon. Currently, scientists are studying the role of changes in composition of greenhouse gases from natural and anthropogenic sources for the effect on climate change. A number of studies have also investigated the potential for long-term rising levels of atmospheric carbon dioxide to cause increases in the acidity of ocean waters and the possible effects of this on marine ecosystems. This can also cause rise in sea level and flooding (Bradshaw et al., 2007).

Influence of urban planning: Adelye and Rustum (2011) analyze the cause of the flooding problems in encountered to recommend sustainable management solutions to them. Data on climate, drainage infrastructures and physical planning regulations were collected and extensively analyzed. These were combined with evidence from field inspection and discussion with stakeholders, including relevant government departments, university researchers and selected resident. The investigation revealed that, contrary to popular wisdom, climate change or unusually high rainfall is not the primary cause of flooding problem in Lagos. Rather, the increased urbanization, lax planning laws in relation to the city are to blame. It is augured that a lasting solution to flooding problems will require the incorporation of sustainable drainage system within the existing flood management strategy for the city and planning for this must start now.

Types of flooding:

Tidal flooding: Both sea and river defenses may be overtopped or breached by a combination of low pressure weather systems and peak high tides. Storms with high wind speeds cause tall and powerful waves and low pressure fronts cause sea levels to rise above normal levels. High tide levels vary through the lunar and solar cycle and when superimposed upon other tidal variations exceptionally high tides result. The onset of flooding from the sea and tidal rivers is often sudden and the extreme forces driving it present a significant danger to life. The east coast storm surge of 1953 claimed 307 people's lives in the UK and 1,835 in Holland. A similar storm surge tide in September 2007 came within a few centimeters of breaching a number of the UK's coastal defenses. It is often possible to forecast, with reasonable accuracy, this type of flooding due to the predictability of the tide and track ability of low pressure systems. The duration of this type of flooding is also limited by the cycle of the tides where drainage is available (Dance and Hynes, 1980).

Fluvial flooding: Flooding occurs in the floodplains of rivers when the capacity of water courses is exceeded as a result of rainfall or snow and ice melts within catchment areas further upstream. Blockages of water courses and flood channels or tide locking may also lead to ponging and rising water levels. River defenses may then be overtopped due to increased water levels, or breached by large objects of debris carried at high water velocities. Flooding from rivers has in recent years been experienced in the Severn Valley, in Sheffield, in Hull from the river Humber in 2007 and Carlisle on the river Eden in 2006. The onset can be quite slow in some catchments with steadily rising water levels.

Flash flooding: Flash flooding can occur in steep catchments and is far more immediate. Flooding from rivers, particularly, in recognized floodplains, can usually be predicted with good accuracy. However flash floods from sudden downpours such as those in Carlisle continue to challenge the capability of detection and forecasting systems. Water over about 250 mm in depth may carry debris particularly in urban locations and can also be very cold. Even travelling at low speeds this can make it extremely hazardous to people caught in it.
Ground water: Low lying areas sitting over aquifers may periodically flood as ground water levels rise. This type of flooding is often seasonal and therefore can be forecasted with good accuracy. It is often slow in its onset.

Pluvial flooding: Surface water flooding is caused by rainwater run-off from urban and rural land with low absorbency. Increased intensity of development in urban areas has given rise to land with a larger proportion of non-permeable surfaces, a problem often exacerbated by overloaded and out-dated drainage infrastructure. These circumstances, combined with intense rainfall, can give rise to localized flooding. This sort of flooding often occurs outside of recognized floodplains and because it is caused by quite localized weather conditions it is very difficult to forecast. Its onset can also be very rapid and the level of flooding very severe. In the summer of 2007 much of the flooding experienced in Gloucestershire and Yorkshire was not directly caused by rivers but by surface water. Large volumes of rainfall early in the year saturated the ground and intense rainfall later caused both urban and rural areas to flood.

Flooding from sewers: Flooding from sewers can occur where there are combined storm and foul sewers and their capacity is exceeded due to large amounts of surface water run-off in a short time. Poor cleaning and maintenance can lead to blockages that can also cause local flooding. This type of flooding is hard to predict, has significant sanitary consequences for those affected and can occur very rapidly.

Flooding from manmade infrastructure: Canals, reservoirs and other manmade structures can fail causing flooding to areas downstream. Industrial activities, water mains and pumping stations can also give rise to flooding due to failure.

Factors which determine the effects of flooding:

The level of predictability: This affects the timing, accuracy and communication of warnings given before a flood.

The rate of onset of the flood: How quickly the water arrives and the speed at which it rises will govern the opportunity for people to prepare and respond effectively for a flood.

The speed and depth of the water: This dictates the level of exposure of people and property to a flood. It is difficult to stand or wade through even relatively shallow water that is moving. Flood water often carries debris, including trees and water over 1m in depth can carry objects the size of cars. Fast flowing water can apply devastating force to property and other receptors.

The duration of the flood: This is another important factor in determining the extent of its impact, particularly on individuals and affected communities.

The effects of flooding:

Primary effects: This includes physical damage that can damage any type of structure, including bridges, cars, buildings, sewerage systems, roadways and canals.

Secondary effects: This includes Water supplies that results in contamination of water (water pollution). Clean drinking water becomes scarce. Unhygienic conditions and Spread of water-borne diseases result.

The effects of flooding from the sources outlined above are felt by various 'receptors'. These include, people, buildings, infrastructure, agriculture, open recreational space and the natural world.

In extreme cases flooding may cause a loss of life. At least 102 people are now thought to have been killed by floods in and around the south-western Nigerian city of Ibadan. Floods took a deadly toll in northeastern Nigeria in August 2011. Torrential rains pushed rivers over their banks, collapsed mud houses and washed away livestock.

Floodwater, resulting from heavy rains, damaged three bridges and caused a dam to overflow, submerging buildings across the city. Most of the victims were children. The social and emotional costs from flooding can also be significant and are often widespread and indiscriminate in flooded areas. These costs include: displacement from homes, the loss of personal valuables and the ongoing fear and insecurity caused by the experience. Potable water supplies may be lost or contaminated in a flood and this can have immediate health effects upon people and animals.

The economy can also be severely affected by flooding. Businesses may lose stock, patronage, data and productivity and disruption to utilities and transport infrastructure can have knock-on effects to a wider area. Tourism, farming and livestock can equally be affected.
Fig. 3: Various forms of pollution carried by flooding

The built environment may be damaged or destroyed as a result of flooding with high repair costs and long periods required for reinstatement. The public realm is often badly affected through damage and the deposit of potentially large quantities of debris. Land contamination may also be transported and spread during flooding.

Vital infrastructure may also be damaged or disrupted. Electricity and gas supplies can be interrupted to individual properties but also to wider communities if sub stations and transformers themselves are flooded. Road links, railways, canals etc., may be blocked causing disruption to the wider transport network and accessibility severely disrupted for local inhabitants, especially amongst those considered most vulnerable.

A knock-on effect of the loss of electricity as a result of floods was the loss of communications networks. Telephones, radios, televisions and the internet are all increasingly reliant upon mains power and without a robust means of conveying information to householders, rescue and clean up operations may be hampered.

Clean-up activities flowing floods often pose hazards to worker and volunteers involved in the effort. Potential dangers include electrical hazards, carbon monoxide exposure, musculoskeletal hazards, heat or cold stress, motor vehicle-related dangers, fire, droning and exposure to hazardous materials. Because flooded disaster sites are unstable, clean-up workers might encounter sharp jagged debris, biological hazards in the flood water, exposed electrical lines, blood or other body fluids and animal and human remains. In planning for and reacting to flood disaster, managers provide with hard hats, goggles, heavy work gloves, life jackets and watertight boots with steal toes and insoles.

It is the source of sediments and all types of water pollution thus affecting both physical and chemical condition of water (Fig. 3).

Water quality plays a role in the distribution of fish. The importance of measuring physical, chemical
and biological variables was considered at the Technical Consultation on Enhancement of Fisheries of Small Water Bodies in Harare. The Physico-chemical characteristics of water are important parameters as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (George et al., 2010).

Variability of water quality influences the toxicity levels of heavy metals on estuarine organisms as it affects the Physico-chemical composition of the ecosystem. Water rising from market stalls and slaughter houses, streets washing and flushing of sewage which flow through drains into rivers altered the chemical composition of the water body thereby causing pollution.

Optimum fish production can be achieved only when the water quality is effectively managed. The required levels of physical and chemical characteristics of the culture medium, is necessary for fish culture. The availability of food organisms (planktons) and the influence of naturally occurring substances such as dissolved oxygen, carbon dioxide, ammonium nitrite and hydrogen ions (H+) are important factors affecting the growth and survival of cultured fish. The role of temperature, salinity and various pollutants in fish culture cannot be over looked. Thus, the water used for the cultivation of fish cannot yield maximum production, if the environmental conditions are not optimal for the growth of fish and other aquatic organisms. Therefore, there is the need to ensure that, these environmental factors are properly managed and regulated on a daily basis. This maintains these factors within a desirable range for the survival and growth of the fish.

Sediment is the loose sand, silt and other soil particles that settle at the bottom of a body of water (USEPA, 2002). It can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice help to carry these particles to rivers, lakes and streams. Sediment strata serve as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity (Abowei and Sikoki, 2005). Sediment is also the major site for organic matter decomposition which is largely carried out by bacteria. Important macro-nutrients such as nitrogen and phosphorous are continuously being interchanged between sediment and overlying water (Abowei and Sikoki, 2005).

The type and intensity of agricultural land use determine sediment load which play a role in determining the insects which survive in a stream (Dance and Hynes, 1980). Intensive agricultural land use produces modifications which reduce the variety of macro-invertebrate taxa. Agricultural land drainage includes channelization of water courses and Hill (1976) points out that such drainage schemes can have a considerable impact on hydrology, sediment load, water temperature, chemistry and aquatic biology. Welch et al. (1977) found that fish and benthos were less abundant in streams near farms than in those flowing through natural and clear-out forests and they stated that chemical contamination and sedimentation had caused the reduction. Dance and Hynes (1980) stated that a comparison of historical and present day conditions indicates that modifications of the drainage basin have produced drastic effects on the stream which flows through the most intensively farmed basin.

Land activities may introduce large amounts of sediment into nearby streams and rivers (David et al., 1981). Sediment input may impact stream communities through a variety of direct and indirect processes (Oschwald, 1972), including reduced light penetration, smothering, habitat reduction and introduction of absorbed pollutants (pesticides, metals, nutrients). Sediment addition has been found to affect benthos (Rosenberg and Snor, 1975). The effect of sediment addition is simply to reduce available habitat area (David et al., 1981). The structure of the sediments in the intertribal zone plays a major role in the distribution of the organisms that live in or on them (Ikomi et al., 2005). Benthic organisms show habitat preference for specific types of sediment. The Physico-chemical parameters of the sediments such as salinity, dissolved oxygen, pH and organic carbon could also influence the occurrence and abundance of species distributed in them Mclusky and Eliot (1981).

Table 2 shows the effects of flooding on the water quality. Surface water temperature, dissolved oxygen, 

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<tr>
<th>Parameter</th>
<th>Flooding effects</th>
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<td>Surface water temperature</td>
<td>Increases</td>
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<tr>
<td>Salinity</td>
<td>Reduces</td>
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<td>Dissolved oxygen</td>
<td>Increases</td>
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<tr>
<td>Conductivity</td>
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<td>Turbidity</td>
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<tr>
<td>pH</td>
<td>Increases</td>
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<tr>
<td>Biochemical Oxygen Demand BOD</td>
<td>Increases</td>
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<tr>
<td>Total dissolved solids in water</td>
<td>Increases</td>
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<td>Depth</td>
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<td>Waves</td>
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<td>Planktons</td>
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<td>Nektons</td>
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Table 2: Effects of flooding on surface water quality
conductivity, turbidity, pH, Biochemical Oxygen Demand, Total Dissolved Solid in Water, Water Depth, Waves and Water Current increases with flood intensity while salinity, planktons and nektons reduces with increase in flood intensity.

Mineral soils are often composed of inorganic particles of varying sizes called soil separates. The relative proportions of the various separate or size groups of individual soil grains in a mass of soil is referred to as soil texture. The soil texture specifically refers to the proportions of sand, silt and clay below 2000 μm (2 mm) in diameter in a mass of soil (Esu, 1999). Sand is generally coarse and gritty, silt is smooth like flour and clay is sticky and plastic when wet. The texture class determines the microbiological population of a soil and hence the biological and biochemical reactions taking place in such a soil, (Esu, 1999).

Excess nutrients especially phosphates, sulphates and nitrates are classified as pollutants in waste water. Large tonnage of phosphate enters rivers and lakes through super phosphate fertilizer washed from soil and from chemicals used to improve the performance of detergents (Abowei and Sikoki, 2005). Phosphate is considered a pollutant principally because of Lake eutrophication resulting in algal bloom (Abowei and Sikoki, 2005).

Benefits of flooding: There are many disruptive effects of flooding on human settlements and economic activities. However, floods (in particular the more frequent/smaller floods) can also bring many benefits, such as recharging ground water, making soil more fertile and providing nutrients in which it is deficient. Flood waters provide much needed water resources in particular in arid and semi-arid regions where precipitation events can be very unevenly distributed throughout the year. Freshwater floods particularly play an important role in maintaining ecosystems in river corridors and are a key factor in maintaining floodplain biodiversity. Flooding adds a lot of nutrients to lakes and rivers which leads to improved fisheries for a few years, also because of the suitability of a floodplain for spawning (little predation and a lot of nutrients). Fish like the weather fish make use of floods to reach new habitats. Together with fish also birds profit from the boost in production caused by flooding.

Periodic flooding was essential to the well-being of ancient communities along the Tigris-Euphrates Rivers, the Nile River, the Indus River, the Ganges and the Yellow River, among others. The viability for hydrological based renewable sources of energy is higher in flood prone regions.

Control of floods: Flood control refers to all methods used to reduce or prevent the detrimental effects of flood waters. Some methods of flood control have been practiced since ancient times. These methods include:

- Planting vegetation to retain extra water
- Terracing hillsides to slow flow down hills
- Construction of flood ways (man-made channels to divert floodwater)
- Other techniques include the construction of levees, dikes, dams, reservoirs or retention ponds to hold extra water during times of flooding

METHODS OF CONTROL

Dams: Many dams and their associated reservoirs are designed completely or partially to aid in flood protection and control.

River defenses: In many countries, rivers prone to flood are often carefully managed. Defenses as levees, bunds, reservoirs and weirs are used to prevent rivers from overflowing their banks. When these defenses fail, emergency measures such as sandbags or portable inflatable tubes are used.

A weir, also known as low head dam, is most often used to create millponds, but on the Humber River in Toronto, a weir was built near Raymore Drive to prevent a reoccurrence of flood damage caused by Hurricane Hazel (1954).

Coastal defenses: Coastal flooding has been addressed in Europe and the Americas with coastal defense, such as sea walls, beach nourishment and barrier islands.

Tide gates are used in conjunction with dykes and culvers. They can be placed at the mouth of streams or small rivers, where an estuary begins or where tributary streams, or drainage ditches connect to sloughs. Tide gates close during incoming tides to prevent tidal waters from moving upland and open during outgoing tides to allow waters to drain or via the culvert and into the estuary side of the dike. The opening and closing of the gates is driven by a difference in water level on either side of the gate.

Flood warning is the provision of advance warning of conditions that are likely to cause flooding to property and a potential risk to life. The main purpose of flood warning is to save life by allowing people, support and emergency services time to prepare for flooding. The secondary purpose is to reduce the effects and damage of flooding.
The benefits associated with flood forecasting and warning are inextricably linked with the effectiveness of the warning dissemination programmes and the activities of the public and supporting agencies (both voluntary and official) in their response. The total benefits can be defined as the reduction in losses (tangible and intangible) resulting from the provision of a warning when compared to the situation prior to the operation of the warning system.

Tangible losses are the cost of the damage arising as a consequence of the physical contact of floodwater with property (direct losses) and the losses which are consequent upon direct flood damage (indirect losses). Flood warning systems can provide a reduction in direct losses through:

- The timely operation of flood control structures (e.g., gates)
- Temporary flood defenses preventing inundation of property and land
- Pre-event maintenance operations to ensure free channel conveyance
- The installation of flood resilience measures (e.g., sandbags, property flood barriers)
- The removal of property to somewhere above the flood level or out of the flood plain

Intangible losses include loss of life and injury and the damage caused to human health and long-term well-being. Such losses are extremely difficult to quantify in economic terms, but are important considerations when evaluating the benefits of any flood management scheme, particularly flood warning where significant impacts can be made through facilitation of timely evacuation of those at risk.

Organizations represented by the PSG have recognized that a revised flood warning system benefit assessment methodology is required that takes appropriate account of both tangible and intangible benefits. This report documents a scoping study undertaken by HR Wallingford, John Chatterton (J Chatterton Associates) and Maureen Fordham (Northumbria University) of the range of approaches adopted to date and recommends potential components and characteristics that could be used within the development of future methodologies.

KEY FINDINGS AND RECOMMENDATIONS

- The over-riding justification for implementation of flood warning systems is mitigating risks to life or serious injury and any future flood warning system benefit assessment methodology should reflect this.
- There is a need for any tangible benefit assessment methodology for flood warning scheme justification to move from a largely uni-directional focus on the movement of possessions, to a holistic approach incorporating the benefits from operational and resilience activities. For an economic quantification approach, damage datasets and flood damage avoided factors used in England and Wales would require validation for Scotland. The dependence of benefit levels on a range of catchment characteristics also requires evaluation through future pilot study work.
- It has only been very recently that there has been any agreement on indicative figures for the intangible impacts of flooding and that research has been confined to England and Wales. There is still a lack of clear guidance on the quantification of intangible flood warning benefits in any part of the UK. This call for a minimum of further research to understand what effects warnings have on people's health and wellbeing and therefore what value warning systems have in benefit appraisals.
- It would be possible to undertake an economic valuation of the tangible benefits of flood warning by adapting and validating the new Multi-Colored Manual (MCM, 2005) model and associated datasets for application in Scotland and enhancing these with any potential operational and resilience benefits that might be realized as a result of flood warning system implementation. However, research to date has demonstrated the high likely level of uncertainties and variability of both potential flood damage datasets and the factors used to convert potential to actual savings attributable to a flood warning scheme.
- The Project Steering Group (PSG) therefore believe that a multi-criteria scoring approach is the most appropriate benefit assessment model for SEPA at present which will allow strategic prioritization of schemes nationally, based on an understanding of the score achieved by a proposed scheme across a range of benefit components.
- A multi-criteria approach will require strict validation via ground frothing to indicate the relative weights of each component and sub-component. The influence of catchment and community characteristics on scores and weights will also require evaluation. Pilot study work including expert opinion surveys, interviews, focus groups and key stakeholder consultation will be
required to support the development of a robust scoring methodology.

- A Decision Support System is recommended to support a structured approach to decision making and to facilitate sensitivity testing. A GIS-based approach, similar to the MDSF system (developed and used by the Environment Agency to implement Catchment Flood Management Plans) would:
  - Allow the mapping of each of the benefit scores and the visualization of
  - Zones and levels of benefits
  - Allow a benefit assessment framework to be coded into the tool
  - Allow systematic sensitivity testing

In many countries across the world, rivers prone to floods are often carefully managed. Defenses such as levees, bunds, reservoirs and weirs are used to prevent rivers from bursting their banks. When these defenses fail, emergency measures such as sandbags or portable inflatable tubes are used. Coastal flooding has been addressed in Europe and the Americas with coastal defenses such as sea walls, beach nourishment and barrier islands.

While flood modeling is a fairly recent practice, attempts to understand and manage the mechanisms at work in floodplains have been made for at least six millennia. The recent development in computational flood modeling has enabled engineers to step away from the tried and tested "hold or break" approach and its tendency to promote overly engineered structures.

Various computational flood models have been developed in recent years either 1D models (flood levels measured in the channel) and 2D models (flood depth measured for the extent of the floodplain). HEC-RAS the Hydraulic Engineering Centre model is currently among the most popular if only because it is available for free. Other models such as TUFLOW combine 1D and 2D components to derive flood depth in the floodplain. So far the focus has been on mapping tidal and fluvial flood events but the 2007 flood events in the UK have shifted the emphasis onto the impact of surface water flooding.

**Europe:** Remembering the misery and destruction caused by the 1910 Great Flood of Paris, the French government built a series of reservoirs called Les Grands Lacs de Seine (or Great Lakes) which helps remove pressure from the Seine during floods, especially the regular winter flooding. London is protected from sea flooding by the Thames Barrier, a huge mechanical barrier across the River Thames, which is raised when the sea water level reaches a certain point.

Venice has a similar arrangement, although it is already unable to cope with very high tides; a new system of variable-height dikes is under construction. The defenses of both London and Venice would be rendered inadequate if sea levels were to rise. The Adige in Northern Italy was provided with an underground canal that allows to drain part of its flow into the Garda Lake (in the Po drainage basin), thus lessening the risk of estuarine floods. The underground canal has been used twice, in 1966 and 2000.

The largest and most elaborate flood defenses can be found in the Netherlands, where they are referred to as Delta Works with the Oosterschelde dam as its crowning achievement. These works were built in response to the North Sea flood of 1953 of the southwestern part of the Netherlands. The Dutch had already built one of the world's largest dams in the north of the country: the Afsluitdijk.

Currently the Saint Petersburg Flood Prevention Facility Complex is to be finished by 2008, in Russia, to protect Saint Petersburg from storm surges. It also has a main traffic function, as it completes a ring road around Saint Petersburg. Eleven dams extend for 25.4 km and stand 8 m above water level.

In Austria, flooding for over 150 years, has been controlled by various actions of the Vienna Danube regulation, with dredging of the main Danube during 1870-75 and creation of the New Danube from 1972-1988. In Northern Ireland flood risk management is provided by Rivers Agency.

**North America:** Another elaborate system of floodway defences can be found in the Canadian province of Manitoba. The Red River flows northward from the United States, passing through the city of Winnipeg (where it meets the Assiniboine River and into Lake Winnipeg. As is the case with all north-flowing rivers in the temperate zone of the Northern Hemisphere, snowmelt in southern sections may cause river levels to rise before northern sections have had a chance to completely thaw. This can lead to devastating flooding, as occurred in Winnipeg during the spring of 1950. To protect the city from future floods, the Manitoba government undertook the construction of a massive system of diversions, dikes and floodways (including the Red River Floodway and the Portage Diversion. The system kept Winnipeg safe during the 1997 flood that devastated many communities upriver from Winnipeg, including Grand Forks, North Dakota and Ste. Agathe, Manitoba. It also kept Winnipeg safe during the 2009 flood.

In the U.S., the New Orleans Metropolitan Area, 35% of which sits below sea level, is protected by
hundreds of miles of levees and flood gates. This system failed catastrophically, in numerous sections, during Hurricane Katrina, in the city proper and in eastern sections of the Metro Area, resulting in the inundation of approximately 50% of the metropolitan area, ranging from a few centimetres to 8.2 m in coastal communities. In an act of successful flood prevention, the Federal Government of the United States offered to buy out flood-prone properties in the United States in order to prevent repeated disasters after the 1993 flood across the Midwest. Several communities accepted and the government, in partnership with the state, bought 25,000 properties which they converted into wetlands. These wetlands act as a sponge in storms and in 1995, when the floods returned, the government did not have to expend resources in those areas.

**Asia:** In India, Bangladesh and China, flood diversion areas are rural areas that are deliberately flooded in emergencies in order to protect cities. Many have proposed that loss of vegetation (deforestation) will lead to a risk increase. With natural forest cover the flood duration should decrease. Reducing the rate of deforestation should improve the incidents and severity of floods.

**Africa:** In Egypt, both the Aswan Dam (1902) and the Aswan High Dam (1960) have controlled various amounts of flooding along the Nile River.

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