CLIMATE CHANGE RISK ASSESSMENTS – WHAT CAN NZ LEARN!

Liam Foster, Opus International Consultants

ABSTRACT

'Globalization is changing the nature of risk. Natural and social systems – from climate to energy, food, water and economies – are tightly coupled. Abrupt changes in one have a domino effect on others. Floods in Thailand in 2011, for example, led to a global shortage of computer hard disks as a result of factories closing, as well as more than US $330 million in damage and around 250 deaths'1.

This paper will seek to share the lessons so painfully learnt across the world over recent years and how unprepared communities, businesses and infrastructure actually is for extreme flood risks and rainfall that seem to be occurring with greater regularity. The author will seek to share that there is a common lack of readiness to effectively managing the evolving risks of today. For example, PwC research has identified that asset management decision making is largely driven by human judgement/decisions – which is looking to be a dangerous tactic in a time of unprecedented uncertainty.

With this in mind, it is obvious we need to take steps to change our approach and become more resilient to uncertainties, particularly against a growing backdrop of asset interconnectedness. The outcome of which is that the flooding impacts are exponentially growing, with the impacts cascading through other infrastructure, in other words, the domino effect.

The paper will showcase how investing in practical resilience measures through to a complete rethink of the approaches to risk, resilience and ongoing planned maintenance can help minimise impacts of these events and keep communities and businesses going.

It is clear that there is the need for a new and comprehensive, long-term strategy to address flood risk across New Zealand, which should seek to encourage everyone to own their risks as much as local and national government.

KEYWORDS

Resilience, Climate change, domino effect, preparedness, long term strategy, flood risk assessments

1. INTRODUCTION

Our economy and society depend on a secure supply of services such as electricity, telecommunications, water, healthcare and transport. Across many countries, many of these essential services are delivered by the private sector, within regulatory frameworks set out by Government. These frameworks specify the responsibilities of private sector operators to deliver a reliable and resilient services.

---

[1] Erisman et al (2015) 'Global change: Put people at the centre of global risk management', Nature, March 015

Recent events have exposed weaknesses in the resilience of national infrastructure to some natural hazards, such as flooding. Across the world, national governments are seeking to understand their current and potential exposure to the vagaries of the current and future climates.

These represent both a risk and an opportunity moving forward and a Climate Change Risk Assessment undertaken at regular intervals enables the identification of the current status and where there are gaps in knowledge that are required to be better understood to help direct the scientific and business community to help achieve the overarching goals of any climate change legislation, namely to better understand the risks and enable the nation and its communities to face into and thrive into the future as opposed to be continuously exposed to negative impacts.

A key element of how countries, communities, individuals and corporate organisations can survive and thrive into the future is to understand the potential range of risks and opportunities that can present themselves and position themselves to adapt to these changes best. The climate change risk assessment is one such tool that can help this identification phase as well as point to simple 'no-regrets' investments that can help to safeguard future infrastructure service potential.

2. THE UNITED KINGDOM CLIMATE CHANGE RISK ASSESSMENT 2017 AND THE NATIONAL FLOOD RISK REVIEW 2016

The UK Climate Change Act requires the UK Government to compile every five years its assessment of the risks and opportunities arising for the UK from climate change. The 2017 report marks the second iteration of the UK Climate Change Risk Assessment (CCRA2) and was presented to Parliament in 2016. The CCRA2 Evidence Report comprises eight chapters written by leading academics, consultants and other experts in the public and private sectors and civil society representing organisations across Great Britain and Northern Ireland.

The UK Climate Change Risk Assessment second report (2017) or CCRA2 identifies that climate risk is a function of the likelihood of a climatic event and the severity of the impacts. A climate change risk assessment is a risk analysis that assesses a wide range of possible climatic conditions and their outcomes, both positive and negative. In relation to the assessment against infrastructure, a broad system view is required that needs an understanding of how the Natural Environment, networks, processes, resources and services would interact with the manifestation of risk. The systematic assessment would follow a typical staged analysis as follows:

1. Understand and analyse the potential climate variable scenarios and then prepare these for further investigative studies.

2. Characterize each infrastructure asset base, the fragility and capacity and response to extreme events and climatic change,

3. Analyse the network-wide effects that occur as a result of the impacts on individual or components or system functions,

4. Analyse the interactions and interdependencies between infrastructure networks to understand cascading impacts,

5. Understand the systemic risks related to the loss of infrastructure service, be that economic growth, social wellbeing or environmental protection,

6. Identify potential adaptations that may be implemented across the system. Asset or network scale engineering, policy or regulatory interventions all aimed at understanding how to best provide the service to customers. This could include working with customers to manage the demand for the service at critical parts.

The CCRA2 report identified that each sector faces specific climate-related challenges, however there are a number of consistently significant risks for each key infrastructure sector are identified in Figure 1.

Hazard / Sector	Floods	Water scarcity	High temperatures	(Wind) Storms	Geohazards (inc. subsidence and landslides)
Water and waste water	✓✓	✓✓	✓		✓
Transport	✓✓		✓	✓✓	✓✓
Energy generation	✓✓	✓	✓	✓	
Energy distribution	✓✓		✓	✓✓	✓
Flood and coastal defences	✓✓			✓	✓
Solid waste	✓		✓		
ICT	✓✓		✓	✓✓	✓

Source: Expert judgement arising from the literature reviewed in this chapter.
Notes: A single tick denotes a relationship; a double tick denotes a strong relationship. These do not consider dependencies between infrastructures.

Figure 1: Overview of key climate risks for each infrastructure sector (Committee on Climate Change, 2016)

The key findings for this study are:

More action is required to understand and adapt the UK to the risks of flooding and coastal change. The damages from these are already high, averaging over 1 billion per annum in the UK alone.

'A number of separate but related risks will arise due to increases in heavy rainfall, river flows, sea level rise and a corresponding increase in the height of tidal surges, and an increased rate of coastal erosion along vulnerable coastlines.'

The report identified that current levels of adaptation are insufficient to avoid flood and coastal erosion risks and damages increasing with further warming, for example it postulates that with 4°C of warming and high population growth, households with a significant chance of flooding is projected to increase from 860,000 today to 1.9 million by the 2050s.

Fourteen key action areas were identified to help support improvements in infrastructure resilience. The list below are those that the CCRA2 team identified required a greater urgency of activity to help deliver greater resiliency:

- Risks of cascading failures from interdependent infrastructure networks
- Risks to infrastructure services from river, surface water and groundwater flooding
- Risks to infrastructure services from coastal flooding and erosion

- Risks of sewer flooding due to heavy rainfall
- Risks to transport networks from slope and embankment failure
- Risks to public water supplies from drought and low river flows

The most intriguing finding from this study was that the top risk/opportunity identified was that of infrastructure interdependency and the potential for cascading failures. The key recommendation was that there was a need to enhance the current arrangements for information sharing across the multiple stakeholders and asset operators in order to improve the knowledge and understanding of the critical risks. This would allow measures and strategies to be developed to help improve the current gaps in knowledge of these connected infrastructures and how they would react in certain events.

In a similar vein, the UK Government (2016) identifies that we should focus in on improving the understanding of the vulnerability of infrastructure and assets of Critical National Importance. The review took place in three phases:

- The UK Met Office developed a set of plausible extreme rainfall scenarios, determined from modelling and analysis of monthly rainfall records across the regions, with a stated 90% confidence that these modelled levels will not be exceeded at any time over the next ten years.
- Modelling these rainfall scenarios to deliver Extreme Flood outlines for coastal and fluvial flooding (it is important to note that pluvial or surface water flooding was not considered at this time and that the actual UK vulnerability is likely to be significantly higher) and using these to test the resilience of key local infrastructure assets (such as energy, water, health, transport and telecommunications) on which services the communities and businesses depend.
- Determining what work would be required to make these key infrastructure sites resilient to the level of flooding portrayed in the Extreme Flood Outlines.

The outcome of which was that there are 1,640 assets that are vulnerable (above the relevant population threshold and within Extreme Flood Outlines) with specific sectors to prioritise for identification of the best methods for improving their resilience. The review also identified that greater resiliency would be achieved through collaboration across the many varying sectors to understand the interdependencies of flooding.

The key impacts for local communities were identified as being acute for the loss of certain services (electricity and hospitals). Separate reviews have been commissioned previously to understand the resilience of the transport network to extreme weather (2014). However once again the review was limited in its scope and focused in on assets of significance, but did note that the impacts of flooding on any infrastructure assets (such as a local electricity substation) would deprive large numbers of people of a critical service. The review focused on larger population thresholds greater than 10,000.

3. CASE STUDIES - CASCADING IMPACTS – 'THE DOMINO EFFECT'

3.1 PRAGUE FLOODS 2002

Pescaroli and Alexander (2015) identified that 'The 2002 floods in Prague, capital of the Czech Republic, were part of a cross-border event of extreme magnitude that involved several states in Central Europe. Heavy rainfall during early August triggered sequential waves of flooding. The main rivers, the Oder, Neiss, Elbe, Mulde, Danube and Vltava, broke their banks and severely inundated the Czech Republic, Germany, Austria, and Slovakia. Physical impacts were visible also in Poland, Hungary, Romania and Croatia. The floods caused lives to be lost and injuries to occur, plus economic damages on the scale of billions of euros, and significant damage to cultural heritage and unique historical sites. The main cascades were visible in the cessation of activity of two large power stations along the Danube River in Slovakia, a chlorine gas cloud released by the Spolana chemical plant outside Prague...'.

The authors identified that the cascade of impacts had to be analysed in some detail in that there were some longer term impacts that have had significant and widespread impacts. For example, the Spolana chlorine and mercury chemical spill did not cause immediate loss of life but required a large commitment of emergency resources and ongoing monitoring and interventions. The pollution has, and continues to, impact the water environment and as such specific European legislation was drawn up to try and avoid future occurrences. The authors further report that the flood event had detrimental long term impacts on water supply aquifers including the need to deliver hepatitis vaccines to large proportions of the population that had become exposed to the contaminate water.

3.2 THE UK FLOODS 2007

BBC (2008) identified that the summer of 2007 was the wettest on record in Britain with more than 400mm of rain falling, significantly more than at any time since it began compiling records in 1766. During June, the average rainfall across the country was approximately 140mm, more than double the usual average. Some areas received a month's worth of precipitation in 24 hours.

The vulnerability of national infrastructure was dramatically highlighted during the summer of 2007, when widespread flooding led to power failures and loss of water supplies throughout Gloucestershire, Worcestershire and East Yorkshire.

However, it was recognition of narrowly avoided disasters that made clear the need for a more systematic approach to resilience planning.

Key areas of damage:

- Flooding of the Mythe water treatment works in Gloucestershire led to the loss of water supplies to 350,000 people for up to 17 days. The floods affected a further four Water Treatment and 322 Wastewater Treatment Works across the UK (Pitt, 2008).

- Heavy rainfall resulted in bank-slipping incidents and flooding on the rail network causing delays in the service and subsequent delay in the supply of fuel.

- Motorway closures affected large parts of the road network. Repair costs of local and trunk roads were estimated at £40-60 million. Specifically, the delivery of a temporary flood defences at Upton on-Severn was unable to be deployed due to severe disruption to the transport infrastructure caused by surface water flooding. The impact of this was over 70 houses were flooded when they could have been protected.

- Damage to electricity distribution assets cut off 40,000 people in Gloucestershire for 24 hours. In Yorkshire and Humberside 9000 customers were placed on rota disconnection (rolling blackouts) for several days.

Figure 2 - Castle Meads Electricity Sub-Station flooded during the July 2007 events impacting 40,000 customers for a period of 24 hours

Near-misses:

- Walham substation in Gloucestershire came close to failure. This would have meant the loss of power to 500,000 people in Gloucestershire and South Wales.

- A near breach of the Ulley Reservoir dam threatened other infrastructure assets including the M1 motorway, a major electricity substation and a gas network connection for Sheffield.

3.3 THE THAILAND FLOODS 2011

The UNDP (2012), identifies that Thailand is susceptible to seasonal flash-flooding incidents due to the tropical monsoon cycles affecting the country. The 2011 flooding crisis was the worst in five decades and affected the whole country. Flooding commenced in northern Thailand in May and continued through to mid-January 2012, ultimately submerging 65 of Thailand's 77 provinces (as shown in Figure 3), including seven major industrial estates north of Bangkok, leaving 815 dead and 13.6 million people affected. The World Bank ranked the flood emergency as the world's fourth most severe natural disaster in terms of economic consequences.

The key element around this event is that this was the real global impact that resulted from the flooding of large swathes of the country and particularly urban centres, where industrial areas were located as shown in Figure 3.

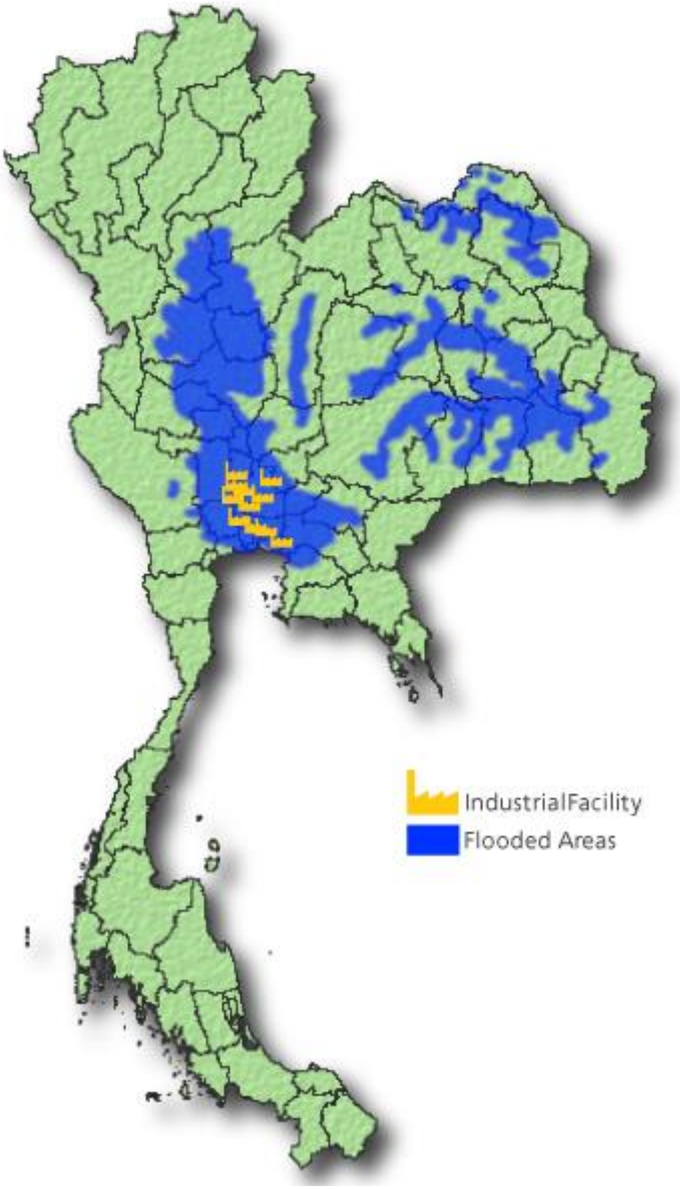


Figure 3 – Diagram of Flooded Areas affecting Thailand during 2011 (Sousounis 2012)

The key impacts can be summarized as being:

- Global economic growth – the flooding was estimated to result in a decrease of 0.6-0.9% in economic growth;
- Hard drives – Thailand is the world's second largest producer accounting for over 25-40% of the global production as well as the supply chain component manufacturing. The key industrial estates to the north of Bangkok that housed the key factories were inundated and production ceased for a minimum of 46 days. The cascading impact of this shortage is that the price of hard drives were elevated due to supply and demand economics and it took over two years to recover;
- Rice – Thailand accounts for 30% of the global rice trade and the flooding was estimated to have resulted in approximately 25 % of the annual Thai crop production being damaged (Phoonphongphiphat, 2011);
- Component production – the flooding had a negative impact on the several Japanese firms that had plants across Thailand (including Toyota, Honda, Hitachi

and Canon), with widespread impacts. For example Toyota had to suspend manufacture in the US as a result of shortage of key components manufactured in Thailand, impacting on these local economies and the livelihoods of staff around the world (Dawson and Takahashi (2011);

- Local population employment – with many factories and agricultural land damaged by the flooding, there was significant long-term job loss that occurred which has been further exacerbated by;
- Investor confidence – although not easy to record it is clear that the impacts of this event have had a significant impact on the investment potential of Bangkok (and others) as an Asian mega-city.

3.4 HURRICANE SANDY 2012

During October 2012, Hurricane Sandy had a severe impact along the Caribbean and Eastern Seaboard of the United States, leaving a trail of devastation with approximately 250 people losing their lives, over 600,000 houses damaged or destroyed. Several cities and towns along the Atlantic coast of New Jersey and New York were devastated, and air, rail, and road transportation ground to a halt. Heavy winds and rain or snow occurred throughout the Northeast and the Mid-Atlantic states. It has been estimated that damage is in the order of $80 billion for the event.

The cascading impacts were best exhibited and amplified in as it hit New York City and environs (as dense population and extreme weather collided), a storm surge measured nearly 14 feet (about 4.3 meters). Along with heavy rains, the surge caused the Hudson River, New York Harbour, and the East River to flood the streets and tunnels of Lower Manhattan, including parts of subway lines. Flooding and power outages occurred near the New York Stock Exchange, forcing its closure for two days, the longest weather-related closure of the exchange since 1888, having an impact on the global economy.

The event cascade resulted in flooding of residential and industrial buildings, resulting in power outages that lasted between several days and two weeks. A knock on impact was that fires of electrical origin broke out and could not be controlled (Kunz et al. 2013)i.

3.5 UPPER CALDER FLOODS, YORKSHIRE, UK 2012

The Calder Valley was affected by severe flooding during the summer of 2012. On Friday 22nd June 2012, a month’s rain fell in 24 hours, and the highest ever river level was recorded at Hebden Bridge. The Environment Agency estimated that “about 900 properties were damaged in the upper Calder Valley floods” whilst the Halifax Courier (2012) signposted that “the bill for repairs and clearing-up operations could run into tens of millions of pounds”.

Leach (2015) introduces the concept of impact pathway mapping, a visual representation of the impact of flooding on the local economy. The diagrams such as Figure 4 below demonstrate how the impact of flooding and flood risk travels and multiplies in the local economy, based upon the impact of the event on real businesses (a Food Retailer in this case) during and after the flooding.

They show the direct losses to the case study business immediately and in the longer term, and then how these impacts in turn affect suppliers, customers and employees. They also show how the impacts of flooding on suppliers, customers and employees in turn affect the case study business.

Key findings of the study are:

- The results show that flooding does impact along the supply and demand chains of flooded businesses. The impacts are highly variable and of varying magnitude. Some are immediately of significance; others are quite subtle but could be replicated across the local economy to a point where they become significant. Impacts can be positive or negative.

- Where businesses have a more localised supply chain, this impact will obviously be higher than where suppliers are based outside the area, but also gives a greater earning potential for the area to assist recovery and prior to the floods was contributing more the local economy.

- Reductions in turnover of businesses in the months up to a year following the floods are significant, with most businesses reporting this. This seems to come from both from footfall reductions and flood-affected customers, and is reflected in comments about the downturn in the whole area made by respondents. Transport disruption was a likely contributing factor, alongside a largely negative media focus. By way of illustrating the reduction in sales, 21 businesses had a collective decrease in sales of £831,324, averaging £39,587 per business in relation to a mean turnover of around £569,733

- There are severe consequences for business confidence from flooding, with a significant majority of interviewees reporting ongoing anxieties and uncertainties.

- Problems getting any, adequate or affordable insurance is a major issue leaving several businesses uninsured and extremely vulnerable.

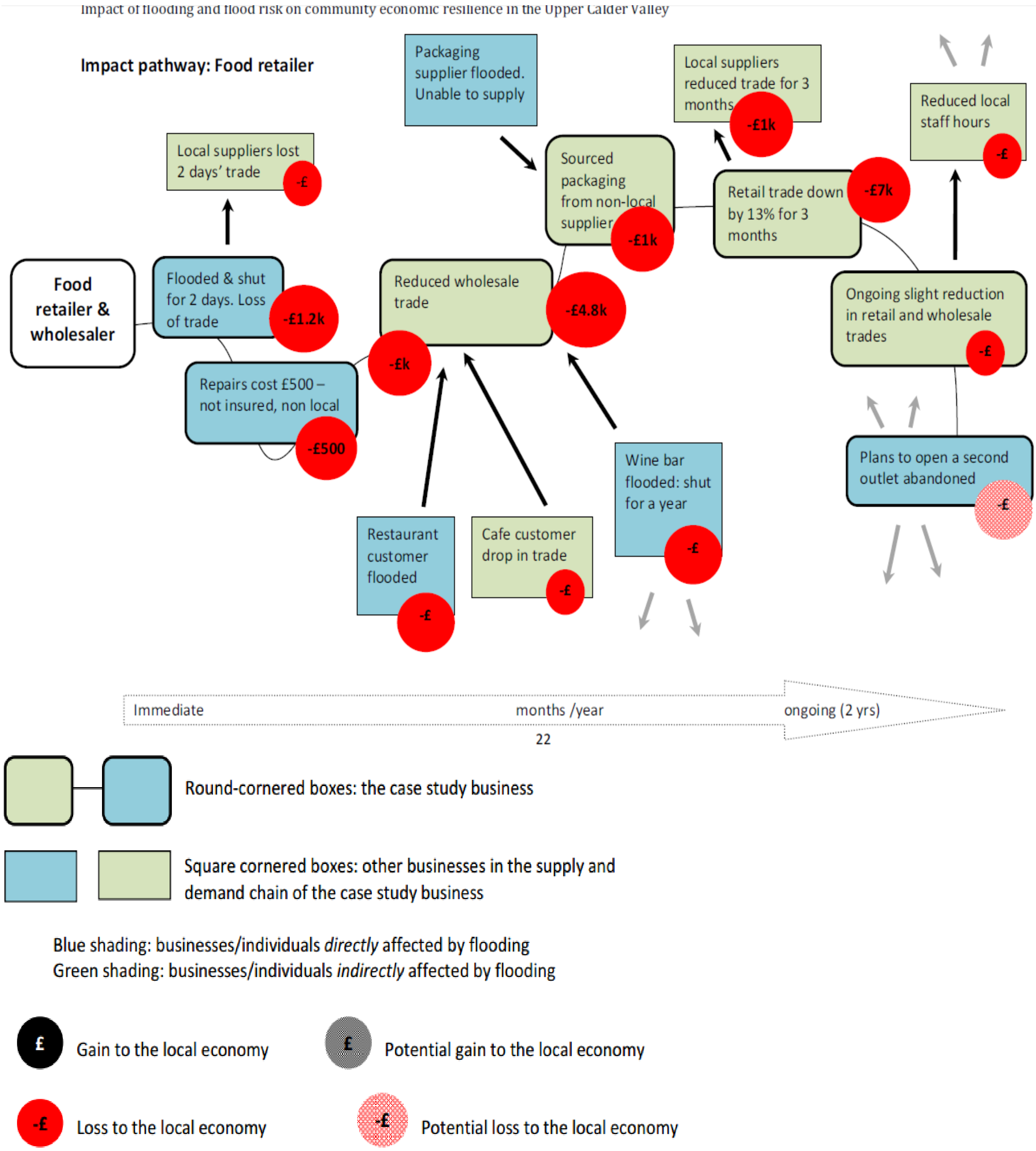


Figure 4 - Impact Pathway Diagram for a Food Retailer and the impacts of flooding on the business and supply chain following on from the 2012 flooding in the Upper Calder Valley (Leach, 2015).

4. COMMON LESSONS

Lesson 1 – We are greatly exposed to the impacts of natural hazard events and the consequences are becoming harder to predict.

Infrastructure sectors are increasingly interconnected and interdependent; failure of one infrastructure network can cause disruption and failure in other dependent networks, amplifying risks as shown in the above case studies. There are a large number of potential interactions and relationships that have been identified), but the additional complexity, and limited data on the nature of many interactions, means there is limited quantitative evidence of the magnitude of many of these risks. This therefore represents a significant constraint in the ability of a community, an organisation or a region to 'bounce back' quickly from such events.

Lesson 2 – Adaptation is a good thing, but must be well-thought out and withstand short term budget focus.

CCRA2 identifies that "Infrastructure adaptation options can be compared on the basis of the impact that they are expected to have on reducing the frequency and severity of climate effects. There are four main strategies to manage infrastructure risks and build resilience:

(i) Increase the resistance of infrastructure components by providing enhanced protection.

(ii) Improve the reliability of infrastructure components so they are able to operate under a range of possible conditions.

(iii) Provide redundancy to increase the capacity, number of alternative connections and diversity of backup systems.

(iv) Build capacity in organisations and communities to deliver a fast and effective response to, and recovery from, climate disruption

Adaptation should therefore not be thought of as exclusively 'major' engineering interventions, but as a wider set of interventions at all scales to manage the impacts of climate change across the wider infrastructure system. Adaptations include technical options but also regulatory, policy and community responses are crucial to enhancing the adaptive capacity (potential to adapt to climate variability and change) of infrastructure systems."

Business models which aim to boost short-term efficiency, such as those which eliminate spare capacity, may conflict with investment in resilience to the detriment of long-term performance. This has led to recent changes in National Governments across the world requesting infrastructure providers (such as Local Government) to frame their shorter term asset plans (Annual to Long Term Plans) within a longer term strategy. For example, New Zealand has a 30 Year Infrastructure Strategy (since 2015) and the UK Water Industry (since 2008) is required to undertake long-term planning by setting their five year business plans within a 25 year context.

Each of these two frameworks however are at the mercy of further criticism, in that these potentially focus too much on customer price impact as opposed to driving through an increasing network/system resilience. A key factor as to why this has not come through with greater focus is that the uncertainties around the cost of adaptation and the understanding of the potential cost of taking no action are largely unknown and therefore represent a large barrier to investment in a world where limited resources are available within institutions and are competing against a series of other pressures.

Little (2012) again identified that 'There is always conflict between spending to avoid an adverse outcome or on something that produces a more immediate and observable benefit. This is actually at the heart of the issue of mitigating the risk of infrastructure failure; monies spent to address failures that never occur often are considered wasted by the public and policy-makers alike. This makes it politically difficult to "do the right thing" and much easier to do the opposite.'

Lesson 3 – Ongoing and regular assessment is necessary to maintain understanding of the risks faced

Effective Asset Management is critical to understanding and mitigating the risks that Natural Hazards pose. Little (2012), identified that 'In many ways, physical infrastructure is much like a living thing which goes through a process of creation, growth, maturation, decline, and death. Unlike natural systems, though, physical systems cannot sustain themselves; they must be renewed from without in the form of maintenance, repair, renewal, and replacement on a more or less continuous basis. These sustaining actions require us to invest capital, materials, labor, and other resources. Depriving a physical system of funding for maintenance and repair, for example, will have a similar effect to depriving a living organism of food or water—it will decline and ultimately, die.'

Furthermore, lack of communication between different operators can make it difficult to identify interdependence, to establish responsibility for resilience and to target resources efficiently and as such it is clear that clear leadership is required to promote the need for infrastructure suppliers to undertake systems-based approaches to unpick the interconnectedness and start to derive strategies for improving the overall resilience of assets.

Lesson 4 – We must do more ourselves as individuals and organisations to be prepared for these events.

Relying on local and national government to resolve and predict all of the potential climate scenarios and their impacts upon our livelihoods, assets, supply chains etc is effectively leading us on a path to ruin. All individuals and organisations of the part they must play in developing their own resilience and encourage them to own the risks just as much as the government and local authorities.

5. WHAT CAN NZ LEARN AND WHAT NEXT

There is considerable information available across the world to showcase the general vulnerabilities of many asset groups as well as the growing awareness of the interconnectedness of several infrastructure types. NZ can seek to continue to learn from overseas to deliver an improved flood risk management process suitable and adaptable for the disparate communities around New Zealand. There are key messages from each of the studies presented above, which have been collated under some key headings below. Increasing our focus on learning the lessons painfully learnt elsewhere would help New Zealand to avoid having to learn the painful lessons themselves:

Affordability and the need for tough choices – It is clear from the UK CCRA2 that even with current significant investment in Flood and Coastal Risk Management per annum by the UK government, that the residual risk of flooding remains high. Improved flood defences will not be possible or affordable across all areas, leading to climate change causing a greater disparity in risk for some communities and businesses. Therefore there must be a greater awareness of the role that individuals and organisations have to play in preparing themselves and that in some cases some infrastructure would need to go through planned managed retreat.

Our Urban Form must promote adaptation – It is becoming clear that the current preferential urban form is no longer sustainable and that burying water away is untenable. Climate change and rapid demographic change (particularly increasing urbanisation) is expected to lead to significant volumes of additional runoff in areas that are already at or over capacity. More action is required to protect individual properties whilst seeking to redesign our urban landscapes to make space for water and to allow multiple beneficial outcomes to accrue for the communities.

A clear need for a National Flood Risk Assessment - It is clear that to enable better understanding of the risks that are faced, that a national-scale understanding of the infrastructure vulnerability to natural hazards is required immediately. Throughout New Zealand many local and regional councils are at different levels of maturity in relation to the flooding hazard understanding.

The risks to our infrastructure need to be quantified and plans to improve resilience put in flight – Undertaking a thorough National Flood Risk Assessment is likely to identify that significantly important local, regional and national infrastructure (hospitals, road and rail networks, water and wastewater treatment works, ports and airports, electricity sub-stations and fixed & mobile communications) assets are exposed to flooding risks. More research is needed to assess and understand how to best manage this.

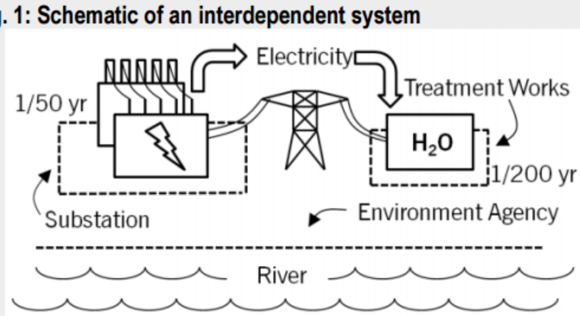
Furthermore, without the understanding of the single infrastructure asset vulnerability, we are increasingly exposed to suffering severe impacts from the interdependency of our infrastructure. It is clear that different levels of service are being promoted across New Zealand for infrastructure and with a chain only being as strong as the weakest link then there should be a greater awareness of Systems Based Approaches.

This is best summed up in Figure 5 (UK Government, 2010) identifying the resilience of UK infrastructure.

Box 5. The Need for Systems Based Approaches

The following hypothetical scenario illustrates some of the challenges posed by interdependency. Figure 1 depicts a water treatment works sourcing its electricity from a neighbouring substation. Resilience to flooding by a local river, indicated by dashed lines, is different for each of the two assets: the substation is protected to a 1/50yr event and the treatment works to 1/200yr.

Fig. 1: Schematic of an interdependent system



However, in this situation the higher resilience of the treatment works is redundant, since it will still be rendered inoperable by cascading failure from a 1/50 yr event flooding the substation. Indeed, identical levels of protection may seem appropriate. But there is another operator in this system: the Environment Agency is responsible for the maintenance of the river; it could raise an embankment to protect both the substation and the treatment works simultaneously. The most effective resilience planning may only be developed by reviewing the system as a whole.

Figure 5 – Example of interdependence of different infrastructure providers (UK Government 2010).

Individual infrastructure sectors employ a wide range of measures to strengthen resilience including: enhancing physical protection of assets; relocating critical equipment on sites; increasing interconnectivity so that service provision is no longer dependent on a single asset; and deploying mobile back-up equipment. The choice in any particular case is determined by a number of factors including risk, benefits, economic and commercial considerations however it is recommended that the concepts of systems based approaches are promoted to ensure that the whole of life asset management costs are understood and that the chain of flood risk management is not unnecessarily weak.

A need to consistently amend and adapt our Land Use Planning and Infrastructure Design guidelines - New and existing settlements and infrastructure must be prepared for effects of long-term climate change, such as extremes of rainfall and as such it is clear that the basket of measures that Flood Risk Management must be promoted and carried out.

In particular design must consider what happens during events greater than their design standard and as such a '**safe-fail**' mentality to design is advocated.

A need to face facts - A key step for New Zealand is to recognise that there is an issue here and that it is growing. New Zealand relatively speaking has a low level of protection (with the exception of some major river systems across New Zealand) in relation to flood risk management approaches of other countries across the world.

Equally and more importantly, there has been no fundamental change to the knowledge of flood risk and consequences across New Zealand since the MFEii report in 2008, despite multiple events affecting a range of urban and rural communities and billions of dollars of tangible and intangible losses across New Zealand. The report in 2008, identified that 'The current level of National Flood Risk still cannot be stated with accuracy, and neither can the impact of climate change or variability be meaningfully predicted on the level of flood risk'

6. CONCLUSIONS

Infrastructure across NZ is already experiencing significant impacts as a result of the natural variability of our climate. It is likely that without significant activity, the increases in the frequency of severe weather events (e.g. flooding) will cause increasing amounts and consequences of disruption of infrastructure that over time will require some significant focus to help improve the ability of our communities to adapt and become more resilient to the impacts of future flooding.

Furthermore it is clear that gradual changes to the long-term averages will also have an impact on the performance of the infrastructure with capacity and efficacy of the asset diminishing over time. This will over time erode the service that the infrastructure provides and require further unplanned investigation and investment into the future.

Many infrastructure sectors need to update standards and guidelines to ensure infrastructure is designed and built for a future climate. Furthermore, climate change will interact with, and exacerbate, the impact of other pressures that include population growth and ageing infrastructure.

There is evidence that significant adaptation steps to manage climate change risks have been implemented, or are underway, across most infrastructure sectors. Where sufficient information is provided, our assessment indicates that these investments will maintain or, in some instances, reduce climate risks over the next decade or two. On longer timeframes, projected changes in climate are likely to outpace current adaptation plans

With this in mind, it is obvious we need to take steps to change our approach and become more resilient to uncertainties that threaten key assets and infrastructure. The key to this is to provide a renewed and stronger national focus on flooding to help understand the risks that face New Zealand as a whole.

Whilst several Local Government organisations across New Zealand are well versed in their understanding of the risks their communities face, recent events across New Zealand during the past three years further give strong evidence that the implementation of a National Flood Risk Assessment is a critical step to delivering a key understanding of how vulnerable New Zealand as a whole is, now and into the future.

Once this is in place, the New Zealand can seek to undertake local, regional and national climate change risk assessments that can help to determine how urban and rural communities can seek to make the best out of the opportunities that climate change will present as opposed to being reactive and responsive to the unforeseen impacts and change that disruption will bring to our lives.

In the meantime, individual infrastructure sectors are recommended to better understand the vulnerabilities to their assets, their supply chain and their access to markets (amongst others) from this critical and most prevalent natural hazard risk that faces New Zealand. This will require significant investment to deliver the understanding on a piecemeal asset sector and as such, the author recommends that several similar asset infrastructure sectors combine efforts to best understand the risks and the potential opportunities that may appear from collaborative and cross sector Systems Based Approach.

There is much to do, but the time is ripe to start our journey towards advanced asset management across all the various infrastructure sectors that perform a public good, such that our lives can be further asset provision and not inconvenienced or even put at risk through ill-planned or mis-understood infrastructure investment decisions now and into the future.

REFERENCES

British Broadcasting Corporation 2008: *The summer floods: what happened* (online) [Cited: 01 02 2017.]. Available from: http://news.bbc.co.uk/2/hi/uk_news/7446721.stm

Committee on Climate Change, 2016 - *UK Climate Change Risk Assessment 2017 – Synthesis report: priorities for the next five years* (online), July 2016, London

Halifax Courier, 2012, *Assessing the cost of the Calder Valley Flood* (online) [Cited: 01 02 2017.]. Available from: http://www.halifaxcourier.co.uk/news/environment/assessing-the-cost-of-the-calder-valley-flood-1-4684184

Extremewatch, 2013, *HDDS back to pre flood prices, SSDS grow as GB holds steady*, online [Cited: 01 02 2017.]. Available from http://www.extremetech.com/computing/153879-storage-pricewatch-hdds-back-to-pre-flood-prices-ssds-grow-as-gb-holds-steady

Kunz. M er al, 2013, *Investigation of superstorm Sandy 2012 in a multi-disciplinary approach*, Nat. Hazards Earth Syst. Sci., 13, 2579–2598, 2013

Leach, K, 2015, *Impact of flooding and flood risk on community economic resilience in the Upper Calder Valley*, commissioned by Claderdale Council and DEFRA (Localise West Midlands).

Little, R, 2012, *Managing the Risk of Ageing Infrastructure*, International Risk Governance Council – Public Sector Governance of Emerging Risks – Infrastructure Case, November 2012

MfE, 2008, *Publication 900 - Meeting the Challenges of future flooding in New Zealand*, Wellington 2008.

Pitt, M., 2008: *The Pitt review: learning lessons from the 2007 floods* (online) [Cited: 01 02 2017.]. Available from: http://webarchive.nationalarchives.gov.uk/20100807034701/http:/archive.cabinetoffice.gov.uk/pittreview/_/media/assets/www.cabinetoffice.gov.uk/flooding_review/pitt_review_full%20pd f.pdf

Sousounis, Dr. P, 2012, *The 2011 Thai Floods: Changing the Perception of Risk in Thailand* (online) [Cited: 01 02 2017.]. Available from: http://www.air-worldwide.com/Publications/AIR-Currents/2012/The-2011-Thai-Floods--Changing-the-Perception-of-Risk-in-Thailand/)

UK Government, 2010, *Resilience of UK Infrastructure*, Parliamentary Office of Science and Technology, London, Postnote Number 362, London, October 2010

UK Government, 2016, *National Flood Resilience Review,* London, September 2016

UNDP, 2012: *Thailand Flooding 2554 – Rapid Assessment for Resilient Recovery and Reconstruction Planning*, Ministry of Finance, Royal Thai Government and The World Bank.