Department of Mechanical and Industrial Engineering

HYLERT: MULTI-LEVEL ALERT SYSTEM FOR INCREASED PREPAREDNESS IN FLOOD SITUATIONS

HYLERT: MITMETASANDILINE HOIATUSSÜSTEEM ÜLEUJUTUSSITUATSIOONIDEKS VALMISOLEKU SUURENDAMISEKS

MASTER THESIS

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Tallinn, 2019

AUTHOR’S DECLARATION

Hereby I declare, that I have written this thesis independently.
No academic degree has been applied for based on this material. All works, major viewpoints and data of the other authors used in this thesis have been referenced.

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THESIS TASK

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Thesis topic:

HYLERT: Multi-level alert system for increased preparedness in flood situations

HYLERT: Mitmetasandiline hoiatussüsteem üleujutussituatsioonideks valmisoleku suurendamiseks

Thesis main objectives:

1. To explore the relevance of designing for floods, as it is a frequent occurrence due to climate change.
2. To analyse how preparedness, impact the timeline of a flood.
3. To develop concepts and propose a solution, which functions as a multi-layered alert system.

Thesis tasks and time schedule:

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3.	Design proposals + expert reviewing	05.05.19
4.	Thesis writing finalization	20.05.19

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ABSTRACT

This study examines how a multi-level flood alert system can increase the preparedness factor during floods. The research mainly focuses on past floods situations and the analysis of the steps, which could have been amended or reorganized to reduce the losses. So far, all designs related to flood risk prevention has been created with the flood itself in mind. However, there is a need to create a more human-centered design that can relate with the user rather than the disaster itself. The behaviour of those affected by a flood, is a crucial variable element to focus on, when researching on the events placed on a timeline.

The proposed design process is based upon making the user an active participant in the flood communication chain, rather than a passive receiver. The aim was to enhance the locals involvement in the communication value chain by introducing a system than responds at levels that are relevant to location. The aspect of combining a partially automated response system built in layers to an alert system, allows the decision making time to be reduced significantly. The system will have a linking between the levels of users, as well as environment when interlinking the communication flow.

The prototyped system, HYLERT is based on creating this interlinking of the communication flow by dividing the requirements into three main levels. It is primarily an alert system that is combined with the levelled feedback structure, to improve efficiency during the pre-disaster phase of a flood. The system will use existing water-level monitoring systems, however it will now include a reactive tool so that for those receiving the alerts can be proactive according to their needs.

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PREFACE

This thesis has been written to fulfill the graduation requirements of the Design and Technology Futures (MSc) program at the Tallinn University of Technology (TALTECH). The writing of this dissertation was conducted between December 2018 and May 2019. Since the study was focused towards designing for a natural disaster, the research phase was fairly difficult as it was primarily based on past floods. Nevertheless, conducting further investigation has allowed me to answer the problem that was identified. While there were certain limitations when conducting research from Estonia, the rising number of floods occuring around the flood, it was brought to consensus that this was indeed a problem, which needed more innovative design thinking. The reason to research this subject was due to my own experience of growing up in an environment where there was a lack of preparedness in terms of facing seasonal floods. Also, the fact that adapting to loss was considered as progress, rather than designing towards the benefit of those living in such situations.

This study was made possible with help from various individuals that contributed directly or indirectly with their relevant expertise. Firstly, I would also like to take this opportunity to thank my supervisor, Professor Ruth-Helene Melioranski and my co-supervisor, Professor Martin Pärn for their guidance throughout the thesis writing period. Appreciate your timely evaluations and field advisor recommendation. I would also like to extend my gratitude to Mr. Gert Teder, Duty Officer of the North Estonian Regional Rescue - Lilleküla fire brigade, for the field knowledge, support and the introduction to fellow acquaintance Dr. Simon Hildon who provided flood related expertise. Mr. Teder contributed a significant amount of information in the initial stages of the thesis, where it was vital to communicate the relevance of this project to the present society.

I appreciate all respondents who assisted, during the primary research phase as without this knowledge, the analysis would not have been successful. My mother deserves a special note of thanks: thank you for your advice, support and kind words that have encouraged me always. It was understood that the design process is continuous, as technology improves and the needs of the environment around us evolves. Solutions are not limited to one product or solution, rather it is about the change that we make with the most appropriate application of resources. This understanding has been my greatest learning from this master thesis.

LIST OF ABBREVIATIONS

EM-DAT:	Emergency Events Database
CRED:	Centre for Research on the Epidemiology of Disasters
CO_2:	Carbon dioxide
EEA:	The European Environment Agency
UN:	United Nations
OCHA:	Office for the Coordination of Humanitarian Affairs
OQCS:	Office of Queensland Chief Scientist
FTS:	Financial Tracking Service
HCD:	Human centered design
HCI:	Human-computer interaction
NRDC:	Natural Resources Defense Council
BOM:	Bureau of Meteorology
RMC:	Regional Meteorological Centre
LL-EWS:	Level line - Early flood Warning System
MC:	Monitoring Component
PSA:	Public Service Announcement
IoT:	Internet of things

INTRODUCTION

With the world's climate been a highly discussed topic of the present day, it is important to look into the impact it has on the human race. As all things in life, people tend to regard matters when issue affect our lives negatively. Climate change has not been a priority to larger institutions as it it was considered a natural notion of life. Nonetheless, with the rising number of natural disasters there has been growing interest on how the human behaviour has caused the nature to retaliate and how we has a community can be proactive when facing such situations.

Looking into the topic of natural disasters, there have been many authors who have discussed the topic of disaster preparedness as a whole. However, researchers have not treated floods in much detail as natural disaster has individual characteristics that impacts the preparedness level. Also, the research to date has tended to focus on floods on a global scale rather than regionally, which means the outcomes are unbiased. First responders, trained for disaster management situations are handed most of the control to be proactive and reactive during flood. While this can be looked at positively, this immediately eliminated the possibility of the civilians themselves been more self sufficient. One must consider that civilian in these situations also have the ability to take control to a certain extent if they are provided with the relevant tools.

In this study the focus is to provide a self sustaining tool to individuals facing a flood disasters. Initially the importance of climate change was discussed and then the impact natural disasters have caused was highlighted. Post-flood relief is much of a discussed topic, while the initial stages of preparedness is mostly related to how one would react after the disaster occurs.

The efficiency of preparedness vastly depends on communication but the element of not been able to react leaves most people helpless. So the purpose is to make a connection between to the two streams, which are preparedness and responsiveness. The methodology of this study was based on analysing the past floods to understand the lack of preparedness that was handed over to the civilians, to be more proactive. As most similarities between the causes of floods can be drawn between Asia and the Australasia regions, these were selected as the primary subjects for the development of this tool in terms of exploratory research.

The differentiations of reactiveness primarily is based on the level of preparedness however, this element has not been discussed priorly as it could be controversial when discussing human behaviour in a cultural level (IDEO, 2015).

Due to the gravity of the impact caused by flood disasters it is vital to understand that floods have a personality of their own. The responsibility to react appropriately depends on the information and the tools provided to humans. Indeed there's a gap in the resources available regionally due to resources available locally. The ability to increase the communication channel with available technology can be done, by structuring the reactive communication line, resulting in a responsive alert system.

In the design brief, the requirement for a reactive system is analysed and framing for concept development is formed in the design brief. Simultaneously with the ideation process, concept development is done as a problem solving step.

For this, the impact of a flood needs to be analysed in based on a breakdown of environments. The choice of environments will depend of the daily habits and behavioural patterns. The design concept should be applicable in different environments and the impact after implementation is examined in the design outcome phase. The overall viability of the study is presented with in the conclusion and the potential studies that can be further developed in this are is introduced.

1 BACKGROUND

Climate change is much of a discussion these days due to the natural disasters experienced by countries around the world. Global warming, has triggered a chain reaction of many other changes to the earth's climate. Negative effects of climate change due to human behaviour has already increased in number and strength.

During the last few decades, there has been an increase of extended periods of excessively high temperatures, heavy rains, extreme floods and droughts. Nature fights back in the form of natural disasters and this can be identified as an after effect of humans' negative impact towards the environment The impact of climate change is not only felt on land but on water bodies such as lakes, rivers and the oceans and seas as well.

Since the earth's surface is covered by more water in comparison to land, the warming of the oceans has accounted for around 93 %, of the total global warming. This warming is happening as a result of increasing release of greenhouse gases (such as CO_2), which as result increases the amount of trapped solar energy in the atmosphere.

Most of this trapped heat is eventually stored in the oceans, affecting water temperature and circulation. "Increasing temperatures are also melting polar ice caps. As the total area of the global ice and snow cover shrinks, it reflects less solar energy back into space, further warming the planet. This results in more freshwater entering the oceans, changing the oceans currents further "(EEA-Europa, 2018).

Global climate is projected to continue to change significantly in the centuries to come. The effect of climate change, beyond the next few decades depends primarily on the behaviour of humans and the patterns that we adapt along the way. Nonetheless, it is important to think of innovations that can work towards building a community that is more self-sustained and aware its surrounding.

1.3 Natural disasters of the present day

Heat waves as shown Figure 1.1.1A are periods that are abnormally hot weather lasting days to weeks. The number of heat waves has been increasing in recent years. Figure 1.1.1B presents a primary challenge during, 'Droughts' where the most valuable resource such as water is scarce. As high temperatures lead to increased rates of evaporation, including more loss of moisture through plant leaves.

Figure 1.1.1A Heat Wave approaching

Figure 1.1.1B Drought conditions (Guardian, 2019)

Heavy downpours have increased globally significantly over the last three to five decades. As shown in in Figure 1.1.1C heavy rainfall events leading to 'floods' frequently forces people in certain regions to evacuate their homes. are an outcome of an overflow or inundation of water that causes or threatens damage anything its path (Figure 1.1.1D). Overall, there's considerable increase in the number of 'hurricanes, winter storms, earthquakes and tsunamis' taking place in the recent years giving importance to precautionary steps on a global scale.

Figure 1.1.1C Flood Evacuation

Figure 1.1.1D Flooded housing (Guardian, 2019)

2. PROBLEM CONTEXTUALIZATION (LITERATURE REVIEW)

2.1 Why focus on floods?

Floods are the most common natural disaster and the leading cause of natural disaster fatalities worldwide. Risk of catastrophic losses due to flooding is significant given deforestation and the increasing proximity of large populations to coastal areas, river basins and lakeshores. At least 3,686 flood disasters have occurred between 100 and 2010. Each year at least 62,000 people died from floods and at least 28 million are estimated to be affected (EM-DAT, 2010.

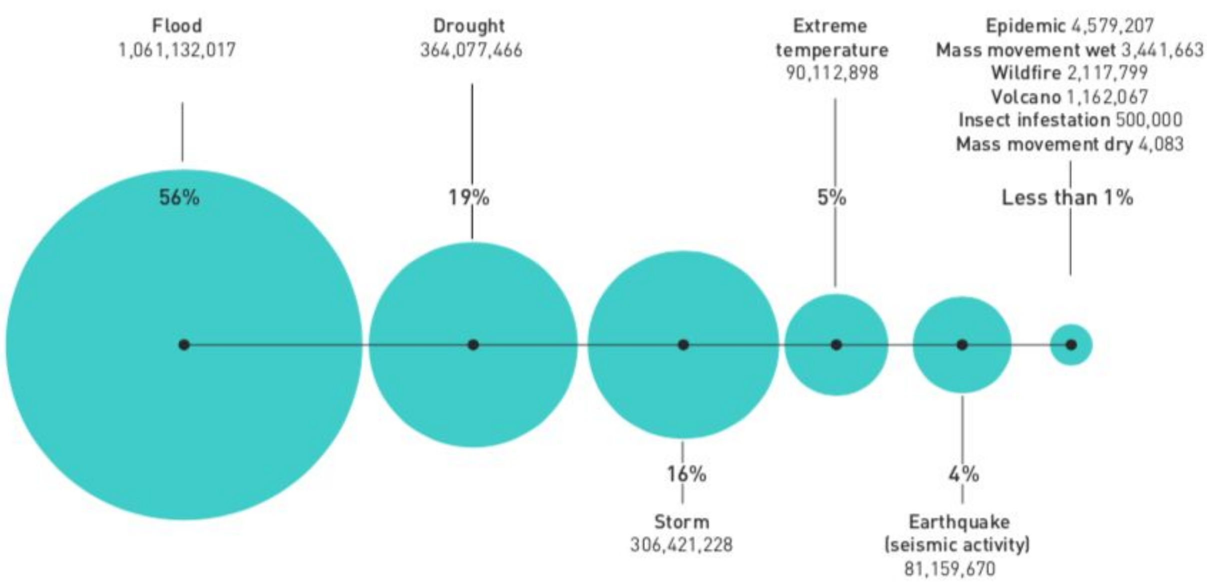

Figure 1.2.1: The number of people affected by natural disaster type, 2003–2012 (EM-DAT CRED, 2012)

Data in Figure 1.2.1 shows that floods affected over ten million people during a decade. Floods cause extensive damage more frequently to some regions, in comparison to other weather-related hazards.

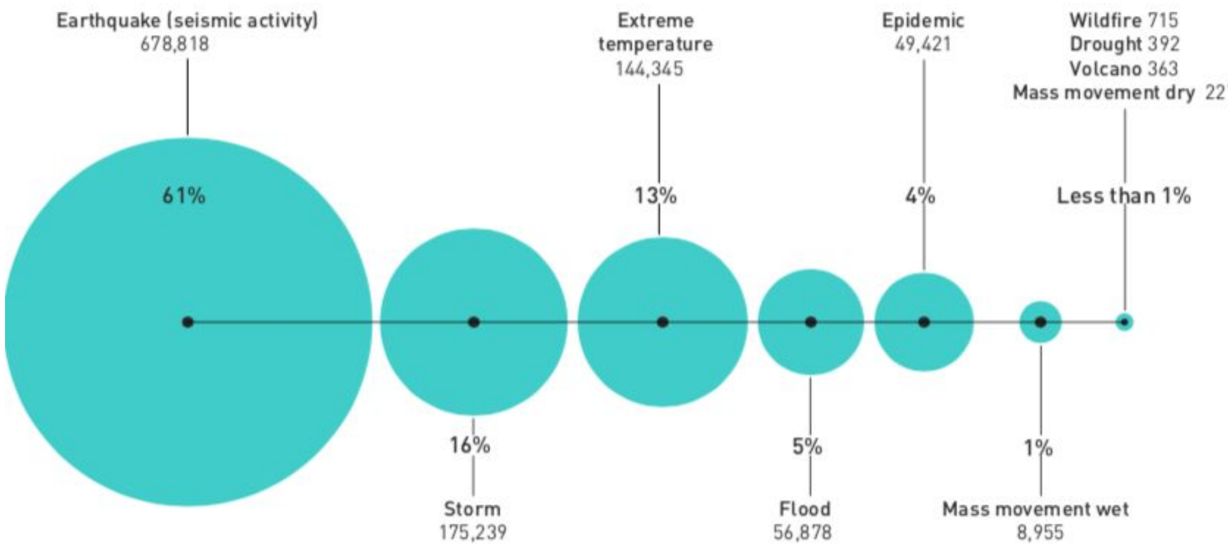

Figure 1.2.2: Number of people killed by a type of natural disaster, 2003–2012 (Development Initiatives, 2013)

According to Figure 1.2.2 floods have caused over 56,000 deaths between 2003 and 2012, which is about 5% of the deaths recorded due to natural disasters during that decade. In the United States, floods caused 4,586 deaths from 1959 to 2005. There was also a property and crop damage averaging nearly 8 billion dollars per year through 1981 to 2011. The risks from future floods are significant, given expanded development in coastal areas, floodplains, unabated urbanization, land-use changes and human-induced climate change. Even Though, rivers and creeks rise several times a year or only every few decades, every at-risk community needs to know what it can do to reduce losses from flooding.

According to NASA, the most recent 'sea level' reading as of November 2018 is 90 (± 1) mm.The cause for the rising sea level has been found to be factors related to global warming, such as "added water from melting ice sheets or glaciers and the expansion of seawater as temperature rises" (NASA, 2018).

In the next several decades, storm surges and high tides could combine with sea level rise and land subsidence to further increase flooding in many regions. Sea level rise will continue past 2100 because the oceans take a very long time to respond to warmer conditions at the Earth's surface. Ocean waters will therefore continue to warm and sea level will continue to rise for many centuries at rates equal to or higher than those of the current century.

2.2 Statistical analysis of floods during the last decade

Floods can be described as one of the most costliest natural disasters to occur, as the impact not only affects the visible destructions but a long recovery in terms of diseases and rehabilitation[1]. In Asia, 345 million people were affected by droughts, with one long-lasting drought in India (South Asia), affecting, in both 2015 and 2016, 330 million people, which is the highest number ever reported of people affected by natural disasters. Economic losses are highest in Asia, followed by Europe and Americas. Floods were the most frequently reported disaster type, with the exception of the Caribbean, North America, East Asia, Western Europe and Polynesia, where storms predominate. Floods were also the primary cause of disaster deaths in all African UN regions, in Central and South America, as well as in Central, South and West Asia.

This number increases the total number of people affected in Southern Asia to almost six times its annual average, while the more than 6 million people affected by floods in this region represents only 33% of the annual average. In East Asia, more than 62 million people suffered from floods- 1.3 times the 2006-2015 annual average. Of these, one alone affected 60 million people in China. Pakistan is the largest recipient of Gulf States' humanitarian assistance, and received a significant proportion of funding from Saudi Arabia (US$200.6 million) and UAE (US$77.6 million) in response to the 2010 floods[2].

In Australia-New Zealand, 50 people affected by an earthquake amounted to 0.08% of the annual average, while the 580 people affected by to floods were equivalent to 1.4% of the annual average.

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[1] Most devastating floods occurred in China, Thailand, Korea where almost thirty other disasters resulted in damages that amounted up to US$ 69.1 billion.

The "most numbers of deaths were because of floods caused by rain-storms that took place in areas such as North America, the Caribbean, Southeast Asia, Melanesia, and Micronesia. Extreme temperatures were the deadliest disasters in Australasia, including some parts of Europe. In 2016, the regional deadly impacts of floods are slightly different. All African and Asian UN regions, and Western Europe saw floods killing the most people. Storms resulted in the most fatalities in North and Central America, the Caribbean, Australia and New Zealand, and Melanesia. In Melanesia, the 9,770 people affected by an earthquake represent 14.3 times the annual average, while the 355,000 affected by two storms are equal to 6.8 times the annual average. In Polynesia, the 392 people reported affected by storms were equivalent to only 14% of the annual average."

[2] Source: Development Initiatives based on UN OCHA FTS data

2.3 An in depth analysis of floods

2.3.1 What is a flood?

When water inundated land that is normally dry, this is called a flood. Floods can be caused by a number of processes, but the dominant cause is excessive rainfall. Floods are a natural process, but mankind's activities affect flooding. Floods occur at irregular intervals and vary in size, area of extent, and duration. As indicated on Figure 1.3.1 (below), flooding is a natural part of the hydrological cycle and the life of rivers. It can become more frequent and severe by human actions such as deforestation and interference of the river channels. Floods can be deadly and destructive, which they provide silt to nourish deltas and fertilise crops.

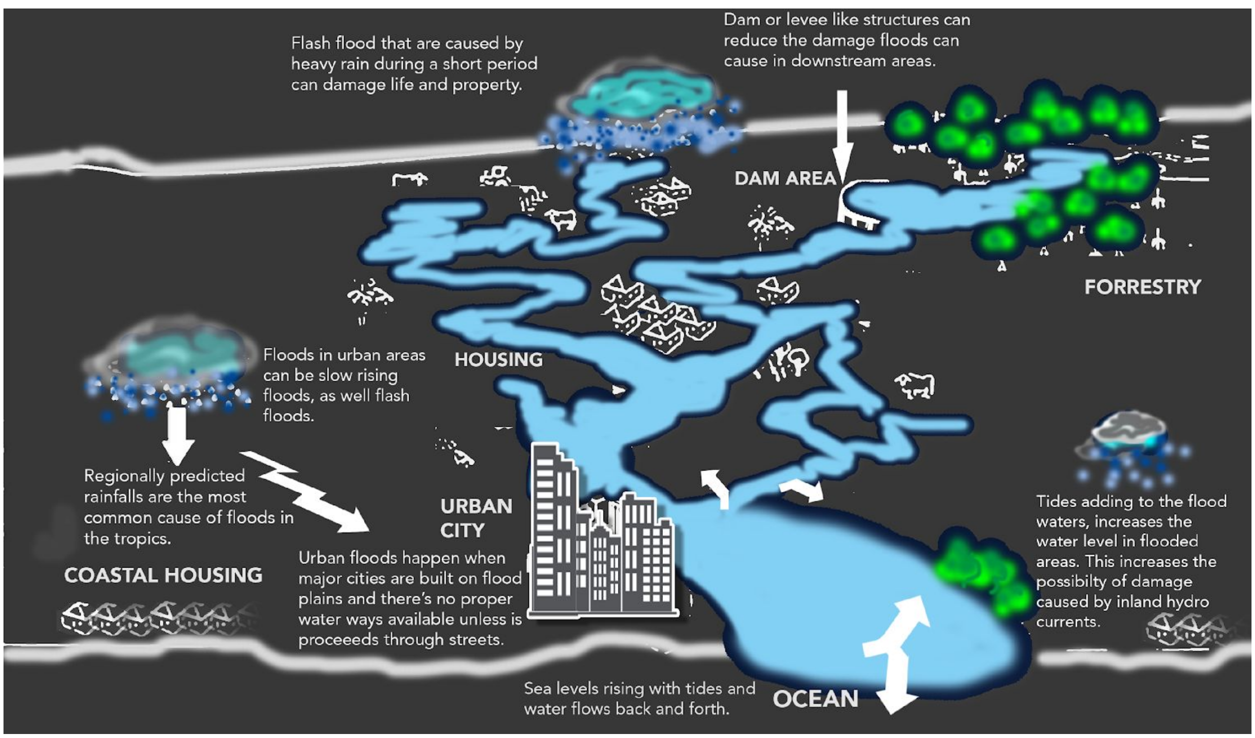


Figure 1.3.1: Conceptual diagram developed about the “Characteristics of a flood”, inspired by the illustration by the “Office of the Chief Queensland Scientist (2018)”.

2.3.1 Physical process of a flooding

Apart from social and cultural parameters, the physical characteristics of are the flood and the flooded area must be considered (Jonkman 2005; Kelman and Spence 2004). The residue and debris also has a great effect on the damage the flood causes. The causes of the floods play a role: whether they are related to events in a "river's catchment" area (such as heavy rains, deforestation, earthquake or mudslides), coastal flooding, storm surges or tsunamis. The important hydraulic characteristics of a flood are:

- Depth and velocity of the water: The total amount of water in the flood, or the flood volume. The volume of flood-water contributes both to the level and duration of flooding. The flood mitigation ability of dams and detention basins are less for large volume floods.
- Speed of water-level rise within a certain time: How fast the flood rises, or rate of rise. A flood that rises quickly obviously provides less time for warning and evacuation.
- Type and height of waves: How fast the water is flowing (velocity). Faster flow causes a higher risk to human life, a higher risk of erosion, and more damage to infrastructure.
- Duration of the flood: The duration of flooding. A flood that lasts for a longer time provides a greater impact owing to the increased duration of the disruption to transport, business and personal networks.
- The areal extent of flooding. Flooding that affects a larger area, either within a river basin or across multiple basins, provides greater impacts.

2.3.2 Variation of inland floods

Flash floods occur in small and steep watersheds and waterways and can be caused by short-duration intense precipitation, dam or levee collapses due debris and ice jams as in Figures 1.4.1A and 1.4.1B.

Figure 1.4.1A Flood through housing

Figure 1.4.1B Flood over levee (Guardian, 2019)

Coastal flooding as shown in Figure 1.4.1C is typically caused by storm that arise with hurricanes and other coastal storms that push a large body of seawater towards the shore. Storms can cause threats to human life, widespread infrastructure damage, and severe beach dissolution. Storm-rainfall can also cause inland flooding and ponding as in Figure 1.4.1D i results in deaths associated with tropical storms. Climate change affects coastal flooding through sea level rise and storm surge, and increases in heavy rainfall during storms.

Figure 1.4.1C Stormy coastal flooding

Figure 1.4.1D Coastal flooding Guardian, 2019)

Urban flooding can be caused by short-duration very heavy rainfall. Urbanization creates large areas of impervious surfaces such as roads, pavement, parking lots, and buildings as in Figure 1.4.1E. Immediate runoff, and heavy downpours can exceed the capacity of storm drains and cause urban flooding. This can result in hydro obstacles for foot traffic as displayed in Figure 1.4.1F where pedestrians face danger with road signs been covered from water.

Figure 1.4.1E Floods stranding pedestrians

Figure 1.4.1F Flooded intersection (Guardian, 2019)

River flooding occurs when surface water drained from a drainage basin is directed to a stream or a river exceeds channel capacity causing overflows as in Figures 1.4.1H. Riverine flooding depends on geography, proximity to water sources as well as the built environment. Figure 1.4.1I shows housing areas drowned out due to such an unexpected flow of water.

Figure 1.4.1H Flood over dam

Figure 1.4.1I River flooding (Guardian, 2019)

Failing to evacuate flooded areas, entering floodwaters or remaining after a flood has passed can result in injury or death. Flooding is a temporary overflow of water onto land that is normally dry. Floods are the most common natural disaster a majority of the world and may:

- Result from rain, snow, coastal storms, storm surges, and overflows of dams and other water systems.
- Develop slowly or quickly – Flash floods can come with no warning.
- Cause outages, disrupt transportation, damage buildings, and create landslides.

The flow of the water inland during a flood can also depend on the structural build in urban areas that are more populated. In accordance to the Federal Emergency Management Agency (FEMA), urban floods are described as "the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems" (NRDC, 2019).

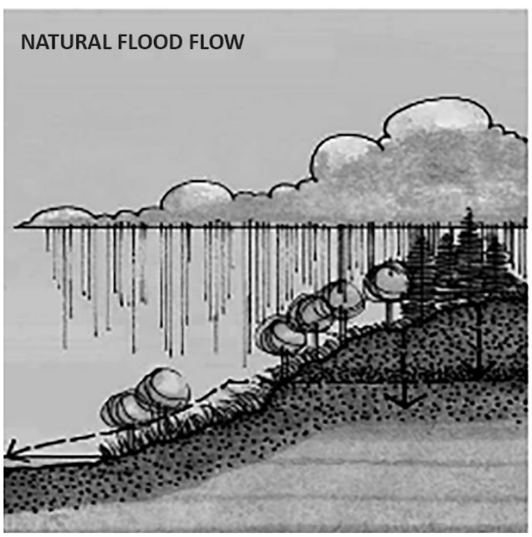


Figure 1.5A Natural flow of floods

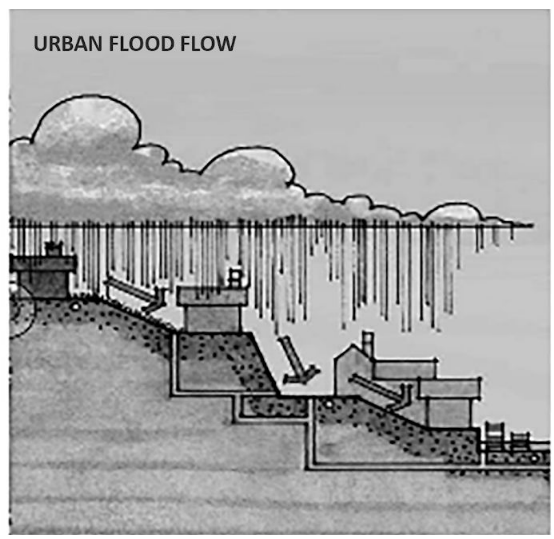


Figure 1.5B Suburban floods over populated areas

Figure 1.5A and 1.5A Conceptual illustrations (above) re-drawn in accordance to the descriptions in BOM website. These images describes the type of floods, depending on the land that it flows through. Here the question of how people reacts in urban and countrysides vary as the landscapes differ according to the built environments.

3 METHODOLOGY

There were a combination of research methods used for this analysis. The primary research was based on case studies of past floods. The analysis was conducted by placing the process of the floods and activities that took place on a timeline.

This was to analyse the element of time which is considerably increase or decrease the impact floods have on the affected. The other was semi-structured interviews conducted with both those affected and open discussions conducted with field experts.

3.1 Research question:

It is recognized that there's a lack of reactive communication traffic during a flood situation. There's a lack of importance given about gathering real-time data from affected areas in comparison alerts that are sent to the people from control stations. Also, there are no reactive tools civilians can use to be proactive against the flooding itself.

How could speed and efficiency of communication be increased during a flood with a reactive-alert system that is enhances the preparedness level.

3.2 Case study based research

There are several case studies that can be selected to analyze based research conducted on natural disasters in the last decade.

Floods in Asia	- Pakistan Floods 2010
	- 2018 Kerala floods
	- 2015-2019 Indian monsoon floods
Floods in Pacific	- 2018 flash flood, Australia
	- 2019 Papua New Guinea floods
	- 2015-2019 Australia monsoon floods

However, disasters that has occured certain regions have a valid comparison depending on the souce cause of the floods. When taking to geological and limnological factors to account floods in certain parts of the world have commonalities with climate.

Asia and Australasia regions have a significant similarity in tropicality, however there differences in in social, cultural and resource availability.
Therefore to draw a comparison between the preparedness of countries, past floods with similar behavioural patterns were analysed by placing the activities that took place on a timeline.

This will help in identifying which areas of the disaster evacuation process needed the most attention and the lack of resources that could have changed the outcome. **Elements** to be analyzed on a timeline:

- Type of a flood; flash floods or slow rising
- Analysis of floods based on type of flood, impact time, regional aspects and resources available.
- Selected geographical regions: Asia and Australasia
- Reasons: Similarities in climate and geographical features
- Comparison: Clear variation in economical, cultural, political and social stances

3.2.1 Differentiation of floods

There are two basic types of floods: flash floods and the more widespread river floods. While flash floods generally cause greater loss of life, river floods generally cause a relatively higher loss of property. However, the main difference is the time in which both these disasters occur. Slow rising floods can occur over a longer period in comparison to flash floods that create a negative impact in a matter of hours.

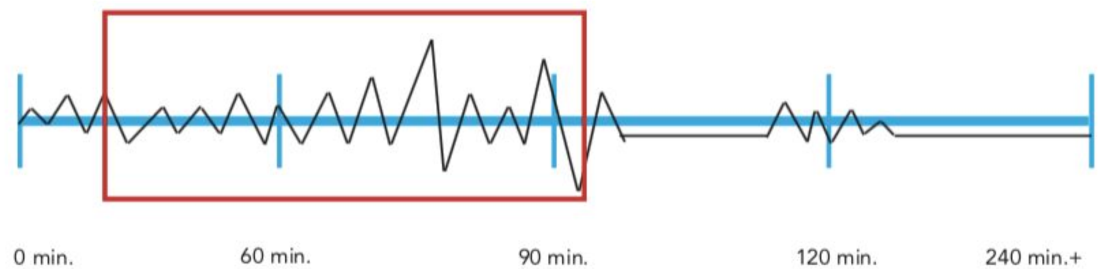


Figure 2.1A Timeline of a flash flood **Flash flood:** This happens when an overwhelming amount of rainfall occurs during a short period of time.

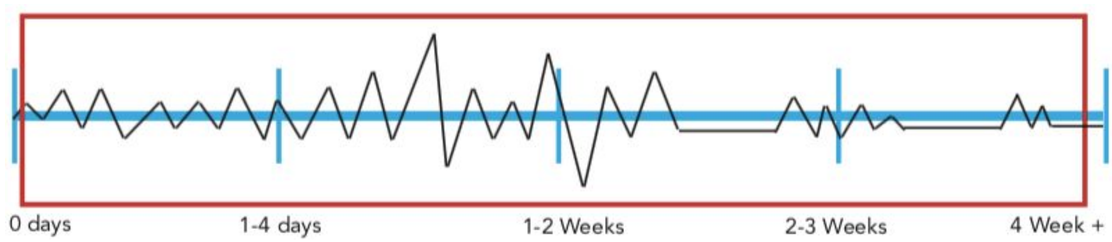


Figure 2.1B Timeline of a **Slow rising flood:** Flooding that occurs during a longer period of time, however the impact can be similar or less disastrous in comparison to a flash flood.

Figures 2.1A and 2.1B shows the variations of the types of rains that can lead up to two main types of floods. A heavy rainfall that can take more than four weeks to cause a slow rising flood, can take place within a couple of hours resulting in a flash flood causing massive damage. There's a need to increase the preparedness when facing these events, in the hours leading up to the first rainfall.

FLOOD TIMELINE LEGEND	
	The timeline of the flood that can vary between days or weeks as a result of the flooding.
	The intensity of the flooding activity parallel to period of rain.
	The overlapping factor of time vs quantity of water that amount to a flooding situation. It is necessary to understand the preparedness for floods greatly depends of the flood itself so the more data is gathered during the occurrence, there's more possibility to lessen the damage to life and property.

Figure 2.1C Legend for the timelines drawn (above) in Figure 2.2A and 2.1B

Flash floods: Flash flooding occurs within 4-6 hours of the rain event.

Figure 2.2A Flash floods in urban areas, traffic roads submerged in water and rescuers arriving for evacuation

This is an overflow of water invading a regularly dry land, caused by heavy or excessive rainfall in a short period of time that can be about 6 hours. Flash floods are usually characterized by tremendous inundation after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. High speed flooding can take place even if there's no rain. This case be due to a broken dam or a sudden flow of water by an ice jam or debris.

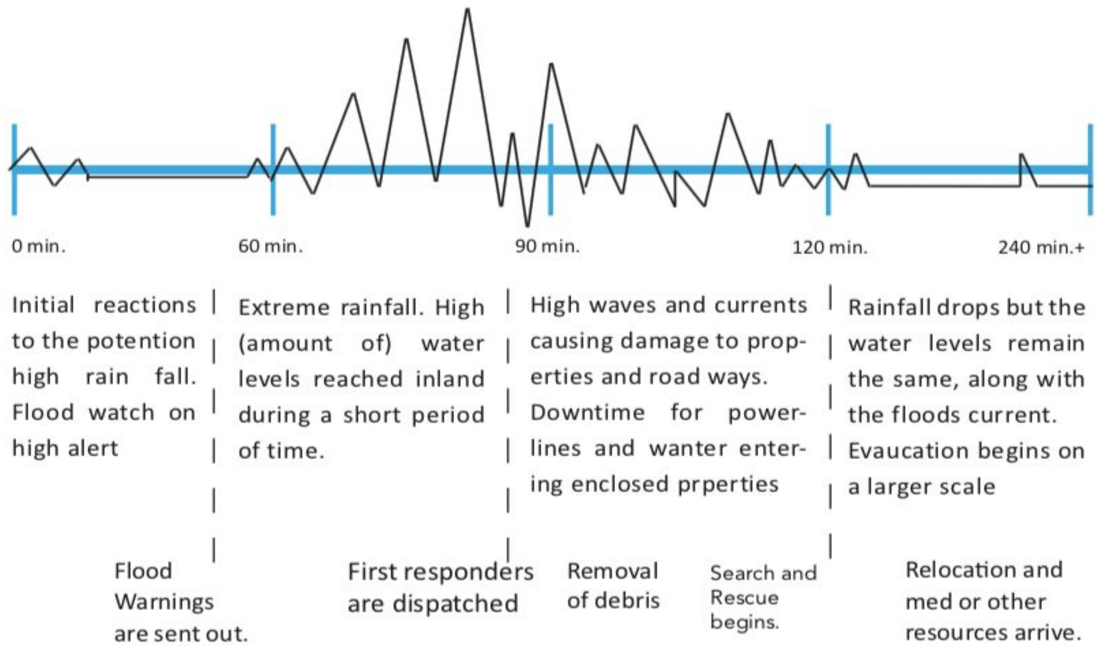


Figure 2.2B Flash flood events in parallel to the source rainfall activity, related to legend in Fig 2.1C

This is an overflow of water invading a regularly dry land, caused by heavy or excessive rainfall in a short period of time that can be about 6 hours. Flash floods are usually characterized by tremendous inundation after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. High speed flooding can take place even if there's no rain. This case be due to a broken dam or a sudden flow of water by an ice jam or debris.

Flash floods are generally unexpected however, there instances where areas that are regularly prone to slow-rising floods are the first to face such a danger. So why not increase preparedness levels in areas that are regularly subjected to ponding during events such as monsoon rains.

Slow rising floods: Flooding is a longer term event and may last a week or more.

Figure 2.2C Aftermath of a seasonal monsoon flood and an unpredictable evacuation process

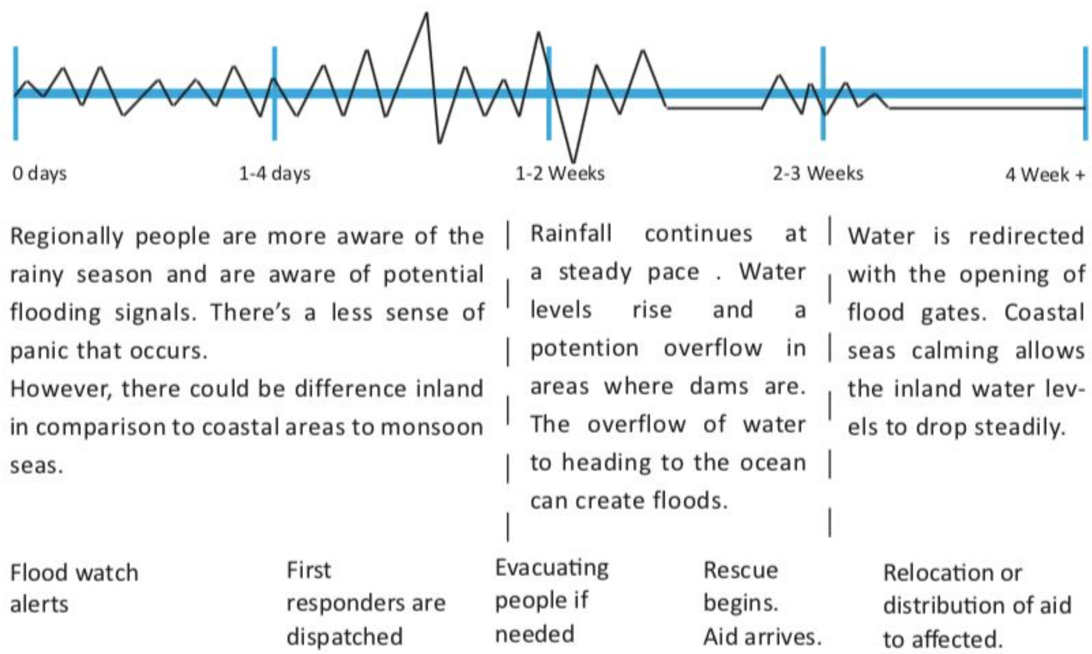


Figure 2.2D Slow-rising flood events in parallel to the source rainfall activity, related to legend in Fig 2.1C

An overflow of water onto normally dry land caused by river flooding or monsoon rain that stretches over weeks and months, can be considered as slow-rising floods asn in Figure 2.2C. An excessive amount of water collecting at or near the point where the rain fell. This may last days or weeks. Heavy rains from decaying hurricanes or tropical systems can also produce river flooding. During the 2nd and 3rd weeks of such rains as per Figure 2.2D there can be urban flooding where streets can become rivers with currents and basements can become life threatening.

Asia flash floods

Figure 2.2E Aftermath of an unexpected flash flood during Pakistan's monsoon season and evacuation of affected.

Unprecedented levels of monsoon rainfall led to the catastrophic floods in Pakistan's Indus River basin in July 2010. Many highly populated provinces such as Jammu and Kashmir were all affected by the floods and hundreds were evacuated as shown in Figure 2.2E.

Heavy rainfalls of more than 200mm happened during from 27 to 30 July 2010 (a four day period) in the other provinces such as Khyber Pakhtunkhwa and Punjab according to the data from the Pakistan Meteorological Department. The rainfall intensified over the subsequent two days as displayed in Figure 2.2F. During these flash floods, there were minimal levels of preparedness as the expectancy was of a slow flood as per the monsoon season.

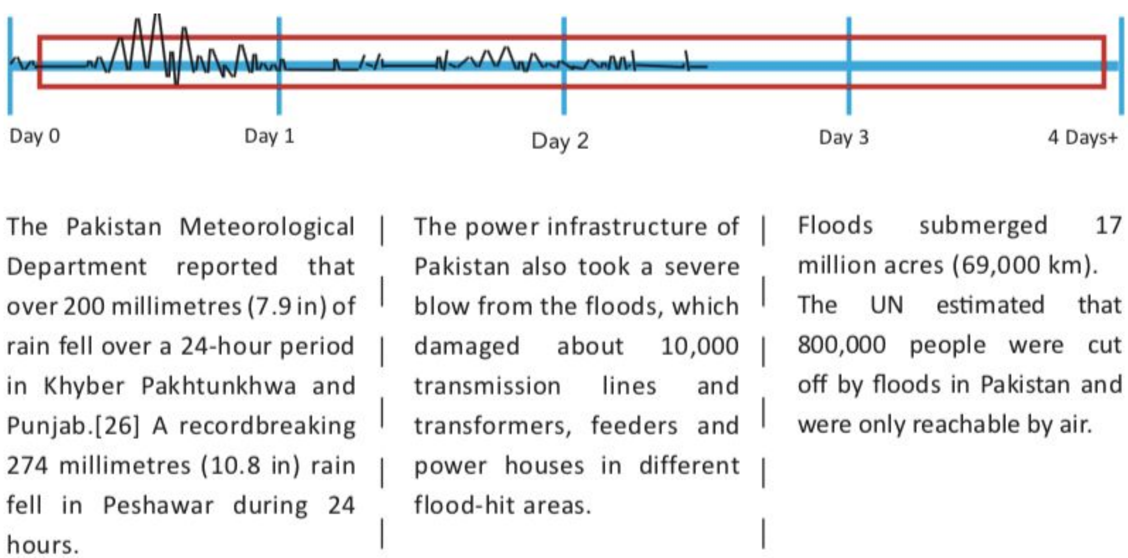


Figure 2.2F Timeline and the main events that took place in Pakistan during 2010 flash floods.

Australasia flash floods

Figure 2.2G Aftermath of an unexpected flash flood in Australia and the urban areas been blocked due to ponding.

A significant flash flood happened Sydney in the 2018, when a months worth of rain fell within a two hour period as shown in Figure 2.2H. A series of storms happened in Sydney and nearby areas such as New South Wales, Australia, causing flash floods and wind damage. Urban areas were blocked and housing was destroyed since about 104mm of rainfall took place in a the first half of the 24 hour period. Fire and Rescue of Queensland areas mentioned that “crews were working hard dealing with downed power lines and falling trees” as in Figure 2.2G. This was not expected during a monsoon season, so there were not enough resources which lacked the preparedness element.

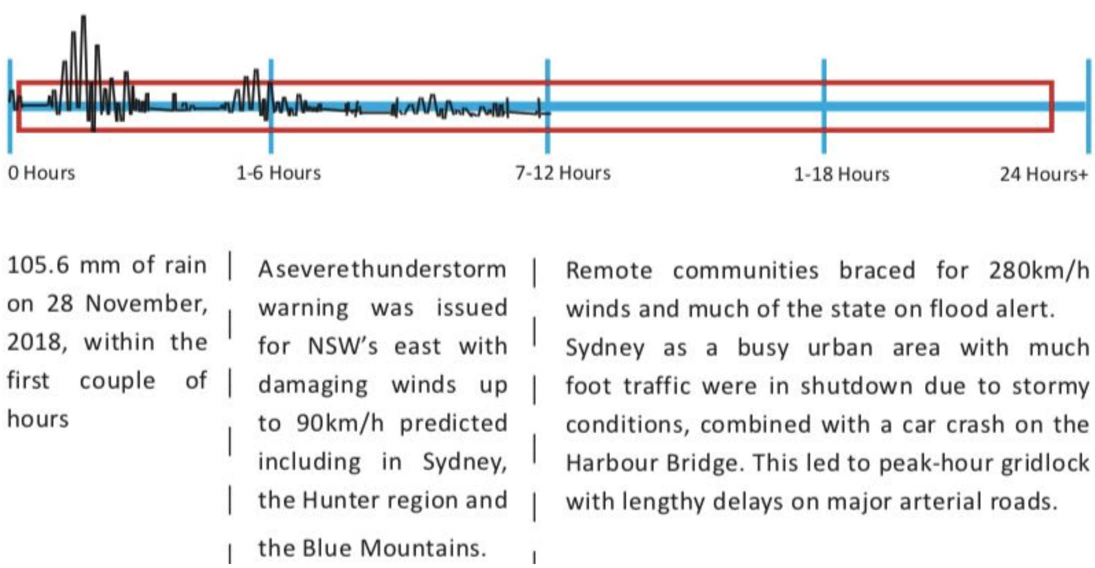


Figure 2.2H Timeline and the main events that took place in Australia during 2018 flash floods.

3.2.2 Regionally forecasting floods

Weather forecasts can provide advance warning of a flood, and seasonal forecasts can alert of a heightened chance of flooding in the coming months. However, forecasting river levels and flood extent is a complex process that is continually being improved. Regional e.g.: Australia and Pakistan.

Australia:

The “BOM” is the lead national agency for flood forecasting and warning services, working in partnership with agencies at the state and local government levels. The BoM provides forecasts of river-water level in critical sites during flood events. Local governments and emergency units may further interpret the water level predictions and advice on potential ponding areas (BOM, 2019).

The BOM also provides severe weather warnings that include risk of flash flooding. In addition, the BOM provides forecasts of rainfall and river flow for the coming three months. These seasonal forecasts may help alert agencies and the public of entering a period of heightened chance of flooding.

Pakistan

Weather Forecasting is the most important service of “RMC Karachi”. The RMC karachi provides weather, climate forecasts and warnings for Sindh Region. Different kinds of forecasting tools such as satellite & radar images, various nwp models, meteorological charts such as surface, pilot, temps, change of (pressure & temperature) charts etc.). Also real-time data is used for daily weather inference and forecast. Information obtained are used for assisting with different activities in the region (agriculture, aviation, mining, research etc.). Weather observation tools for monitoring are surface data, satellite data, radar data and wind profilers (RMC, 2019).

3.2.3 Graphical representation of the communication process

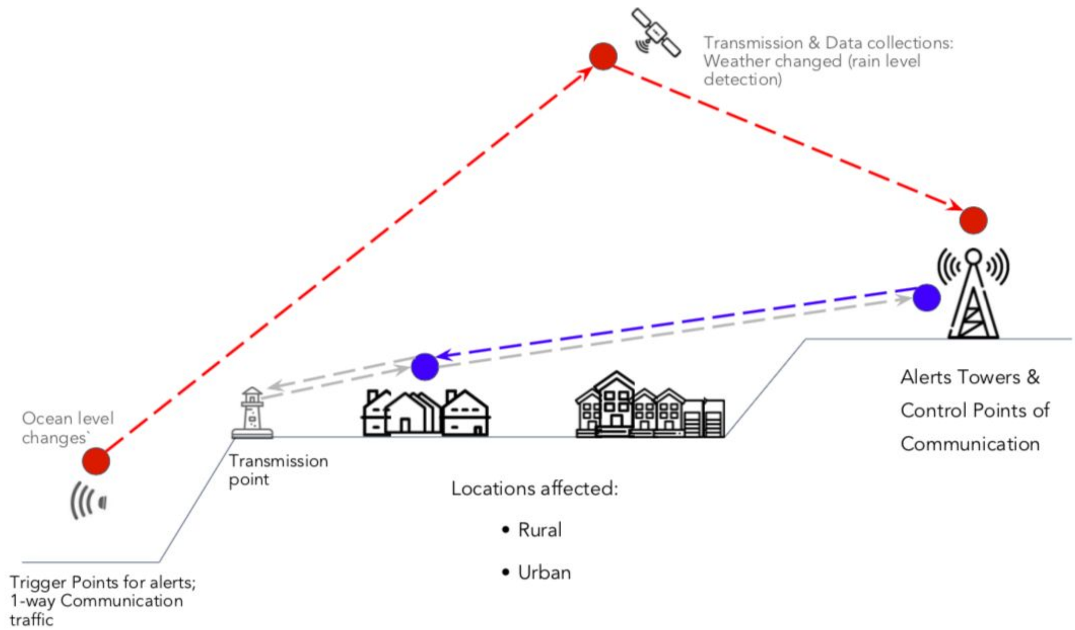


Figure 3.2 Conceptual illustration. The triangulated communication flow which is in one direction. In blue the reverse communication that is missing is indicated. This flow of information is rigid and has no conviction, causing people to ignore alerts sent out as most times the execution is left ambiguous

Global sea level trends and relative sea level trends are different measurements. Sea level rise at specific locations may be more or less than the global average due to many local factors such as "subsidence, upstream flood control, erosion, regional ocean currents, variations in land height". As conceptually illustrated in Figure 3.2 there is one direction of alerts sent from sensors to the control towers (RED) and then after factorial decision making alerts are sent out to those living in affected areas (BLUE).

The grey lines of communication indicated the lack of communication between main sensors and affected areas, which could significantly increase the reactive timescale. Sea level is primarily measured using tide stations and satellite laser altimeters. Tide stations around the globe tell us what is happening at a local level—the height of the water as measured along the coast relative to a specific point on land. Satellite measurements provide us with the average height of the entire ocean. Taken together, these tools tell us how our ocean sea levels are changing over time.

3.2 Interview based research

The semi-structured interviews were mainly divided into two main categories. The expert interviews were done with an open-flow in relevance to the experts' knowledge. However, the interviews with the survivors of floods were conducted in a semi-structured manner as there was a level of empathy in the questions asked. As the flood itself is traumatic experience for those affected, it was important to relate the questions asked in a more personal way. As the information given were based on the survivors own timeline and was promised anonymity, personas were created to summarise the findings.

3.2.1 Semi structured Interviews

However, the interviews with the survivors of floods were conducted in a semi-structured manner as there was a level of empathy in the questions asked. There were general questions asked such as:

- Could you please introduce yourself?
- Explain a little about the day you faced the flood? *(if possible: date , time , location of event)*
- Are you comfortable with explaining the events that took place?
- Did you expect a flood to happen that day? Did you receive any warnings?
- Where were you when it happened? Were you with someone?
- What or whom were you most concerned about and why?
- Was anyone hurt during the flood? Were there any damages?
- What was it like during the first few moments? Did you know where to go or who to contact?
- What was it like once it ended?
- Is there anything you would have done differently, if you has more knowledge of what was happening?
- If there was one thing that could have helped you cope that incident relatively better, what would that have been.

Figure 3.2.1A Questions asked from victims and those living in flood areas for open discussion.

3.2.2 Personas

Personas were created to maintain the anonymity as promised to the survivors interviewed.

Figure 3.2.2A An accumulation of information from survivors of floods to better understand their experiences.

Maria (35 years), living in a rented house in Moratuwa, Sri Lanka. It is very common to have the hour flooded on a regular basis. The landlord has focused on the interior and has not taken any precaution to reduce the water flow into the house during rain-seasons. As there's no way to monitor the situation at home, it is a constant surprise to find some areas of the house flooded. Since it is a rented property she has minimal control over what can be done.

John (28 years), living in Victoria with wife and 2 children. Has adapted to small house living, however the constant flooding has made life quite difficult. The traffic is redirect almost each time it rains due to flooding. If there's a possibility to know where the floods are worst it can make the rush hours much better during rain seasons. The radio alerts are not in correctly and there's physically nothing done to reduce the water levels except wait for maintenance to open drain-gates.

Luca (65 years), based in Queensland for 25 years and has been living with his retired wife. Water flowing-in and drowning out their front porches, it is difficult to drain out the water. High water levels stay as is for weeks, causing health dangers as well. As their fitness level is not up to par to divert the water themselves, they have no option but to wait. Due to deteriorating health he is worried that the pair might be stuck during a medical emergency due to high water levels.

Alexa (21 years), as a freelancer she works most of the time out of home. The monsoon period can be quite worrisome as her house is located in a land close to the coast as well as a main river. As there's no proper drainage system in place on the main roads, most of the entrances to the housing schemes are constantly drowned. On the way home from work, there's no proper guidance or marking as to which roads are safe to walk upon because of marshy lands.

Figure 3.2.2B An accumulation of information from locals living in flood risk areas with various concerns. Their safety requirements differ from individual needs, concerning family members and fear of property damage.

3.2.3 Expert Interviews

Findings from the experts were based on their professional experience and training. These were more structured, leading to discovering the gaps that exist during flood situations. Nonetheless, the knowledge was valuable in terms of preparation, technology used and difficulties faced on scene with people in panic. This was a structured interview process and the questions based on their expertise:

- Could you please introduce yourself?
- What is your designation and expertise?
- Are the flood situation in need of additional devices to assist with communication?
- What is the importance of providing users with a reactive tool?
- What technological gaps have you faced when dispatched to a flood site?
- What are the pain point you would highlight from recent experiences?
- What sort of trainings take place when preparing for such an event?
- Are civilians involved in such discussions, to spread awareness?
- Would you prefer to have more involvement from locals in such events?
- Do you think having somewhat of an automated system can increase efficiency?
- What are your suggestions in terms of technological improvements?

Figure 3.2.3A Questions asked from experts in the flood risk management field.

3.2.4 Interview Findings

Personas in Figures 2.2.2A and 2.2.2B were created on the basis of answers given, by survivors and locals, to the questions in Figure 2.2.1A. Most findings would convey that the level of preparedness was low or non-existent as there was a lack of resources available on sites built-in as warning system. While local chose to ignore such warning, individuals such as tourists in flood sites mentioned that there were no clear instructions conveyed to them.

Responses by the experts revealed that there's indeed gaps in the value chain as it excluded the human aspect completely. Rather than been rescued those living in affected areas preferred been notified on and time and given the option to request assistance if needed. According to experts the waste of us-used resources constantly sent to flood sites, only delayed the rescue process.

3.3 State of the art

There are several existing products in the market that serve a similar purpose to making civilians more proactive when facing potention floods. However, there a lack of proactiveness in terms to sending out a reactive instruction to limit potential losses. While technologically the monitoring systems are of a higher level, if the same were applied in a regional area such as Asia, the outcome would not be the same if installed in Pacific regions. The following are the findings when examining the existing products related to flood monitoring systems and reactive devices in the market at present.

- CAMPBELL SCIENTIFIC – ALERT/ALERT 2:

Figure 3.3A Campbell Scientific designs and builds standard ALERT, ALERT2, hybrid ALERT, and customized flood warning systems. This includes a turn-key transmitter packaged in a traditional ALERT-style “cylinder for the vertical pipe installation”.

The “ALERT 200” shown in image 3.3A is a basic ALERT type 2 transmitter that is designed to be a commercial replacement for existing flood warning stations. Designed to be accessible, cost effective and reliable. This device also uses the AL200 modulator and an sensor interface. as well as the industry-standard Maxon SD125E-series radio. This is a fully configurable and pre-programmable device that can be used alongside a flood warning applications.

- LEVEL LINE EWS; EARLY FLOOD WARNING SYSTEM:

Figure 3.3B The LeveLine-EWS functions as both an early flood warning system, providing instant alerts to rising water levels and as a continuous water level monitor.

The LeveLine-EWS (LL-EWS), function as both an early flood warning system providing instant alerts during rising water levels and as a continuous water level monitor. The water level sensor records changes in water level and send a SMS or an email alerts when preprogrammed alert levels are reached. Daily reports are then sent direct to one's email address and are automatically archived in the web application so that trends can be monitored.

3.4 Limitations

Overall the research was based on three main focuses timeline of significant past floods, the expert experience and the view of those once affected from floods. However, there were several areas that were not examined due to the lack of resources.

When looking into placing the activities that took place during past floods there were not much details about certain actions that were taken during the heavy rains. If the only information available is the level of rain in a certain region during a specified period, it lacks the ability to provide the insight about other factors such as the flow of water, current speeds and locating or tracking of people in affected areas.

4 ANALYSIS AND FINDINGS

There are two interlinking research concepts discovered:

- Preparedness
- Two-way communication

4.1 Preparedness

Many emergency situations can be avoided or resolved before they take place. The 'preparedness' for critical situations can increase efficiency by coordinating the needed services to the precise location

"Disaster preparedness" defines the measures taken to prepare and minimize the negative effects of disasters. That involves prediction of location, prevent methods and lessen their harmful impact on people. Alsto to respond and effectively manage with the aftermath. Preparedness provides a foundation to design effective, coordinated simulations, reduces repetition of efforts and heighten the overall efficiency of national institutions, households and communities. This in turn results in effective and timely disaster preparedness and response efforts (IFRC, 2018).

Risk communication is a trading of information about risks that take place, between interested groups such as forms of governmental organization to civilians. Within risk communication there are several types of communication theories in place:

- "Trust Determination Theory": This is when people who are upset is most likely to distrust information channels. Therefore, trust level must be formed with the public over time.

- "Mental Noise Theory": People when upset have difficulty in processing information as it was intended to. Experts advice that information should be precise with visual aids if possible that can be combined with other senses such as sounds and vibrations.

- "Negative Dominance Theory": Those stresses are likely to view all aspects of a situation negatively.. Communication should focus on instructions that are safety related (do's and not a continuous stream of don'ts).

- "Risk Perception/Outrage Theory": This is when the level of concern among the public is high and a group of people are feeling hopeless at the same time. The emotion, which is an outcome of outrage tends to spread as individual fears heighten.

All four theories together forms the foundation for risk communication and was used towards the solution in Figure 7.1A (below). The importance of understanding how it is most efficient to communicate with the public in stressful situations and how to build-in risk communications into a flood preparation timeline was clear when researching about these theories (NPHIC, 2014).

4.1.1 Mapping the phases of a flood

To understand the complete domino effect of the preparedness, actions that take place in regards to floods were categorised into several areas. However, when consulted with field experts it was discovered that there are several methods of arrangement. The most common is the linear process, where there's a clear start and end point but limits the possibility to explore the knowledge growth of human due to experience.

Therefore to draw a comparison, both a linear and continuance comparison was drawn. The linear process begins at a static stage of existing data and analysis. As mentioned in the figure below, the timeline is a combination of four main categories. Each stage as a set of

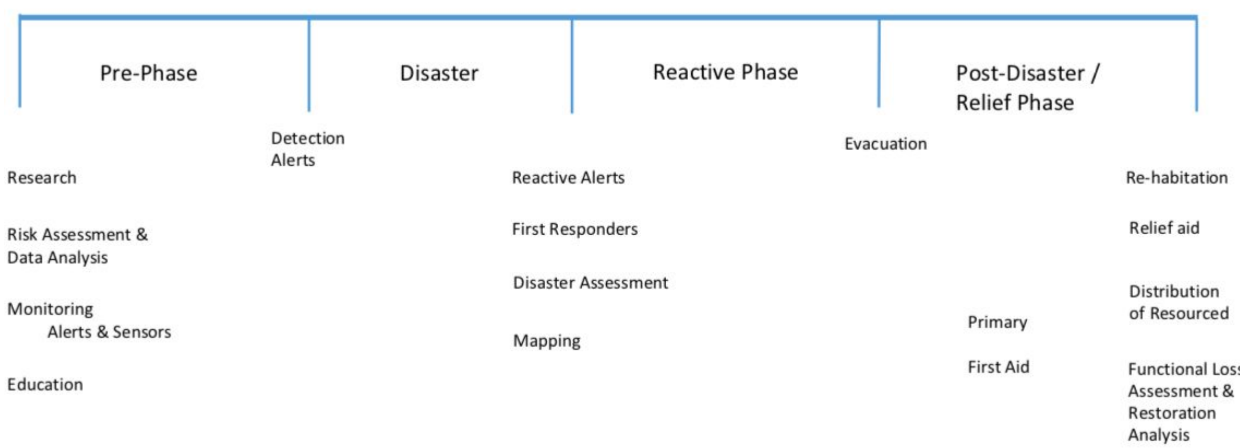


Figure 4.1.1A The phases of activities that take place centering an event of a flood, while eliminating the connection of the post disaster phase with a potential future flood.

With this analysis, there's a clear bridging between time and preparedness. The ability to prepare for floods depends on several factors. There are clear differences in the way countries prepare for floods. Asia and Australia, due to the topicality one is always prepared for the rainy season. In Asian regions, each floods is looked at individually and the amount of knowledge taken away is limited. As shown in Figure 4.11A, the characteristics of floods are noted as common and the learnings are not applied for the purpose of preparing for a future flood. However, the steps to control the damage caused by floods can be affected by unaccountable factors such as the perspective of civilians living in potential floods regions.

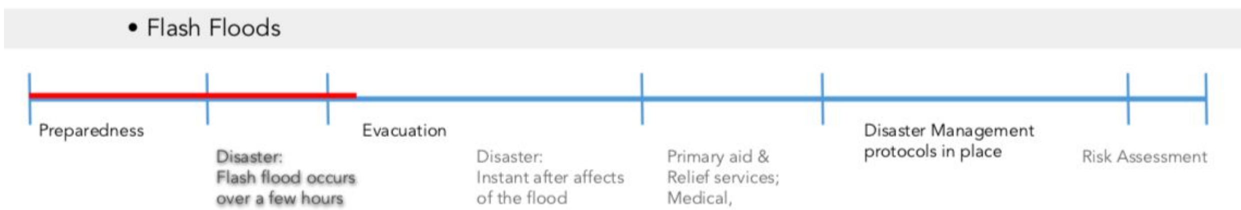


Figure 4.1.1B The phases of a flash flood placed on a linear timeline. The importance and the length of initial interception is indicated in red to show the importance preparedness in the initial phase.

During an event of a flash flood as shown in Figure 4.1.1B there's not enough time to bring the prepared resources as it happens within a period of hours, with elements of surprise and destruction. This eliminates the pre-conceived notion that those living in the flood risk areas will behave exactly how the simulations were planned.

Figure 4.1.1C The phases of a slow-rising flood placed on a linear timeline. The importance and the length of initial interception is indicated in red to show the importance preparedness in the initial phase.

Disaster preparedness activities embedded with risk reduction measures can prevent disaster situations and also result in saving maximum lives and livelihoods during any disaster situation, enabling the affected population to get back to normalcy within a short time period. Preparedness is a continuous and integrated process resulting from a wide range of risk reduction activities and resources rather than from a distinct sectoral activity by itself. It requires the contributions of many different areas—ranging from training and logistics, to health care, recovery and livelihood to institutional development.

When comparing the preparation time between the two types of floods in Figures 4.1.1C and 4.1.1B, there's a clear elimination of the pre-conceived notion that those living in the flood risk areas will behave exactly how the simulations were planned. The human aspect becomes the most variable element, therefore it is important to place the variability of an individual's reaction to disaster to this framework.

4.1.2 Weather forecasts provide advance warning of a flood

Dependable weather forecasts channels can serve as advance warning and forecasting of floods, which can not only educate people about potential dangers but also save lives (OQCS, 2011). This can increase the preparedness in a situation of slow-rising flood, which is very common during the monsoon season in tropical countries. Weather forecasts for the next one to seven days rely on increasingly accurate computer models of the atmosphere and ocean or atmosphere interactions. Clear improvements in the data available to such models (from satellite observations) and in computing power have contributed to this increased accuracy. In some parts of the world, three-day-ahead forecasts of heavy rain are now as accurate as one-day-ahead forecasts were in the mid-1990s.

4.2 Two-way communication

Two-way communication is the flow of information where the receiver provides feedback to the sender. Communication that is only directed in one-way, is when a message flows from sender to receiver only, resulting in providing no feedback. Two-way communication is especially vital in disaster situations, as feedback enables the sender to evaluate whether the provided information was well received and if additional services need to be provided to improve the situation. Feedback can eliminate estimation steps taken by the authorities and increase accuracy. Therefore the time of contemplation and providing unnecessary resources to affected flood sites can be also be eliminated. Communication is also negotiated which means that the sender and receiver listen to each other, the messages then gathers information to respond.

When crises period such as floods occur, un-professional radio messaging is often used as a channels of emergency communication when other modern means of communications fail to work. These radio channels unlike commercial models with more updated technology is not as dependendable and can provide ambiguous details. It is dispersed throughout a community without "choke points" such as cellular telephone sites that can be overloaded.Amateur radio operators are experienced in improvising antennas and power sources and mostequipment today can be powered by an automobile battery. Annual "Field Days" are held in many countries to practice these emergency improvisational skills. Amateur radio operators can use hundreds of frequencies and can quickly establish networks tying disparate agencies together to enhance the operability.

Existing communication link:

Sender – Local Bureau of Meteorology → Receiver – Affected civilians

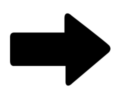
The information sent to the civilians are indeed important. Initial flood warning messages contain information about possible weather changes, local traffic diversion (when necessary) and present water levels if the rained areas have situation of ponding.

4.2.1 Forms of informing civilians during floods

- Flash flood or flood watch: These are timely alerts of a particular flood are categorised as a “watch area”and those within in such areas are constantly updated .
- Flash flood or flood warning: These messages are are report or set actions that needs to be immediately taken as taken as precautions to avoid imminent flood related dangers.
- Urban and small stream advisory: These are educative blurbs about flooding of streams, streets, low-ground level areas (areas under railroads or bridges) and city-storm drains.
- Flash flood or flood statement: This is a set of information that follows up as a summary regarding a flash flood or flood situation

4.2.2 Missing communication link:

The lack of 2-way communication during natural disasters due to the lack of electricity and unavailability of communication devices for those affected. Also the lack of reactive products available to the public during manageable floods creates a panic situation. The pain point is not about the information sent out to the civilians, it is more so of the lack of feedback to the information sent out.

Sender - Affected civilians  Receiver – Local Bureau of Meteorology

There are multiple questions that arise once the information about floods is sent out.

- Initially, were all those potentially living in those areas informed successfully of the incoming dangerous conditions. How are the weather control stations aware of the numbers living in those areas.
- Are there variations in the flood flow of within a particular area, due to the built environment.
- Could there have been flood prevention mechanisms built into the infrastructure, which could have been automated saving significant amount of time and human resources.
- Does an individual in their own home, require the same type of assistance while on the way or when in a communal space.
- Is there a variation in the type of information transferred as alerts or is the water level considered as sufficient. Are people already aware of dangerous water-levels or is this an assumption. How are the senders aware that sent information convinced locals to to take the necessary precautionary steps.

4.2.3 Continuance model for flood operations

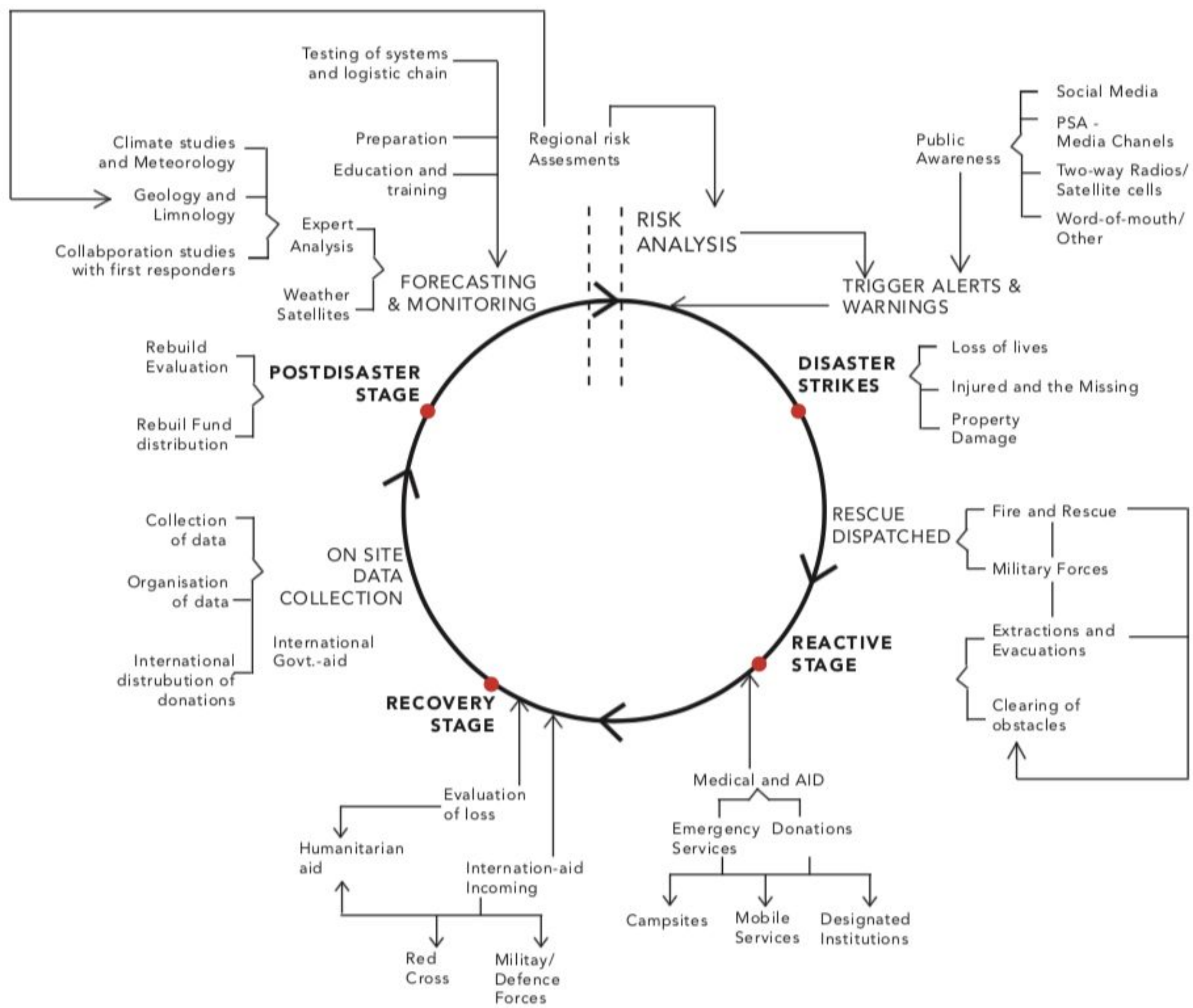


Figure 4.2.3A An analysis of the findings made through the research, plotting the stage of a flood (Dinukshie Nirmanie Gunaratne, 2019).

The above model in Figure 4.2.3A, it shows the overall activities that In regards to the insights collected by those who were affected by past floods and the model put together by the author a focus is drawn to design a system based product that works in multiple levels. The methods of alerts that are sent are impersonal and have minimal informal and quite rigid. While people are aware of dangerous water levels look physically, sending information as statistics remove the level of familiarity and the urgency of an incoming disaster.

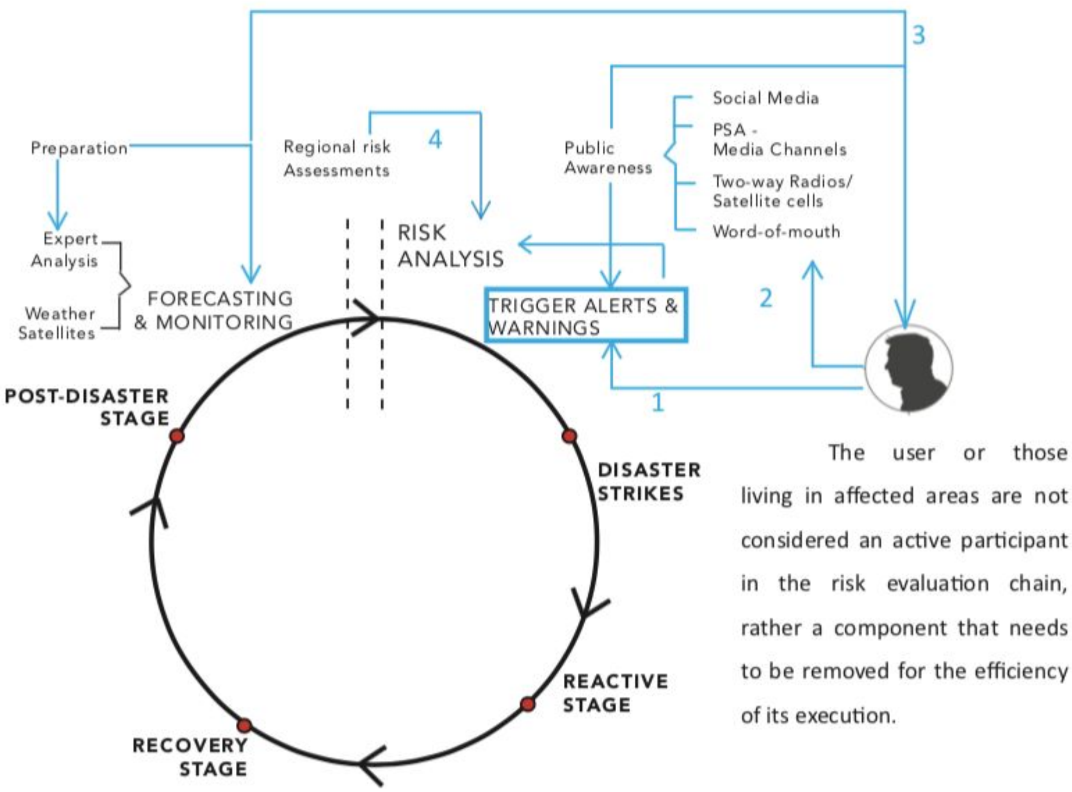


Figure 4.2.3B Amended model that described the pre-disaster phase with the inclusion of the user, resulting in additional communication streams that can add value and create efficiency (Dinukshie Nirmanie Gunaratne, 2019).

The introduction of the user to the model in Figure 4.2.3A at the disaster detection stage, creates a new value chain that make the user an active participant. Therefore the user, now has the ability to influence the actions that lead up to the flood situation The additional connections in blue as per Figure 4.2.3B is as mentioned below:

1 - The additional feedback from the user can lessen the time of search and also concern for family by geographically clearing their location from site. Also, the ability to monitor the affected area from afar.

2 - The user become of source of information distribution, rather than a passive recipient. Detection devices are constantly monitored to provide more real-time information such as water-levels.

3 - Users' actions become a source of feedback when analysing the types of preventative steps that needs to be taken for future floods.

4 - Real-time data can provide feedback about the validity of the warnings sent out through user responses

5 DESIGN BRIEF: HYLERT

Based on the conclusions drawn from literature review and research methodology, a focused approach is needed to move forward with the conceptualization phase of the solution. A vast understanding is achieved through case studies of the needed preparedness in terms of time and the lack of it left to the civilians that would be in the floods area during the disaster. The pain point was identified as the lack of a reactive communication stream. It is either that the data is collected in a more domestic scale but it stays static with the use with no contribution to the continually monitored weather conditions. A more technological understanding was gained with the examination of existing flood alert systems that exist in the market. The expert discussions revealed how the dispatching of aid is provided in a local and an international scale.

After the research conducted on existing developments in the industry of floods risk prevention, the Level line EWS was selected as the technology for the monitoring an the alert system. This together with reactive prototype for water diversion will assist locals with a more proactive solution. There’s indeed a gap between the flood occurrence area and the period in help is sent. Therefore, the civilians remain as is since the necessary tool are not in place and rather all attention is focused toward relief that in needed post-disaster phase. The gap of communication, was a vital insight to continue to with the development of concepts.

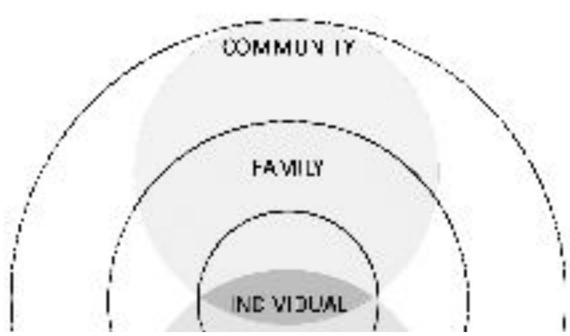


Figure 5.1A Categorising the potential user levels and ripple effect that is created when parties communicate with one-another (Dinukshie Nirmanie Gunaratne, 2019).

As shown in Figure 5.1 (above), the focus is to design an alert system focusing on the user; those living or potentially affected from a local flood. The main stakeholders were categorised 3 main groups such as; individual user, family or group, community overseen by the Government. While one might be able to receive a notification there's no further step that can be taken going forward.

Thereafter, for the purpose of connecting the user with placement, the model in Figure 5.1B (below) was created to show the variation of circumstances one would face. The needs of an individual would change if they were away from home or had a family members at a flood site. Also, one's situation and needs would be different if they were in a communal space in comparison to a more familiar place like their own home.

The entire system would also have to monitored by the government, and this requirements if displayed in grey. Since there are areas that needs to be assisted on a larger scale, especially when taking communities as a target demographic, institutions that are directly in link with the government can provide resources that are vital in flood risk management.

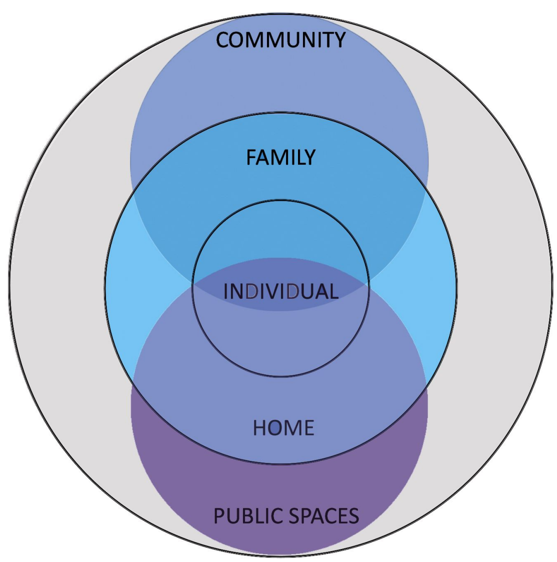


Figure 5.1B Linking the potential users of the system with placement. This will be the foundation to creating the communication links between places and users (Dinukshie Nirmanie Gunaratne, 2019).

6 CONCEPTUALIZATION

HYLERT is a proposed initiative to introduce local affected by floods, as an active participant in an event of a flood rather through a reactive tool that is linked to an alert system. It will create more confidence among those living in areas where floods are frequent and will also built a community that is more aware of precautionary methods. As of now the society is taught to be adaptive towards floods and be passive in its actions. Most tools and projects are aimed towards steps that are taken after a floods takes place rather than be proactive.

As an individual's needs differ the proposal is designed as a multi-level system that is a combination of a product and a service. This will be a HCD that is aimed towards assisting one's initial requirements during a potentially dangerous natural disaster. The system will be an interlinked service based on the person and location, which was a requirements that was discovered during analysis. This would bridge the gap where most people who were away from the flood sites been unable to send out a notification of receipt or a request for help.

HYLERT will be a combination of a flood alert system that has a used based reactive (feedback) system. For the benefit of a community at a larger scale, the value add would be that the alerts, would work in a controlled ripple effect. This stage of the process, will be about developing individual subsystems of 2 way communication and how these systems react with one another. Thereafter, it will be prototyped with an use friendly interface (HCI) that will show the chain reaction between the system, that will enable a more efficient communication process - the design outcome.

6.1 System flow: Chain reaction

Figure 6.1A The process flow of the interaction between the levels. The connection between the layers of information shared that is initially triggered from one end and carried through with help from sensors.

Chain reaction also commonly known as the "domino effect" is taken as the underlying inspiration of the the system design as shown in Figure 6.1A. The idea is to have one base signal that has a sets of off a chain events depending on the first effect produced. Figure 6.1B is the conceptual design for the linking of signals between the multi-level system. The primary alert that triggers an alert sent to an individual, which can be then linked to a system in a street or home base and finally a large communal safety alert system. Flows of communication or indication signals depending on user and location:

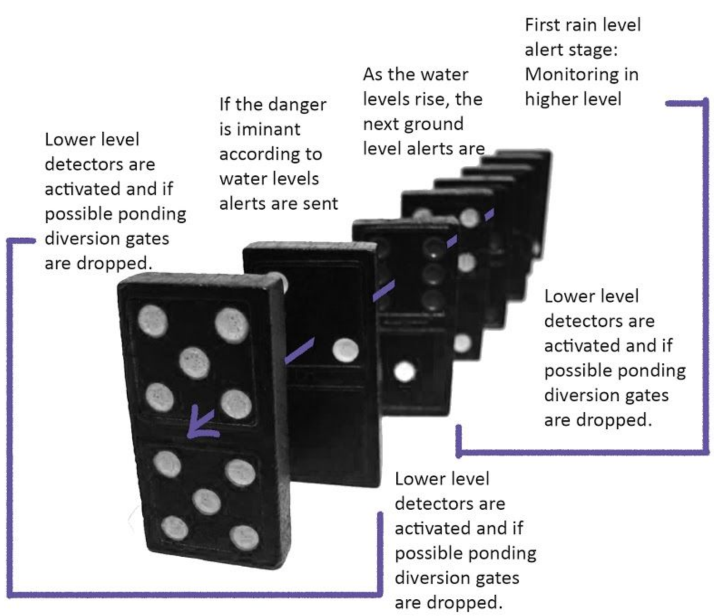


Figure 6.1B Alerts triggering one -another through proximity sensors, creates a chain reaction (Dinukshie Nirmanie Gunaratne, 2019).

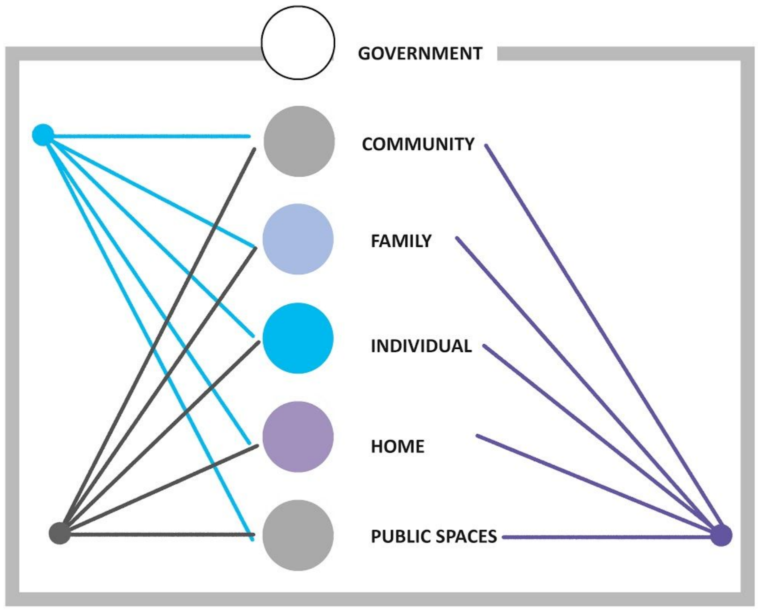


Figure 6.1C This is sketch of horizontal and vertical communication flows that could potentially take place within this system to increase efficiency in the human interaction.

The Figure 6.1B proposes the concept of the communication flow in the system. The process would be to use proximity and the data available each point as a resource to 2 way communication of data. A monitoring unit does not have to serve one purpose, it should be able to multitask and be an information point to civilians as well.

With this in Figure 6.1C interaction would operate in 2 main directions in the multi level system. When designing this system an individual's variable requirements were considered in terms of where one would be during a flood and what there immediate concerns might be.
One would be the vertical that would differ according to person and location. The other would be scaled according to the action depending on whether the alert is sent to a person or a location linked with a group of people. This can be either a home of a family or a public area such as a street with is of communal usage and have multiple levels of variable concerns, such as road structure and traffic flow.

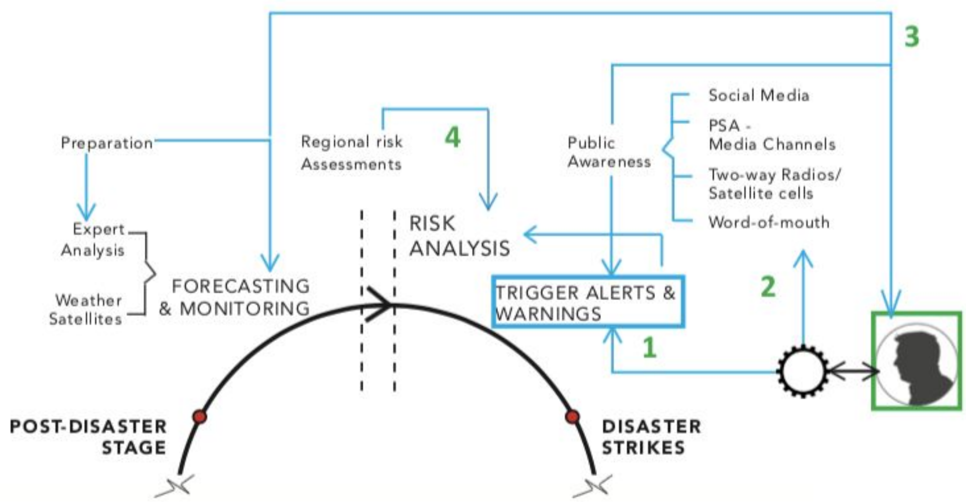


Figure 6.1D This model introduces the user to the flood event timeline through the HYLERT system, as a reactive communication channel that works alongside other existing public awareness channels (Dinukshie Nirmanie Gunaratne, 2019).

The Figure 6.1D proposes the concept including the user as an active participant in the communication chain to assist the flood warning phase. However, with the introduction of the feedback tool the user is now enabled to take precautionary steps that would increase preparedness.

The following changes were made, according to the initially analyzed model in Figure 4.2.3B:

1 - HYLERT, will act as a source of information accumulation that can assist the overall flood warning system. Even though the existing aqua-telemetry are of commercial use, the data shared will be available to both users and weather stations.

2 - The system will be considered an emergency communication channel during floods as it helps connect those in affected areas and help create a network that can help one-another if needed.

3 - Information shared will be used in future forecasting. This will not only have details about water levels but also about the types of assistance requested by users and their feedback as well.

4 - Feedback shared will result in the improvement of the food risk management phase by creating regionally specific changes to help assist those in flood sites more efficiently in the future.

7 FINAL CONCEPT

The final concepts integrate the alert and monitoring systems to the user, which results in a multi-level system. To communicate the alerts to individual a user friendly interface is used, that can be accessed via a smart-device or an object of the user's preference with GPS. Each level will be denoted through a blueprint of the user journey, showing the before and after stages with the application of this system to a virtual timeline.

Functionality: The system will be categorised into the main levels from 01 to 03 with the needs of the user in mind, with the the difficulty of communication (See Appendix 01).

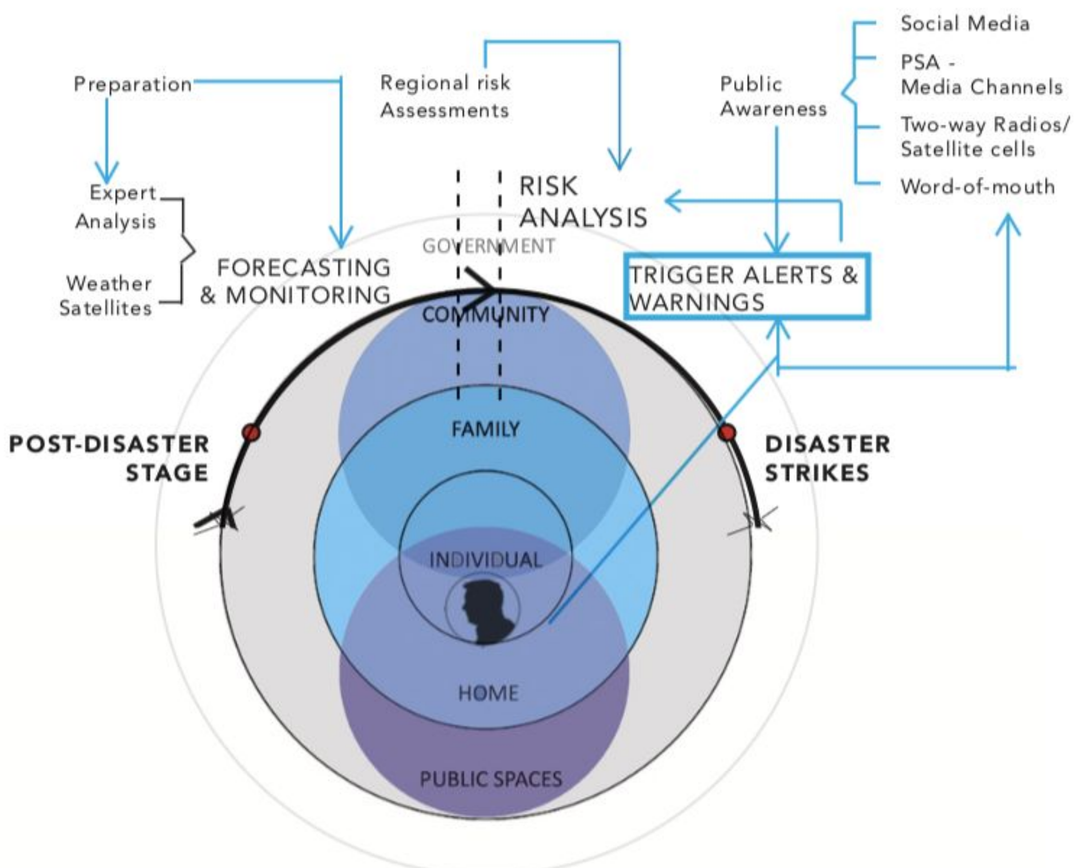
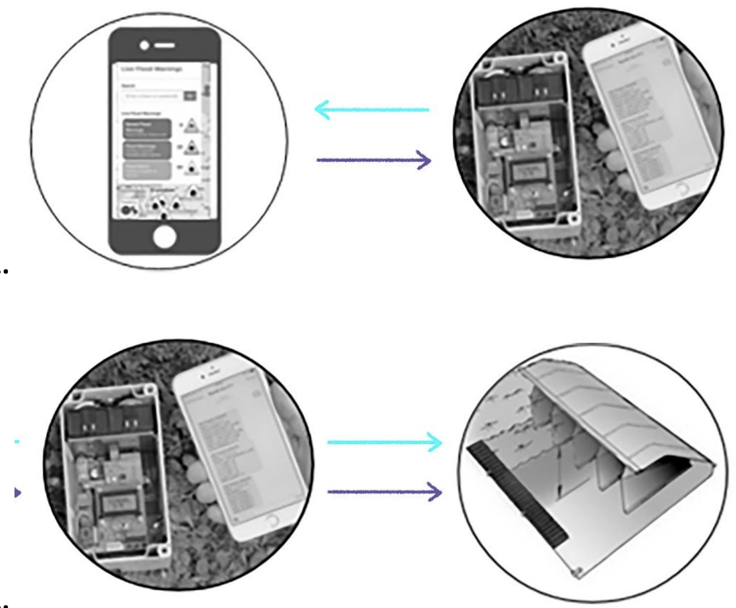


Figure 7.1A The main detection component would be an independent installation, that can be of commercial use and placed at homes. However, the core design can be built into the infrastructure's existing elements such as infrastructure power supply, bridge load bearings or dams. This detection component will act simultaneously with the alert interface.

Design: In line with the model in Figure 7.1A there will be three main elements that will link to one another to support each user need. Primarily there will be a monitoring system, alert system and and feedback (reactive) system. Depending on the users needs and placement the connections between the alert system the reactive system will alter. The monitoring will be based on the environment of the monitoring component and the reactive component will act accordingly (See Appendix 1).



1.

2.

Figure 7.1B The main two-way streams of communication that will take place in the HYLERT system to provide an efficient exchange of information during floods situation.

Communication system: The multi-level alert system will primarily depend on 2-way communication as shown in Figure 7.1B according to the user type: individual, family or communal.

1. Alert and monitoring units: The water levels will be continuously monitored and users will be notified of dangerous water levels as preprogrammed. Also, weather stations will be able to keep track of the same to improve regional risk management.
2. Monitoring and reactive mechanisms: While the monitoring device can be a reactive device, there can be excess water redirective mechanisms in populated communal settings. Once automated, there will be a possibility to activates these units remotely, increasing efficiency.

8 USER JOURNEY

There will be multiple user journey models for each user level of HYLERT. The system will primarily focus on increasing the preparedness in the pre-disaster phase with the involvement of the user. Previously the moments after the flood depicted the way users and third parties got involved in the flood management model as in Figure 4.2.3B, removing those living in flood sites as victims. The only reason that people were left helpless was due to the fact the necessary tools and resource were not in place for them to be proactive.

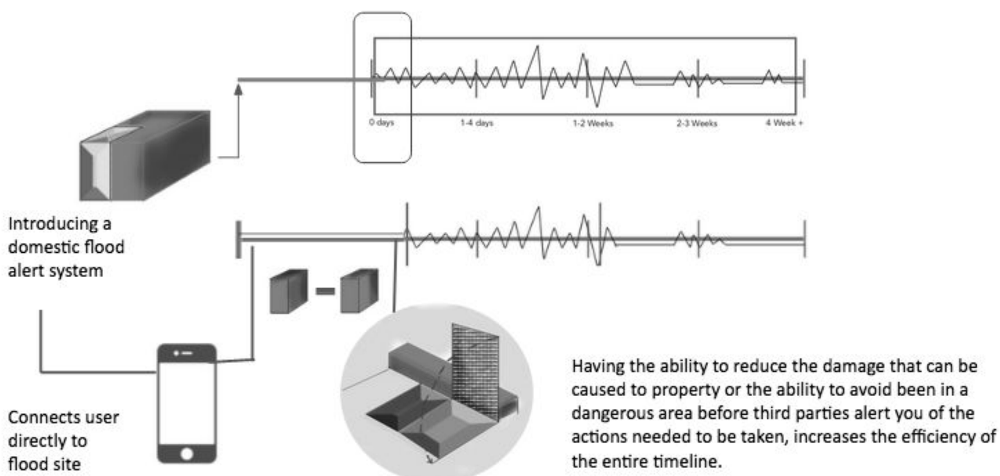


Figure 8.1A The flood event timeline will extend in the pre-disaster phase with the introduction of HYLERT, increasing preparedness. This will be a combined system where user has can interpret the flow of data according to their own needs as well as make use of the automated mechanisms build into the system.

Appendix 2 to 4 will depict the journey of an individual in various scenarios, during a flood situation when the HYLERT alert system is applied. This will be a service based system and will initially operate at 3 main levels. The aim is to have flow of information of given to the user as alerts and simultaneously be able to collect feedback of the users' actions at each time frame. The feedback will not only amend the system according to use requirements but will also provide data for experts to analyse to better prepare for future floods.

8.1 HYLERT: Level 01

The first level of the HYLERT system will focus on the needs of an individual user. To many working away from home, the primary factor is safety. While some alerts are already in place to warn one of imminent danger, the trust level users have those systems are considerable less as the information is not specific enough when received. In this phase, there will be an interface offered with more customised information according to the user and their placement (See Appendix 02).

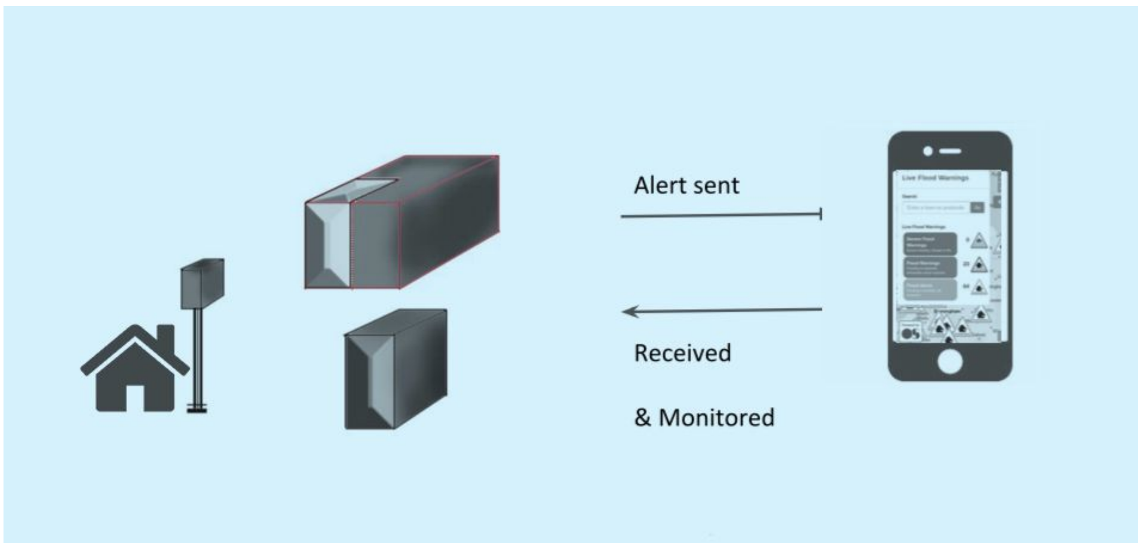


Figure 8.2 The first level of the HYLERT system will interact with an individual user primarily. The receiving data or feedback will be monitored and gathered for documentation purposes of regional variations.

Here, the main component would be the monitoring component that will also, send out an alert according to the preprogrammed water levels. On the interface, it will be displayed in colours so that the user is able to understand the situation at home relatively quickly in comparison to reading through statistics. The system will also enable to mark themselves as safe, however if help needs to be sent to a certain location that too can be marked accordingly. Users can also create a temporary network with those in the flood site, so that local can reach out to those at home if needed without having to wait for the first responders to arrive at the site when floods worsen.

8.2 HYLERT: Level 02

The secondary level of the HYLERT system focuses on a place such as a home where there's collection of individual with various behavioural patterns. In regards to the findings from interviews, most mentioned that the floods were not expected, even though alerts have been sent out already. The reason for this is that many consider their homes to be the safest place to be in. Even if there are are dangers in their region, many expect homes to be the exception during a flood (See Appendix 03).

The reason for the distrust in communication channels is that all details given are generalised and only mentioned the details of the flood. It is understood that staying at home as the alerts does not provide specific information in regards to routes that are in operation or the current status of the area that they live in. From past experiences, locals mentioned that sometime even during visible dangerous floods levels people choose to stay at home as it is more likely to be stranded on the streets as there are no safe zones marked in real time. The aim of this level is to connect monitoring components that are placed in a region to create a digital footprint of the flow of flood-water in real-time through proximity sensors and user feedback as shown in Figure 8.3A.

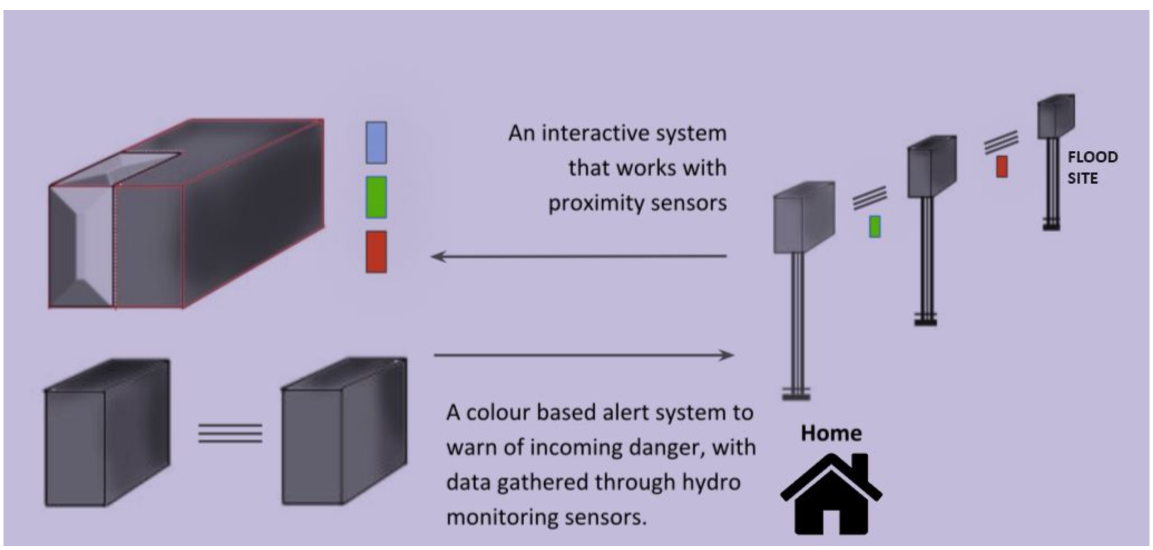


Figure 8.3A The secondary level of the HYLERT system will interact between the detection component and use proximity beacons to transmit information. This will have a colour coded system that can be easily identified at a distance and the same coding will continue onto the user interface when alerts are sent to the user.

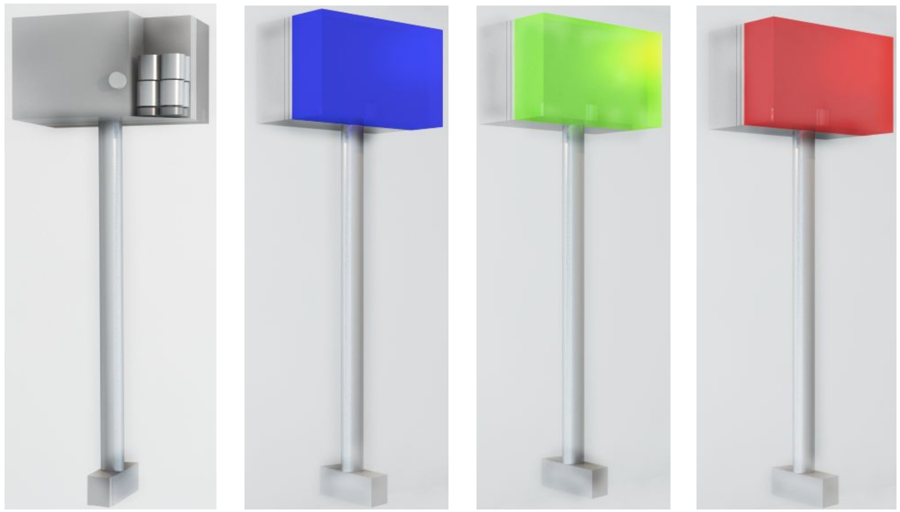


Figure 8.3B The secondary level of the HYLERT system will interact between the detection component and will operate through a traffic signal lighting system. It will alternate colours in regards to the flood streams that are incoming and if placed in streets, it will warn the public who have no access to a mobile alert system. This could be a communal use installation as well as a social design built into infrastructure, that will enable accurate information transmission about regional water level changes.

The monitoring components will also act as indicators that will visually indicate to locals about imminent dangers of warn of potential floods. As displayed in Figure 8.3B, he aqua-telemetry integrate alert component will be neutral in grey tone and with the first rainfall the acrylic light will change to blue. This will remain as is and the light will return to been switched off if needed. However, if there's a movement in other components in the regions close by due heightening water levels and user feedback, the light will amend from blue to green showing an increase in activities.

Finally if water levels reach dangerous levels the component will indicate a red light that shows urgency in reminding the user to take action. The same visual levels will be displayed on the applications used by users to monitor the system status. Also, users will have the option override the system and request for help to their home if needed so that local can reach out faster. Once in the red zone, the weather stations have the capacity to take over and if needed to send sounded warnings to locals with instructions. However this will depend on the installation of the HYLERT-MC and its preprogrammed structure by user.

8.3 HYLERT: Level 03

The third level of the system is designed towards helping communal spaces that has more foot traffic in comparison to homes. The aim is to reach out to a larger crowd and minimize individual involvement with the risk prevention process. This phase is also more suitable to lower income communities as the monitoring components will be built into the infrastructure, rather than have each user invest in a system for individual use (See Appendix 04).

Rather than the alert and user feedback communication method, at the level information will be exchanged between the monitoring device and reactive mechanisms. The indication of potential dangers from floods will be done via the visual alert system as shown in Figures 8.3A and 8.3B.

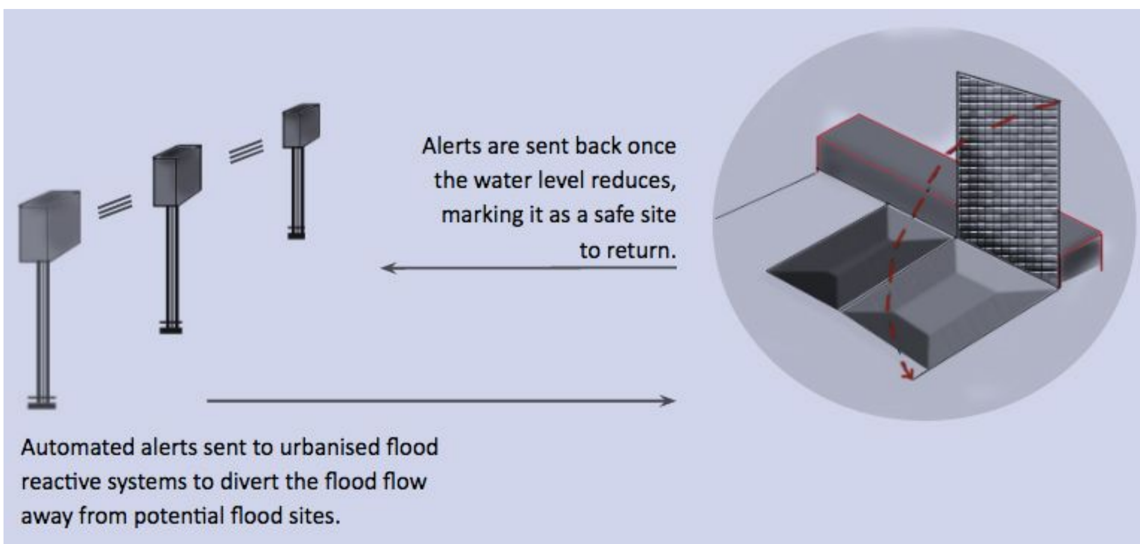


Figure 8.4A The third level of the HYLERT system will interact with the detection component and flood water redirecting system that is activated through proximity sensors. The receiving data or feedback will be monitored and gathered for documentation purposes of regional variations.

Here, the level of automation in the HYLERT system comes into play with the introduction of flood redirective mechanisms. When analysing , expert finding there was a significant amount of steps that were manual which could be replaced with processes that are remotely controlled. By doing so, the amount human resources that needs to be dispatched to flood sites can be significantly reduced.

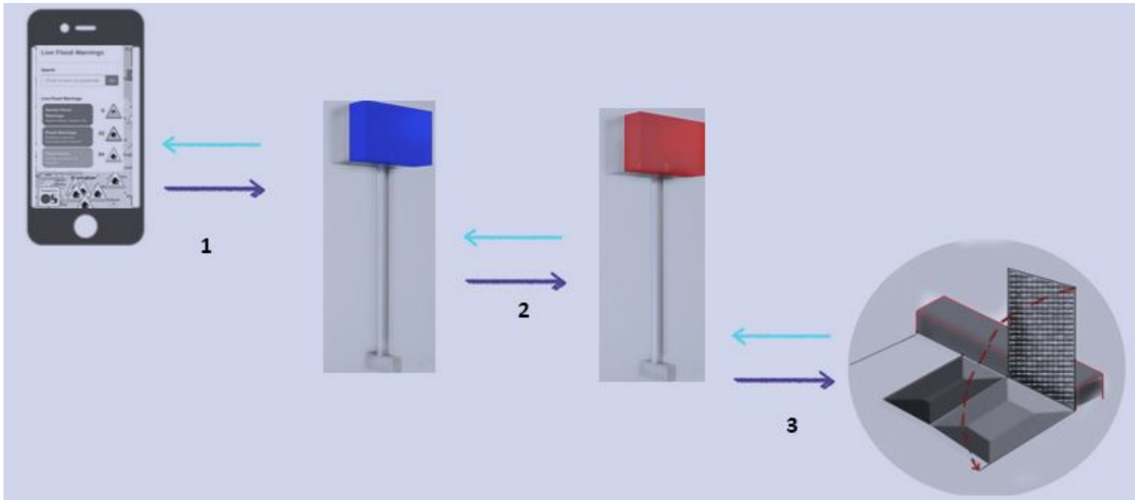


Figure 8.4B The third level will also a 2 way communication streams at each phase to increase the efficiency and accuracy of the data transmitted.

The following interactions will take place within a communal setting during a potential flood.

1. The alerts systems will receive information and feedback can be communicated back according to personal requirements to other users or the monitoring component.
2. MCs will exchange information through sensors and work as indicators to locals. In phase 1 it will primarily deal with sending alerts to users but also operate as proximity sensors.
3. In phase 3 an automated mechanism will be triggered to redirect flood-waters if needed. The sensors in the reactive mechanism will also be able to provide feedback in regards to water levels, currents and create a digital footprint to better understand geographical requirements.

8.3 HYLERT: Expert Review

The expert review concluded that there was indeed potential for this system to be put into practice, considering the number of floods in the recent years and the lack of resource management regardless if it is a developed or a developing country. It was also understood that process simulations must be made to evaluate the response times of this system. In regards to the systems, multi-level factor must be further explored to create more connections in the feedback phase through an advance user interface by introducing features such as volunteering, traffic mapping during floods and interlinking the current levels with first responder system to maximise the potential of risk management.

9 CONCLUSION

Multi-level practices in system design is common in most design fields however, when designing towards disaster management the ideation process is scattered. Each aspect such as programming, monitoring, interfaces for alerts, feedback methods, reactive tools and hardware has been designed with its own functionality in mind. There’s a lack of systemization where existing and upcoming innovations that are built are aimed to collaborate with one another. Creating a system that overlaps with monitoring devices, alert systems, precautionary tools and IoT can increase preparedness as it condenses the decision making period, during time sensitive events such as floods.

HYLERT offers a multi-level alert system that addresses the needs of the user during a floods situation. Thus far, most designs and practices have been created with the flood itself in mind. However, the most variable factor in a disaster situation is the behaviour of people. The needs of an individual will alter according to their lifestyle and placement. The prototype introduces a system that alternates between three main layers according to the requirements of the user. On one hand, the control of big data distribution via satellites still exist, while the locals have more control in requesting assistance and keeping a track of the information that is important to them. The system works as an alert system distributing information and the feedback can be be filtered according to an individual's need.

The solution relies partially on an automated solutions to speed up the response times in communal spaces, while having a more simplified user-centered approach when dealing with individual and residential areas. There’s a need to have built in devices to redirect water in areas that are more susceptible to floods as sending in third parties also affect the disaster response value chain. Installation of sensor controlled water diversion devices to the HYLERT grid will lessen the damage on human life and property.

The importance is the layering of an alert system that enables a user to be more of an active participant in the pre-disaster phase of a flood, by been more aware of the resources made available to them.

10 SUMMARY

The initial objective of this thesis was to explore the avenues of increasing preparedness during the period leading up to a flood. As different types of disaster impact levels were found when researching upon floods, it was important to find commonalities in social terms. Through a “human-centered design” approach it was understood that those affected by floods need to be given more importance than the disaster itself. Humans are the most variable factor in regards to individual needs, social stances, resources made available by the local government and one’s own responsibility. Therefore a need was identified for a more interactive feedback based system that has a personal touch even during a disaster situation that identifies with the one on a human level.

As a method of addressing this gap, a service based system that combines various forms of feedback flows was introduced as a potential through a leveled prototype. Areas such as hydro-monitoring (Aqua-telemetry) systems, emergency alert systems, offline grid connections and sensors and automated preventative technologies were researched upon, while exploring the possibility of linking to one another based on a conceptual chain-reactive flow. The research phase of the study emphasised the of tackling this issue of floods, while the methodology helped identify the lack of more human centered design solutions created to address the need of those affected. The variable factor of human behaviour was revealed through interviews conducted and the findings led to the a model composed by author as the founding concept of HYLERT.

Further development of the study should be on prototype testing through virtual simulations by inserting the system into past flood events. This enable one to organise the components of the system to maximise the preparedness prior to the occurrence of a flood.

HYLERT, is the beginning of a design revolution that combines technologies of multiple disciplines to achieve a common goal by addressing users’ individual needs, which will eventually contribute to the increased preparedness of a community when facing natural disasters.

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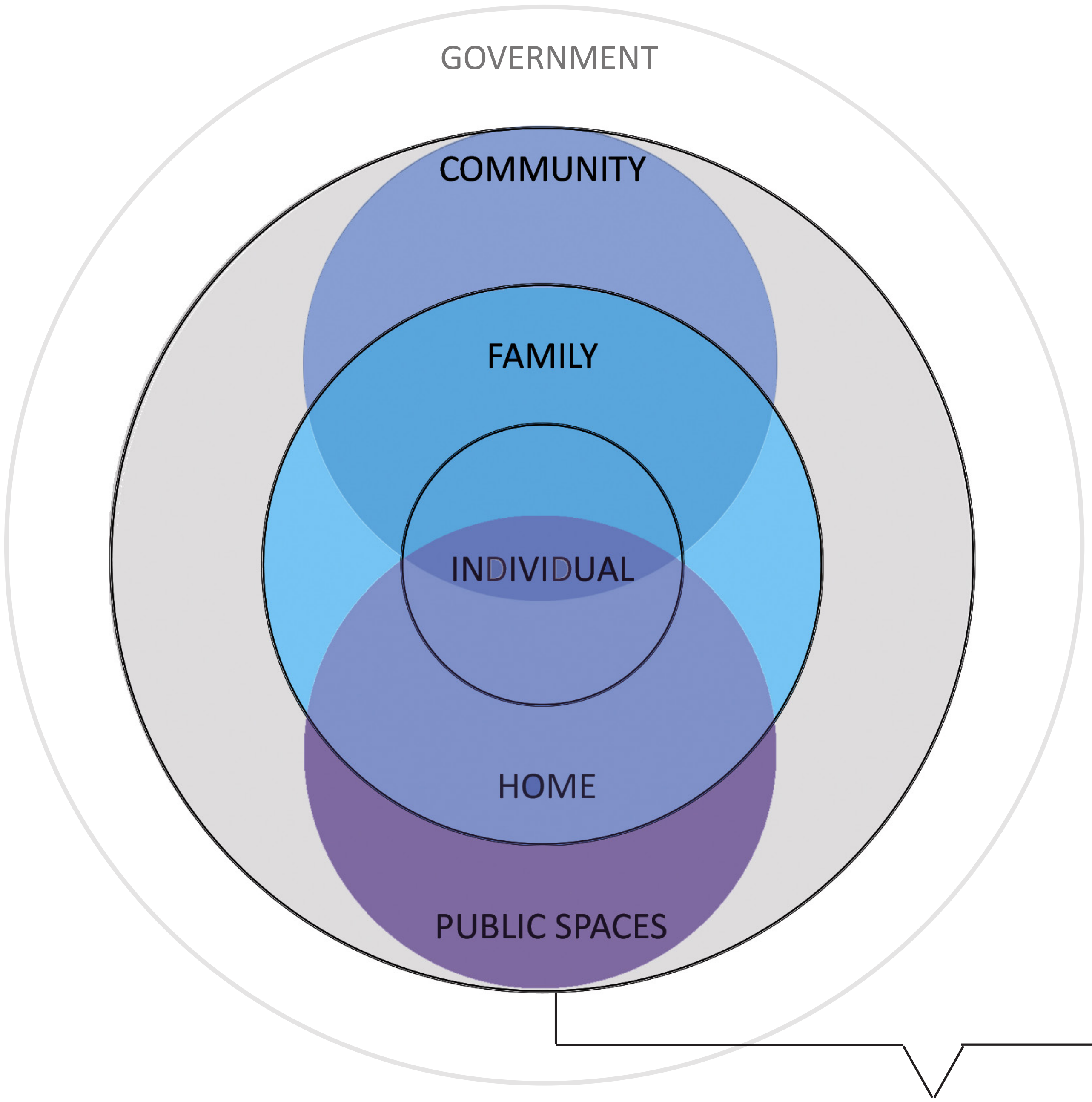
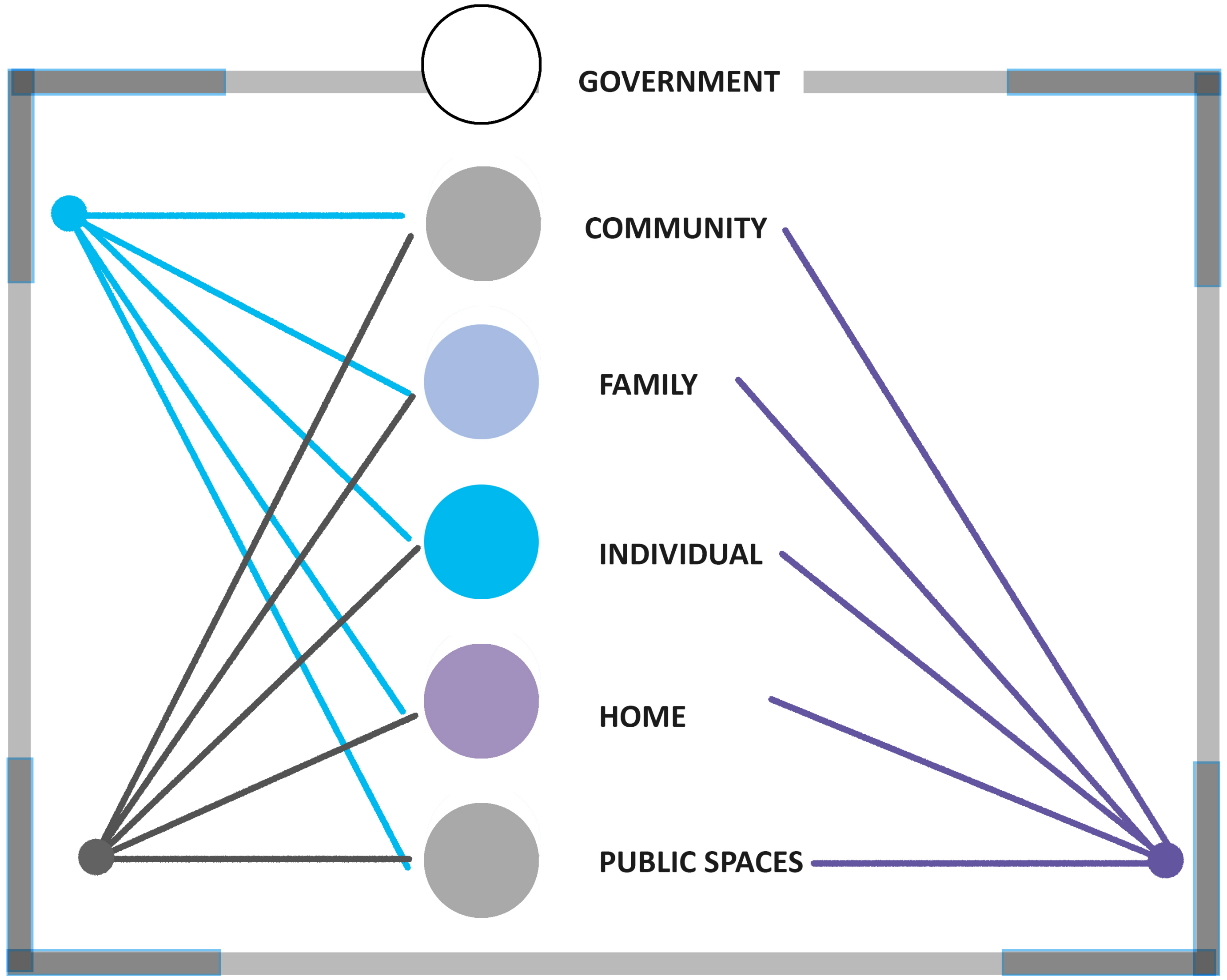
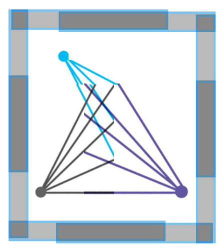




The attempt here is to connect the user's needs to the system, which changes according to their placement.

LEGEND

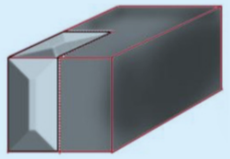
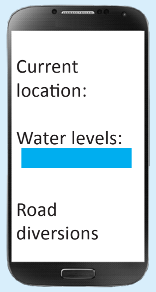
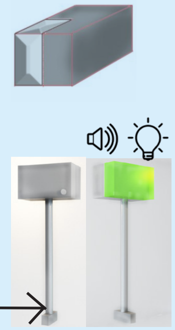
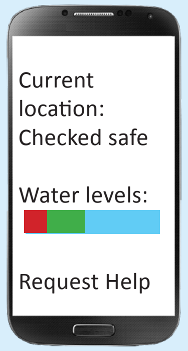
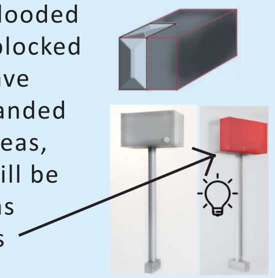
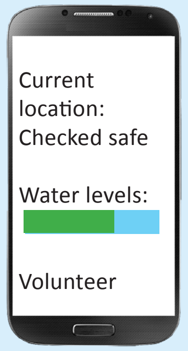
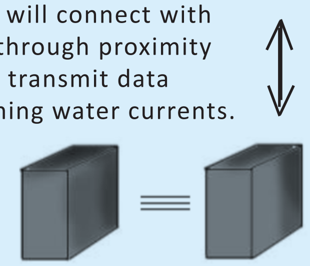
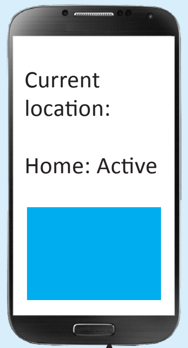
- An individual affected by a flood situation while been away from the flood site
- An individual or a group on site of a flood with family
- A communal space or street where crowds or people are affected by a flood situation.



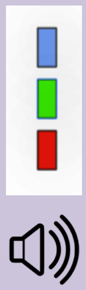
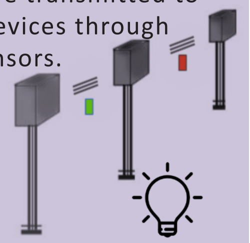
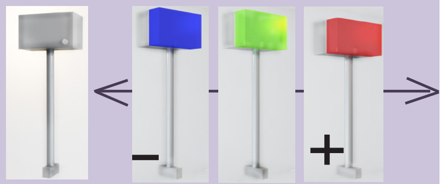
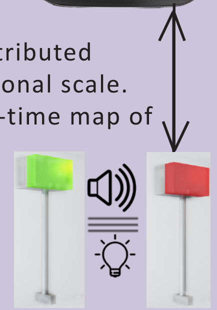
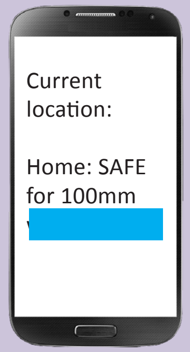
The 2 way communication streams interconnecting the multi-level system in regards to placement.

The grey outlining flow indicates the monitoring systems installed by the government; such as weather stations.

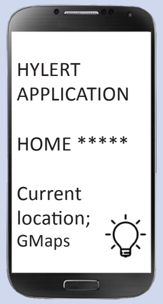
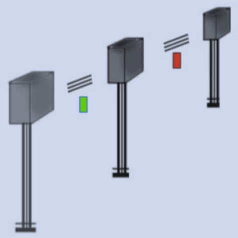
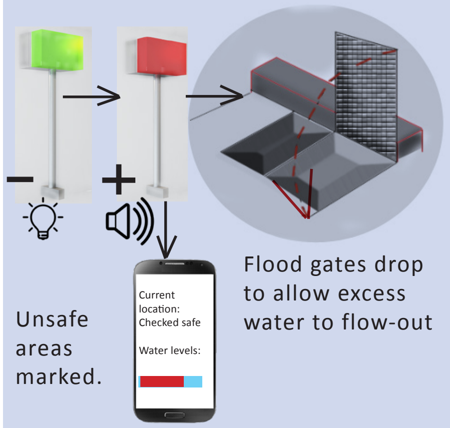
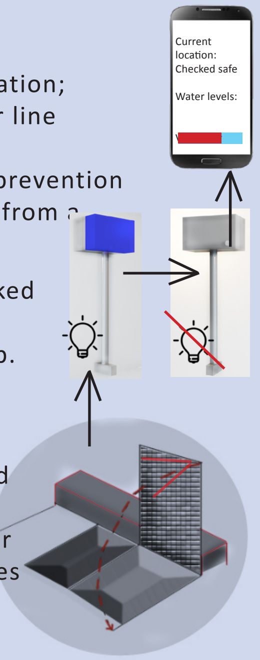
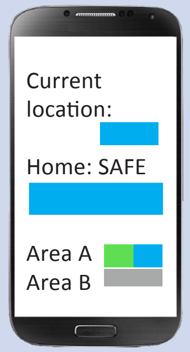
HYLERT LEVEL 01: SERVICE BLUE PRINT FOR INDIVIDUAL USERS

USER JOURNEY	INITIAL OFFERING	ALERT	FEEDBACK	INTERCEPTION	FINALIZATION
MONITORING COMPONENT	The initial interaction to be between the monitoring device and an individual user interface.	Alert sent out during increased water levels.	Depending on water levels it can automatically indicate and send real-time alerts to user.	Once the alerts are checked by the user, it will be indicated so with a colour change.	Once the water levels are reduced, the device will reset and send out statistics to be archived.
USER ACTIONS AND PLACEMENT	User working away from home. Uses the navigation and phone for guidance. Unable to check themselves as safe from areas or reach out for help from neighbours, to check on someone at home.	Alert indicates to user the current and expected water levels. Needing details about roads and diversions unobstructed, according to pre-programmed routes. Options to mark user safe and those at home if needed.	User at this point will mark themselves as safe if away from flood site. If anyone at home needs help they are to mark accordingly. This will include instructions and meet-up points.	Users now have the option of indicating their homes as a safe zone or mark it as a location to send help to. Users can mark their locations and volunteer for assistance as needed, so that the resource first responders can be coordinated well.	Users needing confirmation about the safety levels of the flood sites before been able to return. Flood damage related incident reporting, so that losses in future flood events can be reduced.
FRONT END	Monitoring device at home - exterior, with a light indicator showing safety levels.  Phone application that is linked to the monitoring device placed at home. 	Alert is sent about imminent danger. If not connected to individual user app, alarms are sounded at GREEN and RED levels.  The detection device will begin to triggering with the in contact water levels Aqua-telemetry device: Meter integrated on stem. 	If the water in flood sites continue to reach dangerous levels, users can call for help.  Once the flooded areas are blocked site and have people stranded in those areas, the light will be indicated as SOS signals 	User can: - Mark safety - Request information more regularly - Check water levels of the neighbouring areas - Request help from a local  The devices will connect with each other through proximity sensors and transmit data about incoming water currents. 	The interface is reset and user can access past data if needed.  The monitoring component, resets itself to further accumulate real-time data. 
BACK END	Continuous monitoring of the regional water levels ponding on dry land	Weather stations are alerted about the regional water levels and if those in the relevant areas were informed of the same.	The information about water-level changes are immediately transmitted through proximity sensors and mapping begins with satellite tech.	The information is now collected onto a regional network allowing users to connect with one-another.	Allow big-data to access these components as regional markings and connecting units to one another for proximity sensor transmission
TECHNOLOGY	User friendly interface for App Monitoring: Locally installed Aqua-telemetry device	GPS, Proximity Sensors, Aqua-telemetry device	GPS, Proximity Sensors, Aqua-telemetry device Satellite Technology	Google Maps, Proximity Sensors, Aqua-telemetry device	IoT, Proximity Sensors, Aqua-telemetry device Satellite Technology

HYLERT LEVEL 02: SERVICE BLUE PRINT FOR A FAMILY AT HOME

USER JOURNEY	INITIAL OFFERING	ALERT	FEEDBACK	INTERCEPTION	FINALIZATION
MONITORING COMPONENT	The initial interaction to be between the monitoring devices at homes.	Alert sent out during increased water levels or potential incoming danger.	Water levels are communicated to the user, gained through proximity sensors.	Once a region is marked as unsafe, the monitoring devices will also act as indicators for incoming help	Once the water levels are reduced, the devices will reset and send out statistics to be archived.
USER ACTIONS AND PLACEMENT	Users are generally unaware of incoming dangers, as home considered a safe place. Locals tend to ignore flood warnings as they are familiar with such events but do not consider the possibility of an unexpected event like flash floods.	Alert indicates to user the current and expected water levels. Roads and diversions are indicated with colour changes.	If those at home needs help they are to mark accordingly. This will include instructions and meet-up points. The alert system is able to indicate the updated information that is related locations selected by user.	A home can be marked as safe by users or the complete control can be signed of to the monitoring devices. Locals can be alerted of the surrounding through visual alerts, so that the response time is reduced.	Users at home and away from floods sites are indicated of the safe routes. Areas can be marked safe depending on the water-level reading if homes in that area were not flooded.
FRONT END	Monitoring device at home - exterior, with a light indicator showing safety levels.  Phone application that is linked to the monitoring device placed at home. 	Visual alerts are similar to traffic colour light which are familiar to locals. If not connected to individual user app, alarms are sounded at GREEN and RED levels.  If higher lands begin ponding the signals are transmitted to lower land devices through proximity sensors. 	Users are able to mark their zones as unsafe if in case they need to send help to their homes. Information flow through sensors, activates indicators according to water levels.  ALERT LEVEL INDICATOR: Most dangerous water level is indicated in RED, however it will change based on real-time data. GREY is the safe zone.	User can: - Mark safety - Request in help - Activate flood prevention tools if installed from a distance.  Keep track of the distributed information on a regional scale. Have access to a real-time map of hydro levels 	The interface can serve as a directory for local flood level readings  The monitoring component, resets itself to further accumulate real-time data. 
BACK END	Monitoring of the regional water levels ponding on dry land. Re-evaluation of existing plans and maintenance plans for locale.	Weather stations are alerted about the regional water levels. Also the flow of the excess water and its currents can be monitored.	The information about water-level changes are immediately transmitted through proximity sensors and mapping. This also assists with first responder route planning for dispatch.	The information is now collected onto a regional network allowing users to connect with one-another. The monitoring systems to indicate that this area is shut-off or is still in need of resources.	The information is archived and shared through to sectors such as first responders and traffic control for faster response times during future events.
TECHNOLOGY	User friendly interface for App Monitoring: Locally installed Aqua-telemetry device	GPS, Proximity Sensors, Aqua-telemetry device, Satellite Technology, Sound system (for alert output)	GPS, Proximity Sensors, Aqua-telemetry device	Google Maps, Proximity Sensors, Aqua-telemetry device, First responder network	IoT, Proximity Sensors, Aqua-telemetry device Satellite Technology

HYLERT LEVEL 03: SERVICE BLUE PRINT FOR COMMUNITY

USER JOURNEY	INITIAL OFFERING	ALERT	FEEDBACK	INTERCEPTION	FINALIZATION
MONITORING COMPONENT (MC)	The initial interaction to be between the monitoring devices in communal spaces	Alert sent out during increased water levels or potential incoming danger from locale.	Water-levels are communicated to the users and they are able to mark safety if needed.	Once a region is marked as unsafe, the monitoring devices will also act as indicators for incoming help	Once the areas are marked as safe zones, the MCs will act as guides for public
USER ACTIONS AND PLACEMENT	The system is focused towards a group of users and public spaces. Generally this applies to populated spaces such as streets or common institutions with relatively high foot traffic such as train or bus stations, city centres, etc. - Also, low-level streets, pathways, intersections are considered.	Alerts are of 2 main types: Automated from sensors to individual users in the vicinity warning them of the water levels Instructive alerts between preventative installations such as water gates and MC.	If those at home needs help they are to mark accordingly. This will include instructions and meet-up points. The alert system is able to indicate the updated information that is related locations selected by user.	If an area is marked as unsafe users will be warned to stay away from such areas and traffic (public transport) will be redirected. Also, routes that have institutions such as hospitals and fire-brigades will have priority during diversions	Users can guide themselves to safe zones and use routes marked in BLUE or GREY by MCs Areas that are still flooded will stay within the GREEN and RED zones. As the water-levels drop, the flood gates will be reset and MCs will be notified of the same.
FRONT END	Monitoring device at home - exterior, with a light indicator showing safety levels.  Phone application that is linked to the monitoring device placed at home. 	Alerts are of two main types, visual that is similar to traffic lights.  Sounded alarms or warning recordings if needed. All warning in RED are sounded!  The transmission of information happens in 2 ways according to rise and fall of water levels 	When in communal spaces there's a limitation to an individual's knowledge to local facilities. Therefore designs such as activation of urban flood gates can be automated by linking to MCs.  Unsafe areas marked. Flood gates drop to allow excess water to flow-out	User can: - Mark safety - Provide information; accidents, power line failures - Activate flood prevention tools if installed from a distance. MCs will be marked as safe once the water levels drop. Flood gates will rise up to ground level, if sensors detect safe water levels at the gates positioned sites 	The interface can serve as a directory for local flood level readings.  The monitoring component, resets itself to further accumulate real-time data. 
BACK END	Monitoring of the regionally populated areas. Analysing the traffic flow before and after a ponding situation as a result of heavy rain.	Weather stations are alerted about the regional water levels. Also, the local traffic control and first responders in the area also can monitor in real-time	Monitoring of water levels and activated water redirection devices are marked. This limits physical maintenance sent out to open drain gates.	The information is now collected onto a regional network allowing users to connect with one-another. Diversions and maintenance updates are provided accordingly.	The information shared through to sectors such as first responders and traffic control if needed. The post-flood maintenance crews are dispatched by priority of need.
TECHNOLOGY	Aqua-telemetry devices, App, Proximity sensors Satellite Technology, IoT	GPS, Proximity Sensors, Aqua-telemetry device, Built-in infrastructure mechanism for flood prevention; flood gates	GPS, Proximity Sensors, Aqua-telemetry device Built-in infrastructure mechanism for flood prevention; flood gates	Google Maps, Proximity Sensors, Aqua-telemetry device, First responder network	IoT, Proximity Sensors, Aqua-telemetry device, Emergency radio-services (during outages) Satellite Technology