



OFF the RADAR - Synthesis Report

High Impact Weather Events in the Western Cape, South Africa 2003 - 2014

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EXECUTIVE SUMMARY

Background

Between 2011 and 2014, the Western Cape was severely affected by five high impact weather events that led to four provincially gazetted flood disasters. All five of the flood-triggering weather processes were associated with identifiable cut-off low (COL) weather systems that respectively passed through the province between 7-9 June 2011, 13-14 July 2012, 7-11 August 2012, 15-17 November 2013 and 6-10 January 2014.

The resulting disasters were characterised by widespread flooding, with impacts reported across most of the Western Cape Province. Outside of the Cape Metro, twelve people lost their lives, while more than 23,000 were affected in informal settlements and low-cost housing areas, as well as farms and more affluent areas. Flash-flooding associated with the 15 November 2013 COL forced the rescue of 121 patients from the Mediclinic Vergelegen in Somerset West, the first evacuation of an entire hospital recorded on the continent. The same system affected 18,000 residents in 44 informal settlements within Cape Town (WCDMC, 2013).

Government departments (excluding the Western Cape Department of Agriculture) and affected municipalities reported financial losses in excess R 682.8 million. Farm costs and losses linked to COL weather systems and associated flooding were estimated at R 900.5 million, constituting 56.9% of the total. Altogether, total financial costs/losses to government departments, municipalities and the agricultural sector were estimated at R 1.6 billion.

Research Methodology

In accordance with the National Disaster Management Framework, which requires post-event reviews following disasters and significant events, in-depth multidimensional studies were conducted for each of the four disaster events. Specifically, the study sought to:

- Understand the five weather systems and their hydrological effects.
- Identify measures to mitigate, anticipate and manage the systems' effects.
- Determine the impacts of the events, including social consequences, infrastructural damage and agricultural losses.
- Document the financial losses sustained.
- Identify high-risk areas and infrastructure and the implications for disaster management, climate risk management and sustainable urban and development planning.

The research was undertaken by the Research Alliance for Disaster and Risk Reduction (RADAR) at Stellenbosch University, in collaboration with the Western Cape Provincial Disaster Management Centre (WCDMC), and the Western Cape provincial Departments of Agriculture (DoA) and Transport and Public Works (DTPW).

It examined the 2011-2014 COL-related disasters as a series of high impact weather events (HIWE), or *"weather that can result in significant impacts on safety, property and/or socioeconomic activity."*[1] It was undertaken as a complex, multi-stage transdisciplinary research project that combined in-depth examination of each declared disaster (2011-2014), with cross-cutting meteorological and hydrological analyses and two nested case-studies. In the second analytic phase, findings from eight previous ex post COL studies were integrated with the 2011-2014 data to identify recurrent and changing risk conditions across more than a decade's high impact weather disasters.

[1] Sills (2009).

Summary of Impacts

1. From 2003-2014, there were twelve disasters associated with 14 identifiable COL weather systems in the Western Cape, signalling that high impact weather conditions and damaging floods are not 'rare events' (refer to Table 1, following the Executive Summary).
2. They occurred almost annually, with extensive and recurrent financial losses. From 2003-2014, R 4.9 billion in flood-related damage was reported by government departments and municipalities. Of this, R 2.3 billion was due to agricultural costs.
3. COL-associated associated damage varied seasonally, with average municipal costs in warmer months more than doubling those in cooler periods. Average September-February municipal disaster costs were estimated at R 120.2 million per event compared with R 47.6 million for individual disaster events from March-August.
4. From 2003-2014, Hessequa Local Municipality in Eden reported damage for eight of the 12 events and cumulative losses of R 178 million. George reported R 178 million in damage for six events and Knysna recorded R 142 million for five disasters.
5. Social impacts were wide-ranging but poorly documented, and included deaths, evacuations and temporary isolation. Twenty-three lives were reportedly lost, with more than 30 800 people affected or evacuated. Outside of the Cape Town Metro, the Langeberg Municipality reported the largest number of residents affected or evacuated (6 400). Results indicate that inland residents are at increased flash-flood risk, especially in the Langeberg and Laingsburg municipalities. Meiringspoort also represents an identifiable flash-flood hot-spot.
6. Critical facilities and essential services are at-risk. In the 2012 and 2013 COL-induced disasters alone, impacts included the loss of an ambulance attendant on duty and a hospital evacuation, while wind/ rain damage were reported for 23 schools within the City of Cape Town (CoCT).
7. From 2011, the national introduction of more rigorous infrastructural damage assessment procedures for recovery reconstruction has reduced the range, specificity and accuracy of reported losses. This has weakened the quality of municipal and provincial disaster risk surveillance, especially for non-infrastructural and recurrent impacts (see Sections 1.3.6 and 1.5).

Extreme daily COL-induced rainfall has become more frequent

1. There is an identifiable recent increase in the frequency of extreme daily rainfall associated with COL weather systems. This is also associated with record flood peaks in several rivers during the past decade.
2. The COL weather systems were associated with heavy rainfall as well as other potentially damaging conditions, including snow and hail.
3. COLs occurring in the warmer months have potential to be particularly damaging.

Developmental conditions drive flood risk

Despite their almost annual occurrence, there is still a widely held misperception that *'floods'* are *'disasters'*. This has discouraged the incorporation of flood risk management into integrated development plans (IDPs) and funding models.

1. Developmentally-driven flood risk factors continue to escalate the likelihood of endangering floods. These include shortcomings in integrated catchment and river management that increase flood exposure, especially the *build-up of sediment* of riverbeds around bridges and culverts.
2. They also include inadequate removal of alien vegetation and debris from rivers and floodplains.

3. Incremental changes associated with development and agricultural practices have increased flood risks by altering catchment conditions. Residential, commercial and infrastructural expansion and densification in flood-prone areas have not only placed homes, facilities and infrastructure in harm's way, but also impeded the flow of natural watercourses and overland run-off during heavy rain.

High impact weather responders and forecasters are under pressure

1. The Western Cape Province benefits from high levels of committed, effective and skilled disaster (risk) management and emergency services practitioners.
2. However, current flash-flood forecasting and communication approaches were too broad-brush to give advance warning to specific areas under threat or to accurately inform action. This applied especially to municipalities in the Karoo and mountainous catchments.
3. Constrained weather radar coverage severely hampered early warning of high impact weather conditions and prevented effective implementation of the National Flash Flood Guidance System. This especially applied to inland municipalities where there are tight time-frames for evacuation and life-saving response, but large distances to cover and major resource constraints.
4. Social media is a powerful medium in disaster responses, with potential to be a formidable resource for informed decision-making and disseminating disaster-related information.

RECOMMENDATIONS

Improve COL and flood risk understanding as well as on-going surveillance

The WCDMC should consult with appropriate national, provincial and municipal authorities to:

1. Assess and address sedimentation levels in flood-prone areas on an ongoing basis. This includes the impact of sediment accumulation on flow capacity for bridges and culverts carrying regional and district roads across flood-prone river channels.
2. Engage with the Department of Water and Sanitation (DWS) to evaluate progress of rectification processes to reduce safety risks at various large and medium dams. This particularly applies to the Karoo where sediment loading and retention are high. Where progress is slow or delayed, increased downstream flood exposure must be identified and communicated to the affected parties.
3. Identify critical facilities and infrastructure exposed to flooding, as well as areas at risk of isolation during flood events, such as in the Langeberg Municipality, Hout Bay and Meiringspoort. Contingency plans need to be established to assist in strengthening and streamlining future responses to flooding in these localities.
4. Identify hospitals and health facilities that are potentially flood-exposed. Provincial Emergency Medical Service (EMS) should consider and investigate the scope for making flood-risk assessment a requirement for hospitals.
5. Revisit and harmonise current approaches to disaster risk assessment as well as post-disaster loss estimation in the province, to improve the range, accuracy and spatial specificity of losses. This information should proactively inform and update purposive resilience programming within integrated development planning processes.

Strengthen institutional capacity to manage COL-induced flood risks

The WCDMC should consult with appropriate national, provincial and municipal authorities to:

1. Reinforce the need for prospective flood risk management. Flood-risk should be explicitly incorporated into planning, infrastructural developments and maintenance regimes. Resilience planning and funding mechanisms should be prioritised for high-risk areas.

2. Deepen institutional memory related to HIWEs and their effects within district and local disaster management authorities to build more robust disaster management capacity.
3. Urgently address gaps in the provisioning of emergency response vehicles, particularly in flash-flood-prone and rapidly isolated areas such as the Langeberg Municipality. Emergency response capabilities in these areas should also be enhanced.
4. Explore the role of Neighbourhood Watches and similar institutions as local resources. DRM and response planning processes should identify local capacity and engage to proactively strengthen planning and response.
5. Assist in clarifying the roles and responsibilities in the case of emergencies facing private health facilities. While EMS is mandated and best placed to manage responses concerning health facilities, the respective roles, and chains of command should be clearly defined.

Invest in flood resilience building to protect development gains

The WCDMC should consult with appropriate national, provincial and municipal authorities as well as the private sector to:

1. Ensure that new infrastructure is designed to withstand current risk conditions, as well as possible future upward trends in weather extremes and climate variability.
2. Ensure that flood prevention and preparedness, including cleaning of drains are implemented year-round (not just before winter rainy season).
3. Increase oversight of alien clearing processes, to ensure that cleared vegetation is removed properly from the riparian zone, as specified by the DWS.
4. Support DoA efforts to enable farmers to reduce erosion by encouraging improved farming and land care practices, and advancing river protection efforts, including holistic, system-level river management processes.

Improve both disaster preparedness and capacities to 'build back better'

The WCDMC should consult with South Africa Weather Service (SAWS) to:

1. Collaboratively and urgently address gaps in weather radar coverage, especially for the Province's inland areas. This includes new and additional radars so the Flash Flood Guidance System can function protectively and to enable impact-based forecasting.
2. Explore mechanisms to introduce integrated flash flood early warning systems at hotspots that combine SAWS warnings, an enhanced version of the South African Flash Flood Guidance System (SAFFG), radars (where feasible), automatic weather stations, real-time river gauges, cameras, community EWS, and in specific critical basins, complex hydrological modelling.
3. Provide more spatially specific impact-based forecasts to provide finer-scale information that captures meteorological variability between areas, and improves forecast information at the local level, to fine-tune pre-emptive responses.

The WCDMC should consult appropriate national, provincial and municipal, especially local disaster management officials to:

1. Improve risk communication mechanisms that target flood-exposed populations more effectively, especially those in informal settlements. In Eden District Municipality, this should also include communities living along the Keurbooms River and tourists and others likely to travel through flash flooding hotspots such as Meiringspoort.

2. Improve the effectiveness of social media, by incorporating social media systematically into awareness and flood risk communication strategies.
3. Expedite post-disaster recovery and reconstruction funding processes to support risk reduction imperatives, particularly in less-resourced local municipalities
4. Develop guidelines to 'build back better' as urged by the Sendai Framework for Disaster Risk Reduction. (There needs to be greater emphasis on risk reduction in the repair of damaged infrastructure to strengthen its resilience for flood and other high impact weather exposures).

Strengthen disaster risk management (DRM) capacities in hospital facilities

The WCDMC should consult with Provincial EMS in connection with potentially flood-exposed medical facilities to:

1. Sensitise senior hospital managers to environmental and climate conditions that stand to create unexpected emergencies.
2. Advise managers of both private and public health care facilities in areas potentially exposed to flooding, to undertake risk assessments to inform appropriate risk reduction efforts and planning.
3. Develop evacuation protocols that establish criteria for proactive action and decision-making. These should be based on a strengthened relationship between disaster management authorities and provincial EMS.
4. Ensure continuity of services by planning and preparing for communication and electricity failures/ interruptions.

Prioritise DRM in the agricultural sector

As stressed in previous post-disaster studies within the Western Cape, the agricultural sector sustains unacceptably high recurrent costs due to exposures to high impact weather, flooding and drought. This study shows that 56% of total costs reported by government entities from 2011-2014 were attributed to agriculture.

It is urged that the DoA prioritise its institutional capacity for agricultural risk management. Specifically, the DoA should review the recommendations outlined in the draft Department of Agriculture, Forestry and Fisheries (DAFF)-commissioned Feasibility study on the decentralisation and institutional capacity development for DRM within DAFF (DAFF, 2014) and actively consider the following:

1. "Establish a dedicated DRM unit for agriculture in each province. The unit functions within the respective provincial department of agriculture and becomes part of its hierarchy, similar to the DRM within DAFF. In such a case the unit must be correctly located in the structure so that it has the mandate and ability to coordinate DRM activities across all sectors. These units must also be staffed and funded to achieve their objectives" (DAFF, 2014:14).
2. "Funding should be made available for DRR and disaster response activities as per the Disaster Management Act (DMA) and National Disaster Management Framework (NDMF).[2] Specifically 1.2% of each sub department's budget as required by the NDMF (see page 104) should go to contingency fund for disaster response activities at both levels. This percentage allocation would ensure alignment with the DMA and NDMF. For operational budgets it is advised that provincial and national departments along with Provincial and National Treasuries take responsibility for funding provincial units" (DAFF, 2014:8).

[2] The Disaster Management Act was amended in 2015 by the Disaster Management Amendment Act (No. 16 of 2015). http://www.gov.za/documents/disaster-management-amendment-act-16-2015-15-dec-2015-0000

3. “DAFF should urge the National Disaster Management Centre (NDMC) to develop and put guidelines in place as per the NDMF to eliminate red tape for disaster relief funding within the sector. Provincial units and affected groups should also be made aware of the correct procedures to follow to access funding from Department of Cooperative Governance (DCoG) -NDMC” (DAFF, 2014:8).

Table 1: Summary of the 12 events 2003 – 2014

Date	Event type & area affected	Social impacts	Damage (R mil)	Heaviest total rainfall
Mar 2003	COL: Cape Winelands, Eden, Overberg	More than 3 000 people evacuated Three deaths in Hermanus and Knysna	343.4	Langeberg, 241mm
Dec 2004	COL: Cape Winelands, Eden, Overberg	3 700 homes and 40 business premises damaged	83.3	Knysna, 218.8mm
Apr 2005	COL: Cape Agulhas Municipality	Residents of Kleinbegin flood affected	12.7	Cape Agulhas 228mm
Aug 2006	Two COLs: Cape Winelands, Eden, Overberg, Central Karoo	Approx 1 600 people displaced. Five fatalities	691.4	1: George, 327.8mm 2: Swellendam, 24mm
Jun 2007	COL, followed by a mid-latitude cyclone: West Coast and Cape Winelands	People from low cost housing, informal settlements and farms evacuated.	159.6	COL: Bergrivier, 280-318mm Mid-latitude cyclone: Witzenberg, 50mm
Nov 2007	COL associated with black southeaster: Cape Winelands, Overberg, Central Karoo nd Eden	Approx 2 400 people from low cost housing, informal settlements and farms either provided with relief or evacuated; two fatalities	1 191.5	George, 458.8mm
Jul 2008	COL and strong south easterlies: West Coast		82.0	Roode Els Berg, 275mm
Nov 2008	COL associated with black southeaster: Overberg, Cape Winelands and Eden	One fatality in Langeberg	1 138.7	Hessequa, 247.5mm
Jun 2011	COL: Cape Winelands, Central Karoo, Eden and Overberg	More than 1 400 people from Informal and low-cost settlements evacuated. Households cut-off and Knysna Central Business District (CBD) flooded. 1 death in Hessequa	348.0	Mossel Bay, 299.2mm
Jul-Aug 2012	COL combined with a low-level cold front in July: heavy snow in Eden and the Central Karoo. COL in August: Flooding in the Cape Winelands and Eden	More than 2 000 affected Knysna Oyster Festival and Marathon cancelled. Five fatalities in George, Langeberg and Oudtshoorn	377.7	July: George, 111.5mm August: George, 131mm
Nov 2013	COL combined with a warmer tropical-temperate trough and a low-level low pressure system: CoCT, Cape Winelands, Overberg and Eden	More than 19 000 people in informal settlements and low-cost housing affected across the province. 121 patients evacuated from Mediclinic Vergelegen. Water supply to Worcester disrupted. Two fatalities in the Stellenbosch area	167.5	Theewaterskloof, 231.4mm
Jan 2014	COL combined with a tropical low pressure system Central Karoo, Eden and Overberg	Water supply to Laingsburg and Riversdale disrupted. 33 people trapped in Meiringspoort. Relief provided to people in Cape Winelands and Eden; 4 fatalities in Cape Winelands	465.5	Somerset West, 389.2mm

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ACRONYMS

APMF	Associated Programme on Flood Management
COL	Cut Off Low
CBD	Central business district
CoCT	City of Cape Town
DAFF	Department of Agriculture, Forestry and Fisheries
DCoG	Department of Cooperative Governance
DEA&DP	Department of Environmental Affairs and Development Planning
DiMP	Disaster Mitigation for Sustainable Livelihoods Programme
DMA	Disaster Management Act
DoA	Departments of Agriculture
DRM	Disaster Risk Management
DRMC	Disaster Risk Management Centre
DTPW	Department Transport and Public Works
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EMS	Emergency Medical Service
ENSO	El Niño Southern Oscillation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EWS	Early Warning System
FEWS	Famine Early Warning Systems
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GWP	Global Water Partnership
HIWE	High Impact Weather Events
HPNBG	Harold Porter National Botanical Gardens
IDPs	Integrated Development Plans
IPCC	Intergovernmental Panel on Climate Change
IWEE	Institute for Water and Environmental Engineering
JOC	Joint Operations Centre
MIMMS	Major Incident Medical Management and Support
MEC	Member of the Executive Council
NCEP	National Centres for Environmental Prediction
NDMC	National Disaster Management Centre
NEMA	National Environmental Management Act
PSP	Professional Service Provider
RADAR	Research Alliance for Disaster and Risk Reduction
RMMP	River Maintenance and Management Plan
SAFFGS	South African Flash Flood Guidance System
SANDF	South African National Defence Force
SANParks	South African National Parks
SANRAL	National Roads Agency
SAPS	South African Police Service
SAWS	South African Weather Service
SCS	Soil Conservation Service
UNISDR	United Nations International Strategy for Disaster Reduction
US EPA	United States Environmental Protection Agency
WCDMC	Western Cape Disaster Management Centre
WMO	World Meteorological Organisation
WUA	Water User Association
ZAR	South African Rands

GLOSSARY

Avulsion	River avulsion is the rapid abandonment of the river channel due to the flattening of the channel's slope through sediment deposition, or aggradation. This results in the river finding or eroding a new channel which can maintain the flow rate Source: Slingerland and Smith, 1998.
Aggradation	Aggradation is the increase (or build-up) in land or river bed elevation when sediment deposition exceeds erosion rates. Aggradation typically occurs in lowland areas where river flow rates slow, mostly because of the reduced slope of the land . Source: United States Environmental Protection Agency (US EPA), 2012.
C-band radar	The C-band is the portion of the electromagnetic spectrum in the microwave range of frequencies ranging between 4000 and 8000 MHz, with wavelengths ranging between 3.75 and 7.5 cm. This type of radar is best used for short range weather observation. Source: Lillesand, Kiefer & Chipman, 2008
Climate change	"Climate change … refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity." Source: Intergovernmental Panel on Climate Change IPCC, 2012: 557
Climate variability	"Refers to variations in the mean state and other statistics of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic forcing (external variability)." Source: IPCC, 2012: 557
Corrective disaster risk management	"Management activities that address and seek to correct or reduce disaster risks which are already present." Source: UNISDR, 2015a: 10
Cut off low	"A COL is a mid-latitude cyclone that becomes 'cut-off', or severed, from the main planetary circulation, and spins off independently. Because it is no longer attached to the westerly pressure wave to the south, it loses all momentum and can just sit for days, or move very slowly before dissipating." "COLs are associated with very strong atmospheric instability and powerful convection. This also brings a range of severe weather, including torrential rainfall, snow in mountainous areas and violent winds. COLs are one of the main drivers of damaging floods in South Africa, and can also trigger thunderstorms." Source: Holloway et al, 2010: 18
Disaster	"Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" Source: IPCC, 2012: 558
Disaster risk management (DRM)	"Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development." Source: IPCC, 2012: 558
Economic loss	Economic loss refers to the financial impact on the economy as a whole. This can include indirect costs and expenses. Source: Adapted from Associated Programme on Flood Management (APFM):2007:8
Extreme weather event	The occurrence of a value of a weather variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes.' Source: IPCC, 2012: 557.

Financial loss	Financial losses refer to monetary losses incurred by specific entities, individuals and government departments. Source: Adapted from Associated Programme on Flood Management (APFM):2007:8
Flash floods	"A flash flood is, in short, a sudden local flood of great volume and short duration which follows within a few (usually less than six) hours of heavy or excessive rainfall. Flash floods may also be caused as a result of a dam or levee failure, or the sudden release of water impounded by a landslide dam, ice jam in a river or as a result of a glacier lake outburst." Source: APFM :2012:3
Flood hydrograph	Hydrographs can be used to illustrate discharge. "The severity of a flood is a function not only of its flood peak, volume, and duration, but also of the shape of its hydrograph. The shape of a design-flood hydrograph is also necessary for hydrologists to do effective water resources engineering planning, design, and management. In practice, a river may have various shapes of flood hydrographs, as different storm or snowmelt events may produce different flood runoffs." Source: Yue et al., 2002: 147
Hazard	A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability. Source: UNISDR 2015a
High impact weather event (HIWE)	A weather event "that can result in significant impacts on safety, property and/or socioeconomic activity." Source: Sills, 2009: 623
Hotspot	A place of significant activity or danger.
Hydrophobic soils	"The water repellent layer is formed as hydrophobic materials (such as resins) are volatized during fire near the soil surface and then distil downward according to the temperature gradient within the soil profile". Source: Chamier et al., 2012: 349
Hyogo Framework	"The Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA) is the first plan to explain, describe and detail the work that is required from all different sectors and actors to reduce disaster losses. It was developed and agreed on with the many partners needed to reduce disaster risk - governments, international agencies, disaster experts and many others - bringing them into a common system of coordination." Source: UNISDR, 2015c
Professional service provider (PSP)	"Persons whose primary business is to provide impartial and independent knowledge-based services to clients for a fee." Source: National Treasury, 2012: 4
Prospective disaster risk management	"Management activities that address and seek to avoid the development of new or increased disaster risks. " Source: UNISDR, 2015a: 25
Rainfall intensity	Proportionately more precipitation per precipitation event. Source: IPCC, 2007: 784
Risk	The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Conventionally risk is expressed by the notation Risk = Hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability. Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes. Source: UNISDR 2015a

Risk communication	"Risk communication may be defined as the flow of information and risk evaluations back and forth between academic experts, regulatory practitioners, interest groups, and the general public." Source: Leiss, 1996: 86
Riverine Flooding	An overflow of water onto normally dry land – and over-bank flood. The inundation of a normally dry area along river banks caused by rising water in an existing waterway, such as a river or stream. Flooding is a longer term event than flash flooding: it may last days or weeks (NWS, n.d.).
S-band radar	The S-band is the portion of the electromagnetic spectrum in the microwave range of frequencies ranging between 2000 and 4000 MHz, with wavelengths ranging between 7.5 and 15 cm. This makes them useful for near and far range weather observation. Source: Lillesand, Kiefer & Chipman, 2008
Sediment	Sediment refers to material that is broken down from rock through processes of weathering and erosion and then transported by water or wind. Sediment can apply to a wide range of particle sizes, from boulders to sand, silt and clay particles of micrometre scales and less Source: Reineck and Singh, 1980: p8.
Sendai Framework for Disaster Risk Reduction	"The Sendai Framework for Disaster Risk Reduction is a 15-year, voluntary, non-binding agreement which recognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government, the private sector and other stakeholders." Source: UNISDR, 2015b
Storm surge	A storm surge is an abnormal rise of seawater generated by a storm, over and above the predicted astronomical tide, driven partly by wind pressure and partly by the lowering of atmospheric pressure causing a localised sea-level rise (NOAA, n.d.). It does not have a reference level. It is hazardous to coastal infrastructure and people and impacts on ecosystems such as barrier dunes and estuaries.
Time of concentration	Time of concentration is used to measure the response of a water drainage area to a rain event. Rainfalls of different intensities that last the entire time of concentration provide different peak flows. Where rainfall duration is shorter than the time taken for the entire drainage area to contribute to river flows, the time of concentration is determined from the start of the rainfall to the point when flow levels start declining.

PART I: INTRODUCTION, BACKGROUND AND METHODOLOGY

1.1 Study introduction and background

Between 2011 and 2014, the Western Cape was severely affected by five high impact weather events that led to four provincially gazetted flood disasters.[3],[4] All five of the flood-triggering weather processes were identifiable cut off low (COL) pressure weather systems (Engelbrecht, 2015) that respectively passed through the province between 7-9 June 2011, 13-14 July 2012, 7-11 August 2012, 15-17 November 2013 and 6-10 January 2014.

The resulting disasters were characterised by widespread flooding, with impacts reported across most of the Western Cape Province. Outside of the Cape Metro, twelve people lost their lives, while more than 30,800 were affected in informal settlements and low-cost housing areas, as well as farms and more affluent areas. Flash-flooding associated with the 15 November 2013 COL forced the rescue of 121 patients from the Mediclinic Vergelegen in Somerset West, the first evacuation of an entire hospital recorded on the continent. The same system affected 18 000 residents in 44 informal settlements within Cape Town (WCDMC, 2013a), (WCDMC, 2013b).

Government departments (excluding the Western Cape Department of Agriculture) and affected municipalities reported financial losses in excess R 682.8 million. Farm costs and losses linked to COL weather systems and associated flooding were estimated at R 900.5 million, constituting 56.9% of the total. Altogether, total financial costs/losses to government departments, municipalities and the agricultural sector were estimated at R 1.6 billion. Figure 1.1.1 below represents the spatial distribution of reported impacts associated with the 2011-2014 COL-associated disasters.

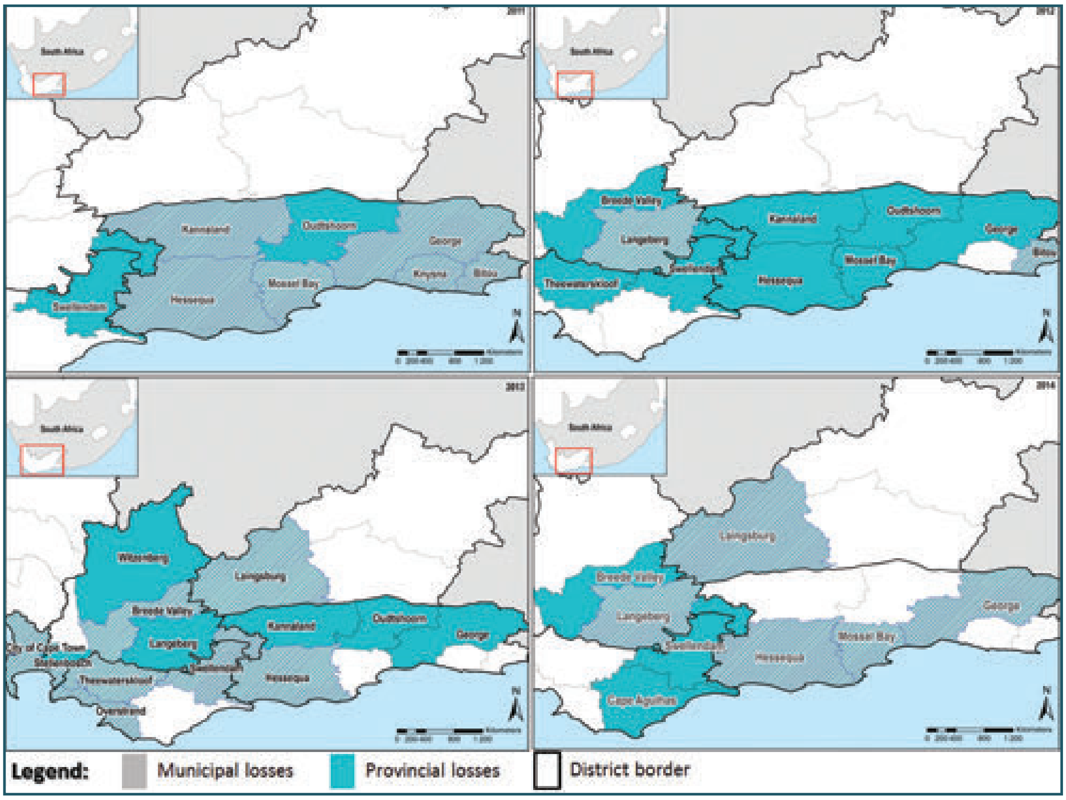

Figure 1.1.1: Spatial extent of reported impacts associated with 2011-2014 COL disasters in the Western Cape

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3 https://www.westerncape.gov.za/assets/prov-gaz-ex-7214-13-december-2013.pdf.

4 https://www.westerncape.gov.za/assets/departments/prov-gazette-extra_7230-friday-14-february-2014.pdf

In accordance with the National Disaster Management Framework, which requires post-event reviews following disasters and significant events (RSA, 2005), in-depth multidimensional studies were conducted for each of the four disaster events. The research sought to co-produce severe weather- and flood-risk knowledge that would strengthen integrated development and risk management planning. It specifically aimed to improve multi-sectorial risk reduction measures, and improved response.

The research was undertaken by the Research Alliance for Disaster and Risk Reduction (RADAR) at Stellenbosch University, in collaboration with the Western Cape Provincial Disaster Management Centre (WCDMC), and the Western Cape Departments of Agriculture (DoA) and Transport and Public Works (DTPW).

This report represents a two-step synthesis process. It first integrates the key findings from the four 2011-2014 reviews (see Parts II and III). These results are then incorporated with research outcomes derived from eight previous ex post studies of COL-triggered disasters from 2003-2008. Along with detailed research on the 2009-2011 Eden and Central Karoo drought (Holloway et al., 2012) undertaken by RADAR (previously the Disaster Mitigation for Sustainable Livelihoods Programme, DiMP), these studies reflect the application of a uniform ex post research methodology (Holloway *et* al 2010). When combined, RADAR's 2003-2008 and 2011-2014 high impact weather/disaster studies have provided a unique longitudinal data-set for trend and loss analysis that spans more than a decade.

1.2 Conceptualising the research: Focus on high impact weather events

1.2.1 The value of post-disaster reviews

The value of post-disaster reviews is underlined by the Western Cape's Disaster Management Framework. This stresses that "*to maximise the benefits of lessons learned, comprehensive reviews must be conducted routinely after all significant events and events classified as disasters. The findings of such reviews will directly influence the review and updating of DRM plans in the province*" (Province of the Western Cape, 2007).

Similarly, the Sendai Framework (UNISDR, 2015b) emphasises that post-disaster reviews are necessary for understanding risk, as well as for strengthening preparedness, response and recovery – to 'build back better'. In the context of recurrent, damaging COL-induced disasters in the Western Cape, the study sought to maximise this research opportunity across a decade-long time-frame to better understand the patterns of risk accumulation, acceleration and loss.

1.2.2 A focus on COLs (COLs) as high impact weather events

The research examined the 2011-2014 COL-related disasters as a series of *high impact weather events* (HIWE). The concept of high impact weather was first defined by the Canadian Meteorological Society as "*weather that can result in significant impacts on safety, property and/or socioeconomic activity*" (Sills, 2009). More recently, the concept has been adopted by the World Meteorological Organisation (WMO) to focus weather forecast efforts on minimising adverse weather impacts due to population growth, urbanisation and climate change (Jones and Golding, 2014).

In the Western Cape Province, COLs are associated with torrential rainfall, snow in mountainous areas and violent winds. They are also key drivers of damaging floods. Meteorologically, a COL is a mid-latitude cyclone "that becomes 'cut-off', or severed, from the main planetary circulation, and spins off independently. Because it is no longer attached to the westerly pressure wave to the south, it loses all momentum and can just sit for days, or move very slowly before dissipating. Cut-off lows are associated with very strong atmospheric instability and powerful convection updrafts. They also bring a range of severe types of weather, including torrential rainfall, snow in mountainous areas and violent winds. Cut-off lows are one of the main drivers of damaging floods in South Africa, and can also trigger thunderstorms" (Holloway et al, 2010; 18). Figure 1.2.2.1 above illustrates the difference between cut-off lows and cold fronts (a cold front is approaching from the west). The image shows how the cut-off low has been cut off from the main westerly flow while the cold front is still part of it (Holloway et al, ibid; 18).

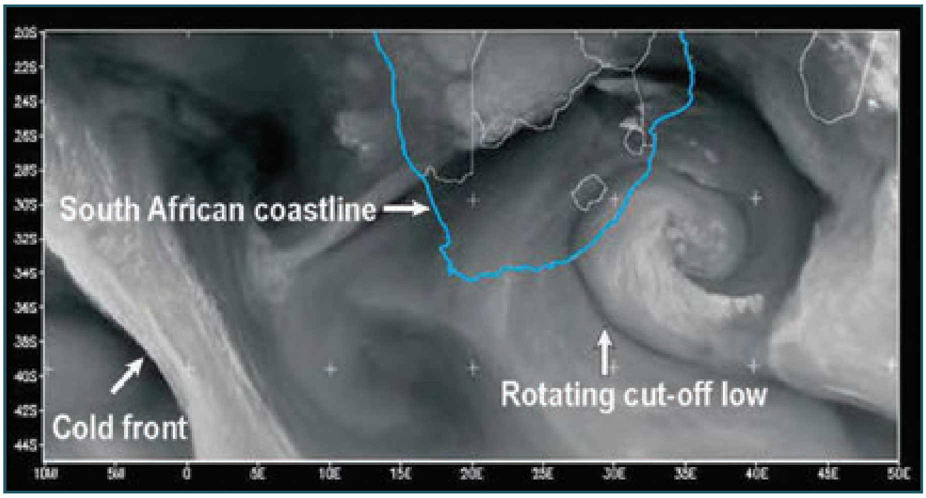

Figure 1.2.2.1: Water Vapour Image showing the difference between a rotating cut off low and a cold front

Research also indicates that the latitudinal position of COLs may be influenced by the ENSO phase; during an El Niño phase, COLs tend to move to higher latitudes - or further south in the southern hemisphere (Singleton and Reason, 2007). The reverse is true during the La Niña phase.

Over South Africa, COL frequencies are the highest during March-May and again in October. Also, June-July-August is the season with the second highest frequency of COLs (March-April-May has the highest frequency of COLs). This has been shown by Singleton and Reason (2007), Favre et al. (2013) and Engelbrecht et al. (2015). COLs situated off South Africa's west coast, have historically delivered very intense rainfalls, contributing significantly to total South African rainfall, more so to the west than the south coast (Favre et al., 2012). Past research also indicates that COLs appear most frequently in the west, off-shore and off the southern coast (Engelbrecht et al., 2015). Since 2003, the Western Cape has experienced fourteen loss-triggering COL systems that have resulted in identifiable disaster impacts.

1.2.3 Hydrological Drivers of Flood Hazards

While the intensity and timing of a HIWE are the most significant drivers of flood characteristics, other hydrological factors also modify flood behaviour, many of which were observed in various forms in the floods of 2011-2014. *Antecedent soil conditions,* which refer to the soil moisture conditions prior to the event, are prime drivers of runoff response (Dunne and Leopold, 1978). Catchments that have become saturated, rapidly produce higher storm-flow peaks than do drier catchments for similar rainfalls. Lower-intensity rainfall on wet soils can produce more runoff and higher peak flows than rainfall on a dry catchment (Dunne and Leopold, 1978). Soil types are also important modifiers of hydrological response. Soils which are shallow or have clayey soil textures reduce the amount of infiltration possible and have higher surface runoff than deep sandy soils (Dunne and Leopold, 1978).

Land use is an additional modifier of flood peaks. Catchments which are significantly urbanised produce substantially more runoff and higher peak-flows (Dunne and Leopold, 1978; Fletcher et al., 2013).

Land use change significantly affects runoff processes and therefore flood generation (Dunne and Leopold, 1978: 277). It is however, more difficult to attribute *flood generation in large catchments to land use change* than it is in smaller catchments. For instance, Bosch and Hewlett (1982) have underlined the difficulties in detecting change in runoff characteristics when <20% of a large catchment has undergone change. In such catchments, (eg similar to those where Montagu or Laingsburg are located), extreme flows are a result of the combination of storm characteristics, antecedent conditions and the physical characteristics of the catchment.[5] In smaller catchments such as the Lourens River basin, the contribution of land use and change to flood exposure can be more readily determined and measured (see section2.4).

In urban areas specifically, the higher quantity of *impervious areas* covered by roofs, roads and pavements causes more of the incident rainfall to convert to runoff, rather than infiltrate soil and groundwater. *Road drainage systems* convey water more rapidly to the natural drainage system, reducing the time of concentration or lag, effectively increasing the likelihood of converting short, localised but very intense rainfalls to significant flood peaks (Fletcher et al., 2013). Most of these actors affecting flood hydrology are well known and established in principles of civil engineering and design.

Outside of the urban area, *land cover which has been converted to agricultural uses* also modifies a catchment's hydrological behaviour (Dunne and Leopold, 1978). Surfaces which lose their absorptive capacity create greater runoff. Surfaces which *shorten runoff flow-paths*, such as ploughing straight up and down slopes, increase the resulting flood peaks by conveying water to the stream channels faster. However, there are limits on the ability of vegetation to influence flood generation. While forests are known for their absorptive capacities, Hoyt and Langbein (1955: 157) had already noted 60 years ago that, for very large storms, "*… nationwide, floods seem to roll out of forests as well as off farms*".

The role of *wildfire* in creating highly water-repellent, or hydrophobic, soils, is a relatively well-known phenomenon (DeBano, 2000). Hot fires result in soil particles lower in the soil profile being coated with water-repellent layers and this phenomenon generates higher levels of runoff and erosion. Research also suggests that while hydrophobic effects of wild fire have a half-life of approximately two-three years, these are less readily detected six years after fire occurrence. Severe wild-fires are the exception, where hydrophobic fire effects may persist for longer (DeBano et al., 1967; Robichaud, 2003).

In the Western Cape specifically, *invasive alien species* create a vegetation cover with higher fuel loads than indigenous vegetation (van Wilgen and Richardson, 1985). Wild fires through stands of invasive plants result in higher soil temperatures and the development of water repellent soils (Scott, 1993). Subsequent heavy rainfall on these soils causes higher levels of runoff and substantially increased erosion as the increased water momentum takes the surface soil with it (Scott, 1993). The resulting sediment is deposited into stream channels and storage dams.

Sediment aggradation, which is a symptom of excess sediment deposition in the channel, raises streambed elevations, decreases channel capacity and increases the width/depth ratio of the water course (US EPA, 2012). Aggradation can occur through deposition of coarse cobbles and gravel, or finer sandy sediments, depending on the nature of the sediment supply. The consequences of aggradation are the abandonment of the river channel by the river and initiation of new channels and then subsequent damage to infrastructure such as bridges over the river bed (US EPA, 2012). If sediment accumulates under and around structures such as bridges, it reduces the flow volumes able to pass beneath them and can change the direction of water flows. This increases the potential for flooding and damage.

Reductions in the flow area (cross-section) under bridges resulting from aggradation of the river bed can result in *erosion or scour of road embankments* on the floodplain as flood waters abandon the channel (Lagasse et al., 1999). Bridges in several parts of the Western Cape are at risk for reasons of aggradation and loss of channel capacity and flow area. Examples of these are given in Parts 2 and 4. The sources of sediment that leads to aggradation in the Western Cape are mostly from agricultural (Le Roux et al., 2008) and fire-related sources (Scott et al., 1998).

[5] This is unless the scale of land use change covers a major proportion of the catchment, (for example in South America (Costa et al., 2003) and north west Europe (Bronstert et al., 2002)).

This diverse mix of contributing risk conditions was probed temporally and spatially in this study to identify causal pathways that contributed to loss, as well as those that mitigated adverse impacts of COL weather and flood exposures.

1.3 Research approach and methodology

1.3.1 Overview

The study was undertaken as a complex, multi-stage transdisciplinary research project that combined in-depth examination of each declared disaster (2011-2014), with cross-cutting meteorological and hydrological analyses and two nested case-studies. In the second analytic phase, findings from eight previous ex post COL studies were integrated with the 2011-2014 data to identify recurrent and changing risk conditions across more than a decade's high impact weather disasters.

Specifically, the study sought to:

- Understand the five weather systems and their hydrological effects.
- Identify measures to mitigate, anticipate and manage the systems' effects.
- Determine the impacts of the events, including social consequences, infrastructural damage and agricultural losses.
- Document the financial losses sustained.
- Identify high-risk areas and infrastructure and the implications for disaster management, climate risk management and sustainable urban and development planning.

The study integrated a diversity of quantitative and qualitative methods drawn from the biophysical, social and economic sciences. For the 2011-2014 research phase these methods are listed in Table 1.3.1.1 below.

Table 1.3.1.1: Summary of categories of data collected (2011-2013)

Component	Data collected and methods
Scoping	Interviews Reports and documentation Media reports
Meteorological analysis	Synoptic, rainfall and other meteorological data for the province Historical rainfall and system data
Timelines, impact and mediating factors	Interviews with disaster management and other authorities Focus groups in affected communities Collection of relevant documentation, including situational reports prepared by disaster management officials and meeting minutes
Financial losses and impacts	Professional Service Provider (PSP) reports Departmental and municipal loss records
Land-use change in the Louren's River Catchment	Aerial photographs of the catchment for 1938, 1953, 1977, 1998, 2000 and 2010 Rainfall data from 15 stations in the catchment Data on the burn scars resulting from historical fires
Social media	Data set containing 70,480 georeferenced tweets for 12- 30 November 2013 Approximately 80,000 non-georeferenced tweets for 14-18 November

1.3.2 Climate and Meteorological Analysis

The meteorological analysis of disaster-related COLs (2011-2014) was undertaken by a climatologist from the Agricultural Research Council, Institute for Soil, Climate and Water, Pretoria (Engelbrecht, 2015). It examined the severity of each weather event as well as accompanying synoptic conditions in the context of the broader climatology of the Western Cape. This research component also examined the storms' potential endangering attributes, such as location and timing of specific rainfall intensities and depths, or features such as hail damage or high winds. This component included information on early warnings issued by South Africa Weather Service (SAWS).

COL tracks were analysed using European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) data as well as atmospheric circulation data from the National Centers for Environmental Prediction (NCEP) reanalysis data set (Kalnay et al., 1996). Subsets of COLs which were particularly important for developing heavy rainfall were identified from remote sensing by the Famine Early Warning Systems (FEWS) (Sylla et al., 2013). Area-averaged rainfalls generated by the COLs above the 95th percentile (exceedance) were then plotted in an exceedance-time plot to examine changes over time in COL-induced extreme rainfall for the Western Cape.

1.3.3 Hydrological analysis

Flood severity was assessed by observing broad patterns of change in the flood peaks. The hydrological analysis was undertaken using data obtained from the Hydrological Services database of the Department of Water and Sanitation, and by evaluating monthly peak flow data (water height above the gauge's zero level). The decision to compare flood peak heights rather than river flow rates sought to overcome limitations of most of the river flow gauges, which were designed to measure only low to medium flows. While smaller gauges are designed to be 100% submerged at full bank flow, they are still able to measure the recorded height of the peak flow. In contrast, more costly larger flow measuring structures are likely to interfere with the flow regime during flooding (D. van der Spuy, DWS, pers. comm.).[6]

This research component benefitted substantially from the detailed hydrology and hydrodynamic modelling studies undertaken by the Institute of Water and Environmental Engineering (IWEE) commissioned by the City of Cape Town after the November 2013 flood (IWEE, 2014).

1.3.4 Analysis of financial costs and losses

This research component was limited to the direct *financial* losses recorded by an organ of state or farmer that could be associated with an identifiable COL. It contrasts with more comprehensive *economic loss analyses* that would necessarily include upstream and downstream economic linkages, and which exceeded the study's scope.

Loss data were obtained from the Western Cape Disaster Management Centre as well as municipalities across the province. Data were also obtained from provincial departments of Agriculture, Cape Nature, Department of Environmental Affairs and Development Planning (DEA&DP), Education, Human Settlements, Social Development and Transport and Public Works, as well as the national Department of Water and Sanitation (DWS). Data on damage costs were also extracted from PSP reports - commissioned by the National Disaster Management Centre (NDMC) from specialists able to assess disaster damages for funding purposes. PSPs are tasked to assess and verify the loss reports submitted by municipalities and other governmental entities to support requests for emergency and recovery funding. They are required to list infrastructure damages reported, assess damages and amend the monetary values on the basis of funding criteria specified by the NDMC for post-disaster reconstruction and recovery.

However, PSP assessments exclude damage not directly related to the flood, as well as damage that could have been foreseen or avoided, or damage to insured infrastructure. They also exclude; damage to boreholes, crops and informal dwellings, infrastructure that may have already been repaired, infrastructure funded by another source (eg private sector), and infrastructure or projects that could not be assessed on-site.[7]

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6 Note: At higher flood peak levels, flow rates can increase exponentially, because the flows inundate greater widths of their flood plains.

7 Detailed information on post-disaster recovery funding procedures in the Western Cape may be accessed at: https://www.westerncape.gov za/assetsdepartments/local-government/Publications/Awareness_Programmes/Emergency_Contacts/Disaster_incidents/disaster_recovery guidelines_2015 pdf)

As undertaken in financial loss analysis of previous disasters (Holloway, et al, 2010), inflation adjustment factors were applied to the 2003-2014 cumulative loss estimations. In consultation with a Stellenbosch University economist, all costs were converted to 2010 values (as a working mid-point in the 2003-2014 disaster dataset). The adjustment factors were drawn from national accounting data published in the Quarterly Bulletin of the South African Reserve Bank[8]. A Gross Domestic Product (GDP) deflator computed from the real/nominal GDP was applied to damage costs for each COL-associated disaster, enabling all cost data to be converted to 2010 values. The yearly deflators are listed in Table 1.3.4.1.

Table 1.3.4.1: Deflators used to convert costs to 2010 values

2011	2012	2013	2014
0.93763	0.888646	0.838459	0.792469

1.3.5 Nested studies

Two nested studies were undertaken, to provide in-depth understanding on flash-flood risk accumulation and escalation processes in the Lourens catchment that necessitated the surprise evacuation of the Mediclinic Vergelegen on 15 November 2013.

<u>Study on the effect of land-cover change on flood peaks</u>
In this nested study to examine the effect of land cover changes on flood peaks, Schaber (2015) used Soil Conservation Service (SCS) techniques, with South African values for storm types and soil conditions (Schulze et al., 1985). Calculations of catchment slopes and inputs to hydraulic length were evaluated using Geographic Information Systems (GIS) techniques. These results were compared with findings reported by the Institute for Water and Environmental Engineering (IWEE, 2014) at Stellenbosch University.

<u>Social media - Twitter analysis</u>
Recognising the increasing role played by social media during disasters, the study examined Twitter traffic associated with the November 2013 COL. Two Twitter data sets were obtained that covered the critical duration of 12 November to 1 December 2013. 72,817 geotagged records were abstracted from the global Twitter data for the areas of Cape Town and False Bay. A further 77 790 records were extracted from Twitter's global 'firehose', by applying key words specific to the flooding incidents associated with the 15-17 November 2013 disaster. Twitter's search facility was also applied to establish the time-lines of specific incidents within the larger event.

1.3.6 Primary data collection and stakeholder consultation

Primary data were collected through more than 120 interviews with a wide range of stake-holders. These included disaster management officials in provincial and local government. The process also involved representatives from provincial departments and municipalities, as well as farmers and others who were affected. More than 60 person-days of field-work took place to gather data in the Cape Winelands, Central Karoo, Eden and Overberg District Municipalities as well as within the City of Cape Town (CoCT).

Additionally, four large multi-stake-holder consultations took place, facilitated by the Western Cape Disaster Management Centre. These included an initial consultation in June 2014 at Nekkies Resort, near Worcester and a Flood Risk Seminar in November 2015 convened by the Provincial Disaster Management Centre that was attended by MEC Anton Bredell.

[8] http://www.reservebank.co.za

Uniform damage reporting for reconstruction … or accurate loss estimation for better risk understanding?

Damage and loss data recorded in the 2011-14 study were drawn substantially from PSP loss verification reports, prepared for the purpose of guiding post-disaster reconstruction.

But, there is an inherent tension between procedures that determine post-disaster damage *for the purpose of repair/reconstruction* and those that estimate losses for *the purpose of understanding risk causation.*

The study team acknowledges the procedural value in implementing a uniform approach to damage assessment. However, the numerous eligibility exclusions applied in the PSP process also eliminated important opportunities for gathering information on recurrent infrastructural impacts as well as non-infrastructural losses.

In addition, the prolonged time-frame between disaster and damage verification exercise presents challenges in the Western Cape – where high impact weather exposures may occur within weeks of each other. For instance, the agricultural costs sustained in the November 2013 and January 2014 COLs were combined and not differentiated by municipality. This made it impossible to establish causal chains between the respective weather systems and the reported agricultural losses.

With growing global attention on accurate damage and loss reporting to guide resilience planning, there is equal need for complementary data gathering processes to understand risk causation as currently prevails for reconstruction.

Box 1.3.6.1 Challenges in loss and damage reporting for reconstruction or understanding disaster risk

1.5 Ethical considerations and limitations

In compliance with Stellenbosch University's research requirements, the study was approved by the research ethics committee of the Department of Geography and Environmental Studies. To ensure anonymity in this report, study respondents are acknowledged by their position, and not by name.

With respect to study limitations, there were substantial challenges in systematically treating reported financial loss and cost data. The most significant factor was the 2011 introduction of nationally appointed PSP to verify severe weather-related and flood damage. This new process applied numerous eligibility exclusions for claiming repair funding through the National Disaster Management Centre. The new criteria excluded non-infrastructural losses (which particularly affected farm reporting for livestock loss and crop damage) as well as repeat losses to the same infrastructure. The application of tighter criteria served to dramatically reduce reported losses (compared to those recorded in earlier events), artificially lowering cumulative losses, compared to previous years. Other costs and losses were also excluded. These included non-agricultural private sector damage, as well any item or infrastructure that was insured, or that was constructed or installed using emergency funding.

Additional agricultural considerations refer to the nature of costs claimed in 2011-2012 and the composite calculation of losses for the 2013 and 2014 disasters which occurred only two months apart. For 2011-2012, agricultural flood recovery costs were actually assigned for the development and construction of new river protection works. Although substantial farm impacts were noted in the media in these events, individual farm losses were not identifiable. Similarly, the close timing of the November 2013 and January 2014 disasters made it impossible to attribute agricultural losses exclusively to one event or the other.

The study team addressed these constraints by referring to all agricultural impacts in 2011 and 2012 as 'agricultural costs' (rather than 'losses'), and by excluding reported agriculture costs and losses from the municipal scale analyses.

A pervasive constraint for the entire study was the loss of records and documents, especially for the 2011 and 2012 disasters. This was compounded by difficulties in recall given the frequency of HIWEs in the Western Cape and staff turn-over. These limitations were addressed by drawing on multiple sources of information and triangulation across a diversity of stake-holders.

1.6 Report structure

The report is organised in five parts. Part II revisits the *key findings* from the four commissioned disaster studies as well as the risk drivers that increased the likelihood of serious impacts. Part III examines the *institutional response* to the 2011-2014 disasters. Part IV *integrates the findings* from the 2011-2014 COL related disasters with results from similar studies undertaken from 2003-2008, while Part V *concludes* with recommendations.

PART II: HIGH IMPACT WEATHER RISKS: COMPLEX,DYNAMIC, DEVELOPMENT-DRIVEN

2.1 Overview

Research findings from the 2011-2014 post-disaster reviews reinforce the results of earlier high impact weather event studies, which examined COL and other storm-related disasters from 2003-2008 (Holloway *et al*, 2010). However they also signal perturbing shifts in the province's weather risk profile that call for heightened attention to developmental risk management and resilience building. This section revisits the key findings from the four commissioned disaster studies, summarised in Box 2.1.1 below and examines cross-cutting risk drivers in greater depth.[9]

- The cut-off low weather systems were **associated with heavy rainfall** as well as other potentially damaging conditions, including snow and hail.
- **Shortcomings in integrated catchment and river management increase exposure to endangering floods.** These include the *build-up of sediment* (also called '*aggradation*') of riverbeds, especially around bridges and culverts. They also include inadequate removal of alien vegetation and debris from rivers and floodplains.
- **Dynamic catchment conditions can dramatically alter a catchment's flood risk profile.** These include *incremental* changes associated with development and agricultural practices, as well as *rapid changes* due to natural processes such as wildfires.
- **Residential, commercial and infrastructural expansion and densification** in flood-prone areas place *homes, facilities and infrastructure in harm's way*, and impede the flow of natural watercourses and overland run-off during heavy rain.
- **Legal/regulatory restrictions on timeous maintenance activities** in riparian zones delay action and increase exposure to flood hazards.

Box 2.1.1: Cross-cutting risk drivers for COL-induced high impact weather disasters 2011-2014

2.2 Post-event snapshot

2.2.1 High impact weather conditions for four disasters

The five COLs studied illustrate many of the challenges that face meteorological and hydrological forecasters as well as disaster managers responding to uncertain weather conditions. Not only did most systems produce heavy rainfall. They were also associated with other potentially damaging conditions, including heavy snowfalls (in July-August 2012) and hail (November 2013). In the case of COL-associated disasters in June 2011, November 2013 and January 2014, cumulative rainfall per event exceeded 200mm in at least one location, with more than 380mm recorded at the ARC's Vergelegen weather station (number 30689) in January 2014.

In a detailed comparison of the COLs, Engelbrecht (2015) noted that hourly rain rates for the summer COL events were notably higher than those recorded in June and July. For instance, in November 2013, hourly rainfall rates as high as 60 mm and 80 mm were recorded respectively in the CoCT and the Theewaterskloof

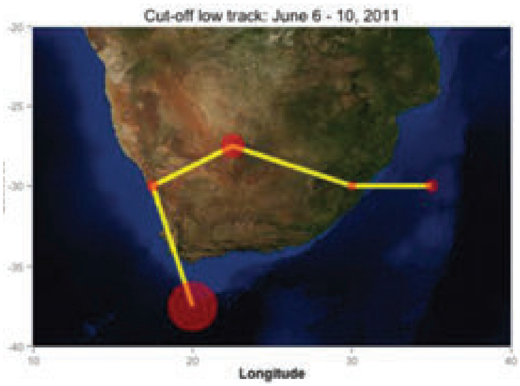
[9] More detailed information on each of the end-to-end high impact weather studies may be found on http:www.riskreductionafrica.org

Municipality. This study also found that the distribution of heavy rainfall was notably denser during the summer COL events compared to the winter COLs – although the heaviest 24-hour rainfall total at an individual station occurred during the June 2011 COL event. These findings are consistent with recent findings from Australia, where Wasko and Sharma (2015) concluded that warm season and year rainfalls are more intense than in cooler seasons.

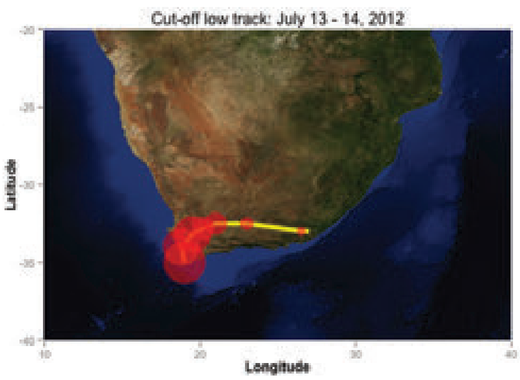
A striking characteristic of the November 2013 COL event was the presence of clearly defined convection embedded within the COL cloud structure. Satellite imagery of these organised convective cells indicated structural features that are associated with heavy thunderstorms. In both the summer COLs (November 2013 and January 2014), heavy rainfall in the Cape Town Metro occurred in the Eastern Metropole, in approximately the same locations (areas characterized by complex topography). While both of the summer COLs were fuelled by tropically sourced moisture, the 6-10 January 2014 COL moved more slowly and was more stationary than the COL of 15-17 November 2013.

Similarly, the 6-11 August COL was influenced by a powerful surface cold front that was responsible for snow-fall in all nine provinces. The cold front was followed by a surface ridge that contributed to a further influx of cold air and moisture into the country[10] .

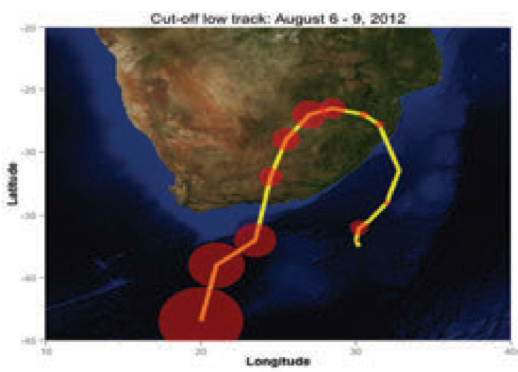
Figures 2.2.1 (a) – (e) show the mapped tracks for each of the five COLs studied. The red dots represent the geographical location of the COL as identified and tracked in NCEP reanalysis 500 hPa fields. The size of the dots represents the intensity or depth of the system, with larger (smaller) dots indicative of deeper (weaker) COL centers.



(a): 6 – 10 June 2011

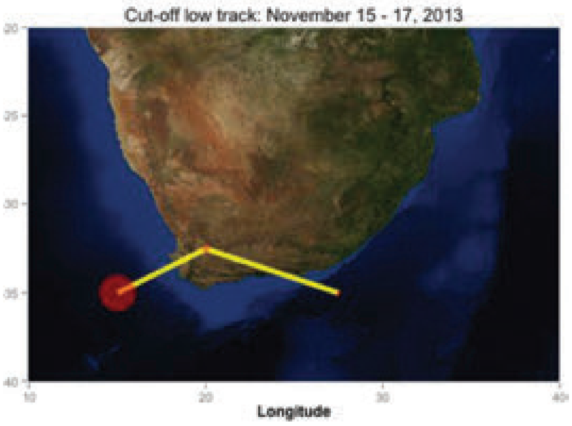


(b): 13 – 14 July 2012

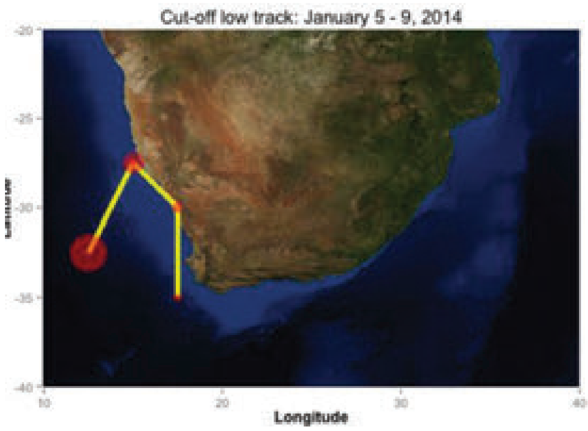


(c): 6 – 9 August 2012

10 http://www.sabc.co.za/news/a/e90a16804c438b228ac1efecb51a2d14/Snow-causes-havoc-on-SA-roads



(d): 15 – 17 November 2013



(e): 5 – 9 January 2014

Figures 2.2.1 (a)-(e): The mapped tracks for each of the five COLs studied

2.2.2 Unrelenting pattern of high impact weather loss for the Western Cape

As Figure 2.2.1 indicates, each of the four COL-related disasters from 2011-2014 affected multiple districts. For disasters declared in 2011, 2013 and 2014, the spatial distribution of losses reflects the path of the triggering COL as it moved across the province. In 2012, reported losses represent the cumulative effects of two COL weather systems less than one month apart.

For the four disasters, cumulative reported financial losses by municipalities, government departments and affected farmers totalled R 1.6 billion (Table 2.2.2.1), with DoA-recorded farm losses of R 900.5 million constituting 56.9% of the total. The January 2014 COL was the most costly of the four disasters studied, with reported losses exceeding R 580 million.

Table 2.2.2.1: Total damage costs reported for the four high impact weather disasters between 2011 – 2014 (in Rand)

	Jun 2011	Jul/Aug 2012	Nov 2013	Jan 2014	Total
National	2 325 100	37 000	0	0	2 362 100
Provincial	164 925 428	34 527 436	71 647 144	177 999 447	449 099 455
Municipal	75 473 164	16 934 768	41 615 880	97 355 996	231 379 808
Sub-total	**242 723 692**	**51 499 204**	**113 263 024**	**275 355 443**	**682 841 363**
Agricultural costs	128 378 878*	373 570 000*	86 555 472	312 000 000	900 504 350
Total	**371 102 570**	**425 069 204**	**199 818 496**	**587 355 443**	**1 583 345 713**

*** Claimed by the DoA for new river protection works**

Of the R 682.8 million in cumulative losses reported across all organs of state (excluding agriculture), 66% were attributed to provincial departments. Of these, R 309 million were borne by the DTPW. Figure 2.2.2.1 illustrates the disproportionate scale of agricultural impacts over the four disasters (in dark blue), in relation to losses reported by other provincial departments.

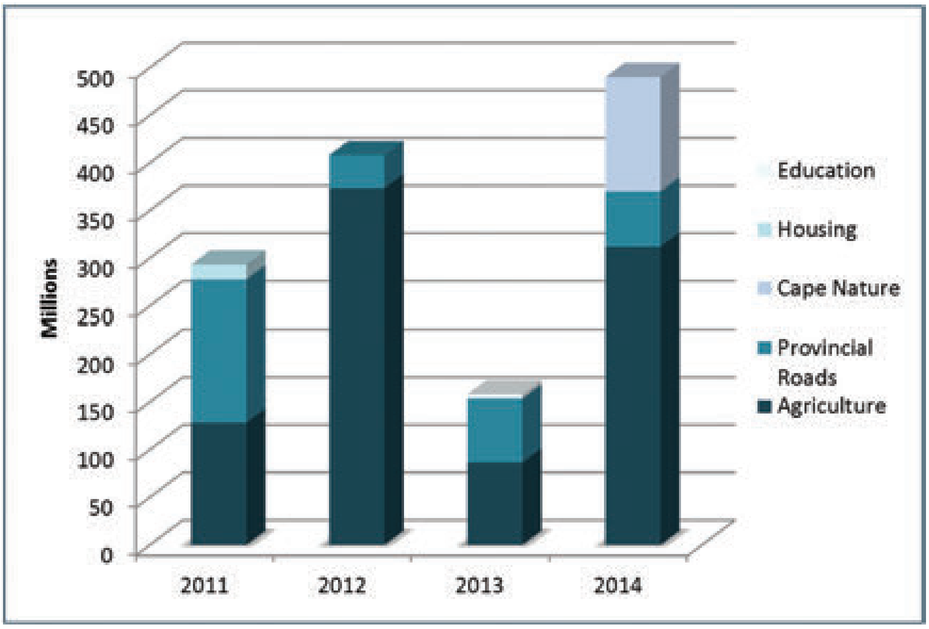


Figure 2.2.2.1: Total costs reported by provincial departments for the four disasters between 2011 – 2014

However, this differentiation of financial costs by sphere of government can also distort understanding of the geographic concentration of damage at municipal scale. Table 2.2.2.2 illustrates the recurrence of COL-associated damage in six municipalities, consolidating all reported municipal, provincial and national financial losses (excluding agricultural costs) from 2011-2014.

Not only does the table indicate that more than 51% of all non-agricultural losses reported were geographically concentrated in only six municipalities. It also shows that three municipalities sustained sizeable losses every year (George, Hessequa, Swellendam), with nearly a quarter of the cumulative reported non-agricultural losses for the four disasters attributed to Hessequa alone.

Table 2.2.2.2: Recurrence of COL-associated damage and cumulative (non-agricultural losses for municipalities affected at least three times from 2011 – 2014

	2011	2012	2013	2014	Total (R. million)
George	X	X	X	X	76.6
Mossel Bay	X	X		X	36.6
Hessequa	X	X	X	X	158.0
Oudtshoorn	X	X	X		18.3
Swellendam	X	X	X	X	19.8
Langeberg		X	X	X	44.8
Total					353.8

2.2.3 Looking beyond reported financial losses

Beyond the financially recorded losses, the 2011-2014 studies also point to an increasing precariousness of essential public services under high impact weather conditions. This was signalled on 7 August 2012, by the death of an on-duty ambulance attendant when her vehicle left the R62 in early morning (still dark), flood conditions at the confluence of the Keisies and Kingna rivers and was swept downriver. It is also indicated by the evacuation of the entire Mediclinic Vergelegen on 15 November 2013.

In 2011, 41 schools were temporarily closed, many cut-off, while in 2013, 23 schools in the Cape Town Metro reported wind and rain damage. COL-associated damage in the Eden District Municipality in 2011 left 256 segments of road needing repair, at an average cost of R 583 921 per segment. Across all disasters, water and sewerage treatment facilities/pipelines were damaged and services disrupted.

More than 3,400 people were evacuated from flood-affected areas in Eden and the Langeberg in the 2011 and 2012 disasters, with 1,700 from Ashton, Montagu and Mcgregor in 2012 alone. In July 2012, more than 200 vehicles, including five buses became trapped in snow on the N1 near Beaufort West, with people on three farms needing rescue by helicopter. In January 2014, 33 people trapped in Meiringspoort in Kannaland also required helicopter rescue. As many as 18,000 residents of Cape Town's informal settlements were reported as flood-affected during the November 2013 COL. Twelve lives were lost in the four disasters, including three from hypothermia in July 2012.

These examples underline the increasingly crucial role that the province's DRM and emergency services play in protecting public safety with scarce resources, often under difficult, dangerous and highly unstable weather conditions.

2.3 Complex and converging risk drivers

2.3.1 Encouraging progress – but no room for complacency

Research findings also highlight how many district and municipal role-players have strengthened preparedness action that are credited for reducing losses. Most municipalities undertake preventive actions, such as clearing storm-water infrastructure prior to the expected winter storms (although the severity of storm damage in summer months suggests this activity should be sustained year-round).

Following flooding associated with the November 2007 COL, the Eden District Municipality introduced estuary-breaching protocols (Box 2.3.1). Although these measures are viewed as having successfully reduced local flood severity, they are still to be empirically tested against comparable rainfall, flood and storm-surge exposures. This is because rainfall and river flow data indicate that the COL storms subsequent to 2007 have been of a lower intensity. Within the Langeberg Municipality, the Voortrekker bridge that crosses the Kingna River, as well as others, has been upgraded.

Estuary Management and Breaching Protocols

The Western Cape has numerous estuaries that are crucial ecosystems for both marine and coastal well-being. Yet, the natural ecological functioning of many estuaries has changed substantially due to development, upstream water abstraction or impoundment as well as construction close to the water's edge. These changes have resulted in estuary mouths being closed for longer periods, which increase local flood risks during heavy rainfall events. The decision to artificially breach an estuary is not haphazard, as this has wide-ranging implications for both estuarine health and public safety.

Estuary mouth management plans constitute an important component of overall estuary management planning, and should include pre-agreed protocols for artificial breaching of estuary mouths during heavy rainfall events to mitigate flood damage. Key stake-holders involved in defining the protocol include Cape Nature, DWS, Disaster Management, South African Weather Service as well as the relevant local authorities). The Great Brak Estuary Management Plan for instance, includes a mouth management plan.

Box 2.3.1 The importance of estuary mouth management plans for flood mitigation[11]

[11] http://www.anchorenvironmental.co.za/Documents/Pdfs/Great%20Brak%20EMP/Great%20Brak%20EMP%20-%20Draft%20-%20Apr%202013.pdf

Despite these concerted efforts however, findings also indicate there are powerful, pervasive, often developmentally-driven flood risk factors that will continue to escalate prospects of endangering floods into the future. In parallel to possible changes in COL-associated rainfall volumes and intensity, research findings underline key developmentally embedded conditions that continue to drive flood risk in the areas studied (see Box 2.1.1).

2.3.2 Shortcomings in catchment and river management as developmental risk drivers

Consistent with RADAR's earlier studies[12] and published research (see Wheater and Evans, 2009 for example), catchment and river management practices represent key factors in either minimising or exacerbating flood-risk. Findings particularly underlined the contribution of sediment accumulation as a crucial flood risk driver – linked to poor farming practices, along with incomplete alien vegetation removal. It is recognised that sediment supplies can increase due to land use changes that promote erosion in the upper catchments at faster rates than the natural erosion rate in river beds (Schumm, 2005). Vegetation encroachment (reeds, alien invasive trees) can also cause in-channel deposition (leading to aggradation), blocking, clogging and subsequent avulsion (Schumm, 2005). Ultimately, sediment build-up within river channels also results in a shallower riverbed and the increased likelihood of faster flow rates during floods (See Box 2.3.2.1 below for definitions of sediment-related terms).

Focus on sediment accumulation (or aggradation)

The research highlights sediment accumulation as an important flood-risk driver in several areas, including Montagu and Somerset West, and in the Floriskraal Dam near Laingsburg.

Sediment refers to material that is broken down from rock through processes of weathering and erosion and then transported by water or wind. Sediment can apply to a wide range of particle sizes, from boulders to sand, silt and clay particles of micrometre scales and less (Reineck and Singh, 1980: p8).

Sedimentation is the process of settling out of still or slow-moving water when the carrying capacity of the water is reduced. The relationship between erosion, transport and sedimentation is governed by particle size and water velocity, and is represented by the Hjulstrom diagram. Slowing down river flow can increase sedimentation rates (Reineck and Singh, 1980: p8-12).

Aggradation means the increase (or build-up) in land or river bed elevation when sediment deposition exceeds erosion rates (Schumm, 2005: p33). Aggradation typically occurs in lowland areas where river flow rates slow, mostly because of the reduced slope of the land. However, it can also be due to lower river flow velocities because of increased flow resistance by vegetation, such as reeds growing in the channel.

Over-bank flooding due to aggradation occurs when a river channel cannot hold the flow of flood water (Schumm, 2005: p33).

River avulsion is the rapid abandonment of the river channel due to the flattening of the channel's slope through sediment deposition, or aggradation. This results in the river finding or eroding a new channel which can maintain the flow rate (Slingerland and Smith, 1998).

Sediment accumulation (aggradation)

Although 'sedimentation' may be a more technically accurate term, many of those interviewed voiced their concerns about silt and siltation. These processes were perceived to be linked to loss of vegetation

[12] http://www.riskreductionafrica.org/publications-documents/partners-reports/

cover due to fires, as well as farming practices, particularly in the Karoo. Sediment production in the Cogmanskloof, Keisie and Kingna rivers was also attributed to farming practices and intensive land-use in Montagu (Central Karoo Water User Association).

Several interviewees, including farmers, were of the view that increased losses, particularly of soil, were due to agricultural encroachment into riverine areas. They explained that farmers under pressure to improve farm productivity were increasingly compelled to plant into the riparian zone. They added that in the Karoo, farmers plant crops such as lucerne, alfalfa and to a lesser extent vegetables in the riverbeds of seasonal rivers, with lucerne actually benefitting from flooding, as long as water was not fast moving. In Ladismith, farmers attributed sedimentation also to overgrazing.

Recognising that such farming practices also contribute to sedimentation in rivers, the Central Karoo Water User Association (WUA) reported that they are working with farmers to reduce endangering farming practices. This includes developing River Maintenance and Management Plans (RMMPs) jointly with farmers, to discourage planting in riverine areas. The WUA also serves as an agent for the Working for Water Programme, signing agreements with participating farmers which prohibit them from farming in riverside areas cleared of alien vegetation.

In Eden, the head of the George Agricultural Society also explained that farmers in his area were gradually shifting from fine ploughing and tilling to more sustainable methods that reduce soil loss and sedimentation in nearby rivers.

Figure 2.3.2.1: Aggradation beneath the Voortrekker Bridge, Montagu (prior to river works) (Source: Jan Durand)

Figure 2.3.2.2: Aggradation beneath the Andreas Pretorius Bridge, Somerset West (Source:IWEE, 2014)

Regulatory obstacles to sediment removal

Several interviewees expressed concern that flood-inducing debris and sediment accumulations around bridge approaches could not be cleared regularly due to obstructive regulatory barriers within the National Environmental Management Act (NEMA). In the past, NEMA always required an environmental impact assessment (EIA) and approval by the DEA&DP for any work that involved moving, infilling or removing more than five cubic metres of soil (RSA, 1998). As this approval process is lengthy and expensive, it reportedly discouraged adherence by both public and private actors with adverse consequences. These include disjointed and sometimes inappropriate management strategies, which contribute to flood-risk in the river system as a whole.

With the promulgation of the National Environmental Management Laws Amendment Act (RSA, 2014)[13] it has since become possible to expedite the EIA process in emergency situations. In these instances, DEA&DP is now authorised to issue a verbal directive, which can be followed by written authorisation later. This will enable more timeous action, and avert or minimise unnecessary flood impacts.

[13] http://www.gov.za/documents/national-environmental-management-amendment-act-2

In addition, RMMPs already offer one avenue to expedite the lengthy EIA process and are increasingly being developed throughout the Province.

<u>Inadequate and incomplete removal of alien vegetation increases flood risk</u>
The incomplete clearing of alien vegetation was once again identified as a crucial flood risk driver. On one hand, alien invasion of the riparian zone, by trees and reeds, changes the hydraulics of the river, causing aggradation of river-beds through sediment capture. It also obstructs natural flow patterns, and is less effective in stabilizing riverbanks, facilitating erosion. Reeds and trees uprooted or broken during floods can also become caught up against bridges, where they either redirect flows, or create the potential for failures due to significant rotational stresses caused by the backed-up water, or lifting forces on the bridge deck.

Figure 2.3.2.3: Debris clogging a bridge leading into Montagu (Source: Patrick O'Shea, Adverteyes: <u>http://montagudriedfruitnuts.co.za/montagu-floods-june-2015-keisie-kingna-rivers/)</u>

However, although the effective clearance of alien vegetation reduces flood risk, poorly executed removal can exacerbate flood losses. During the research, many stakeholders reported compliance failures to remove cleared vegetation above the 20-year flood-line. This drives both the likelihood and impact of flooding, as cleared vegetation washes downstream, clogging bridges and culverts. The resulting water pressure increases stress on the blocked infrastructure, with a higher likelihood of damage (see 2.3.2.4)

Figure 2.3.2.4: Debris blocking Voortrekker Bridge in Montagu (Source: Jan Durand)

2.3.3 Catchment conditions are highly dynamic - focus on wildfires

Changing catchment conditions also escalate flood-risk. These changes can be incremental, and associated with development and agricultural practices, but can also be highly dynamic and due to natural processes. Wildfires, in particular, were identified as contributing to increased surface run-off.

Disaster managers in the Cape Winelands District Municipality ventured that mountain fires in December 2010 and January 2011 contributed to the flooding in Montagu in June 2011. They explained that the fires, along with the large flood in 2008, increased the sediment and debris load in the Cogmanskloof, Kingna and Keisie rivers, which blocked thoroughfares, channels, rivers and bridges, and contributed to the 2011 flooding. Wildfire was also identified a contributing factor in the surface run-off associated with the November 2013 flooding in the Lourens catchment, Somerset West (see 2.4 below).

2.3.4 Residential, commercial and infrastructural expansion and densification: developing in harm's way

Consistent with a growing global consensus on the links between development and disaster risk (UNISDR 2013, 2015d), study findings underscore how development in the Western Cape is increasing high impact weather risks. This is most evident when residential, commercial and infrastructural expansion and densification in weather- and flood-exposed areas place homes, facilities and infrastructure in harm's way. Flood risk is further exacerbated by buildings, bridges and walls that impede the natural flow of watercourses and overland run-off during heavy rain.

In Greyton, for instance, a retirement complex was reportedly built in close proximity to the ungauged Gobos River and according to a disaster management official, now floods regularly. Similarly, in Betty's Bay, local experts argue that development incursions into the floodplain of the Disakloof/Dawidskraal stream (including housing, the construction of the R44 and other gravelled roads, as well as the Harold Porter National Botanical Gardens (HPNBG)), have increased flood hazard exposure. This is further exacerbated by the stream's thin-soiled, mountainous catchment of about 15km^2 with capability for causing a rapid response to heavy rain. In the Overberg District Municipality in recent years, such flood risks have been increased by the rapid growth of settlements in areas with limited storm-water infrastructure.

However, moving beyond a limited focus on buildings and infrastructure, many of the new developments (eg retirement complexes and frail care facilities) accommodate older residents, who may also be more vulnerable in times of duress.

2.4 The 'Perfect Storm'. The 15-16 November 2013 COL over the Lourens catchment, Somerset West

2.4.1 Intense rainfall, flash floods and a hospital evacuation

The COL-associated flash-flooding in Somerset West, situated on Cape Town's eastern fringe, illustrates how development and changing catchment conditions interact to drive, and then accelerate flash-flood-risk. On 15 November 2013, intense rainfall inundated the Lourens Catchment in Somerset West, leading to the evacuation of the Mediclinic Vergelegen. Figure 2.4.1.1 represents the rainfall intensities recorded over the catchment between 1700hrs and 2000 hrs with more than 120 mm rainfall falling in three hours. The exceptional rainfall intensity on 15 November 2013 first overwhelmed municipal storm-water infrastructure in Somerset West at 1700hrs and then created a second lagged flood wave some 70 minutes later.

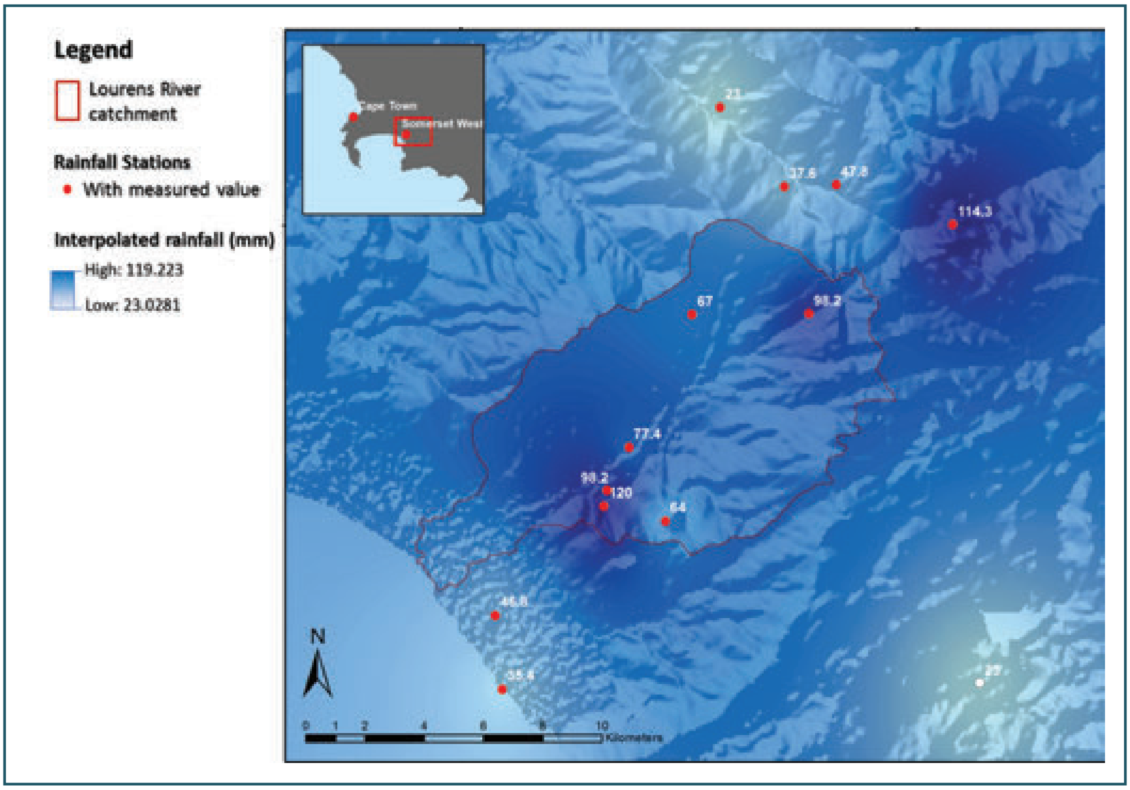


Figure 2.4.1.1: Rainfall over the Lourens catchment, Somerset West 1700-2000hrs 15 November, 2015 (Source: Schaber, E., 2015)

These and other rainfall observations recorded for the Lourens River catchment indicate that the 15 November 2013 rainfall was indeed extreme. This is shown in **Tables** 2.4.1.1 and 2.4.1.2 below that compare expected short- and long-duration rainfall for the catchment, with observations recorded from rain-nearby rain-gauges. For instance, **Table 2.4.1.1** compares the expected **2- and 4-hour short duration rainfall** for selected rain-gauges in the Lourens River catchment with projected data derived from SAWS' Bizweni rain-gauge 0005605 (IWEE, 2014;)

Table 2.4.1.1.: Comparison of the recurrence intervals of the estimated 200 year 2 and 4-hour rainfall, comparing theexpected data derived from SAWS gauge 0005605_A with observed (obs.) rainfall at other nearby rain gauges with data recorded in mm.

	200-year Recurrence Interval values			
	2hr	2hr obs.	4hr	4hr obs.
Bizweni [1]	55		69	
Morgenster [2]		117		148
Waterval [2]		71		124
Vreede en Hoop [2]		85		111
Vergeleë Bo [2]		68		88
Helderberg Nature Reserve [2]		64		83

1. Smithers and Schulze (2000a)
2. IWEE (2014)

Similarly, Table 2.4.1.2. below compares the projected **24 hour rainfall** for two-year – 200-year recurrence intervals from SAWS gauge 0005605 (Bizweni) with that observed and recorded at other rainfall stations within the catchment (Smithers and Schulze, 2000b, IWEE, 2014).

Table 2.4.1.2.: Recurrence intervals for a 24-hour rainfall, comparing the expected data derived from SAWS gauge 0005605_A with observed (obs.) rainfall at other nearby rain gauges. Values in mm.

	Recurrence Interval (Years)							
	2	5	10	20	50	100	200	Obs.
Bizweni [1]	43	58	68	80	95	108	122	
Morgenster [2]								237
Waterval [2]								219
Vreede en Hoop [2]								178
Vergeleë Bo [2]								142
Helderberg Nature Reserve [2]								133

1. Smithers and Schulze (2000b)
2. IWEE (2014)

These data suggest that the rainfall of a core area within the Lourens River catchment was extreme, with a recurrence interval of more than 1:200 years for **both short duration rainfall** (2-4hrs), which is within the Time of Concentration of the catchment, as well as for **the longer 24-rainfall.** The IWEE (2014) report, which provides a more extensive analysis, extended the rainfall values to a full catchment coverage by applying an areal reduction factor (standard practice in such hydrological analysis). This indicates that the rainfall recurrence interval for the whole catchment was between 1:100 and 1:200 years (IWEE, 2014: 28). These findings confirm that the 15 November 2013 rainfall was an extreme event, with exceptional rainfall intensities in a core area within the catchment.

However, even prior to 2015, flood risk accumulation processes had been incrementally mounting for at least two decades. These included land-cover changes associated with urbanisation, changed farming practices, and wildfire occurrence. These changes were further compounded by incremental infrastructural development within the Lourens River floodplain.

2.4.2 Changing conditions within the Lourens Catchment

Changing land-use patterns

Land-use in this already steep mountainous catchment changed considerably after the 1970s. Figure 2.4.2.1 graphs incremental changes in the proportion of different land-cover types in the catchment between 1938 and 2010, while Figure 2.4.2.2 shows these changes spatially.[14] As the Figures 2.4.2.1 and 2.4.2.2 show, the proportion of fynbos declined sharply, while the extent of the urban footprint and cleared land increased.

The proportion of land under orchards and vineyards, in particular, also increased. Study findings suggest that many orchards in the Lourens catchment had been converted to vineyards during the last 20 years as South Africa's wine industry has expanded. The conversion of orchards to vineyards also increases run-off potential. While orchards generally have windbreaks, which serve to capture run-off, vineyards lack windbreaks and tend to be planted up and down the catchment slopes, channelling water downwards. This shift increases the rate of down-hill surface run-off under heavy rainfall exposures.

[14] The mapping was done at a scale of 1:10000, and where appropriate, 1:5000 in the urban settlements. But in years where the resolution was above 4 m, a scale from 1:10000 does not reveal much more information than 1:20000.

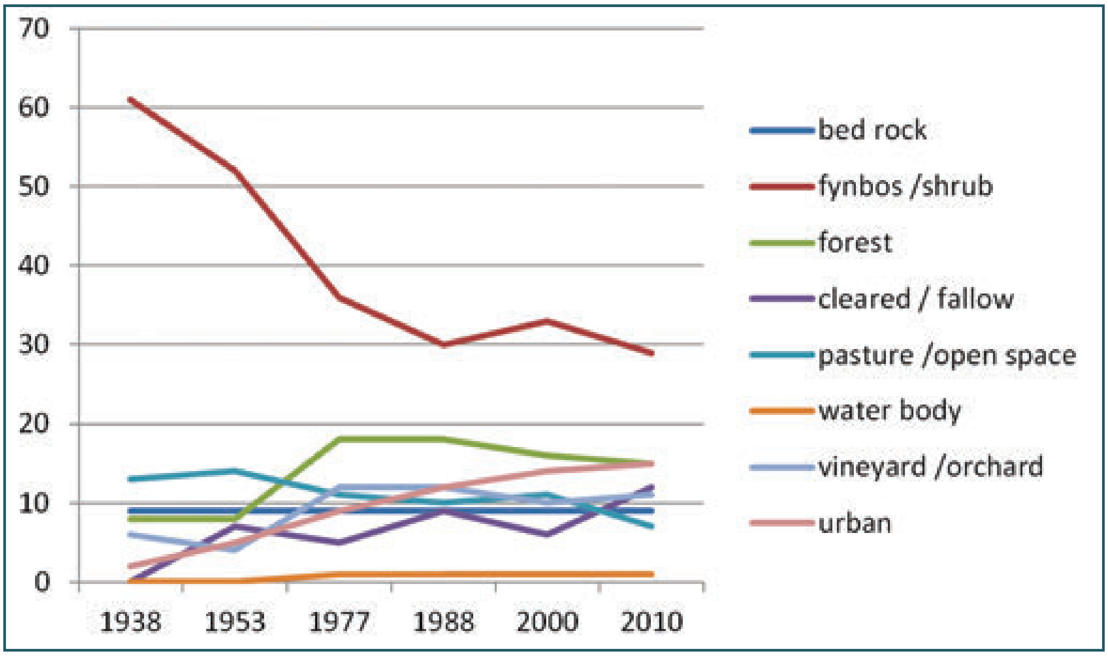


Figure 2.4.2.1: Landcover change from 1938 to 2010 in the Lourens River Catchment - graphed (Source: Schaber, E., 2015)

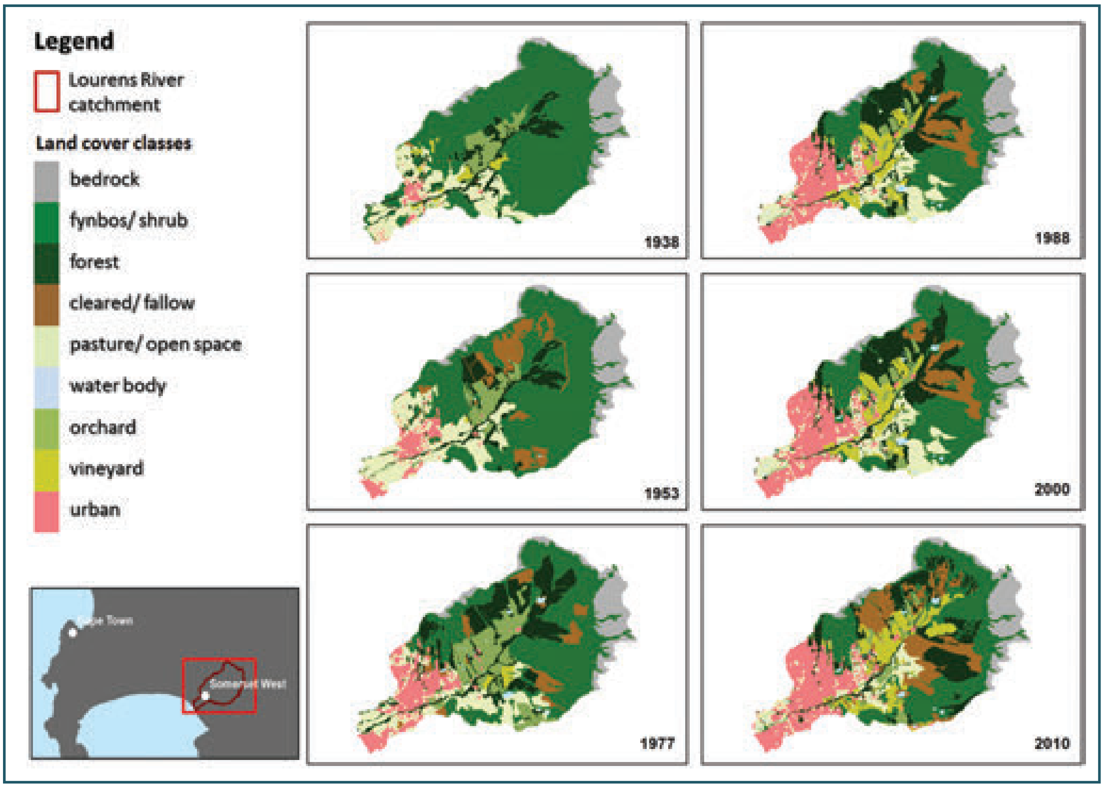


Figure 2.4.2.2: Landcover change from 1938 to 2010 in the Lourens River Catchment - spatial representation (Source: Schaber, E., 2015)

Wildfire occurrence in the catchment

In addition to these gradual land-cover changes, the catchment's run-off potential was further increased by the area's recent fire-history. Figure 2.4.2.3 shows the burn history of the Lourens River Catchment from 2004-2013. It indicates that in 2009, a large wildfire burned much of the catchment (identified by the green-hashed shading) except for the urban and cultivated areas.

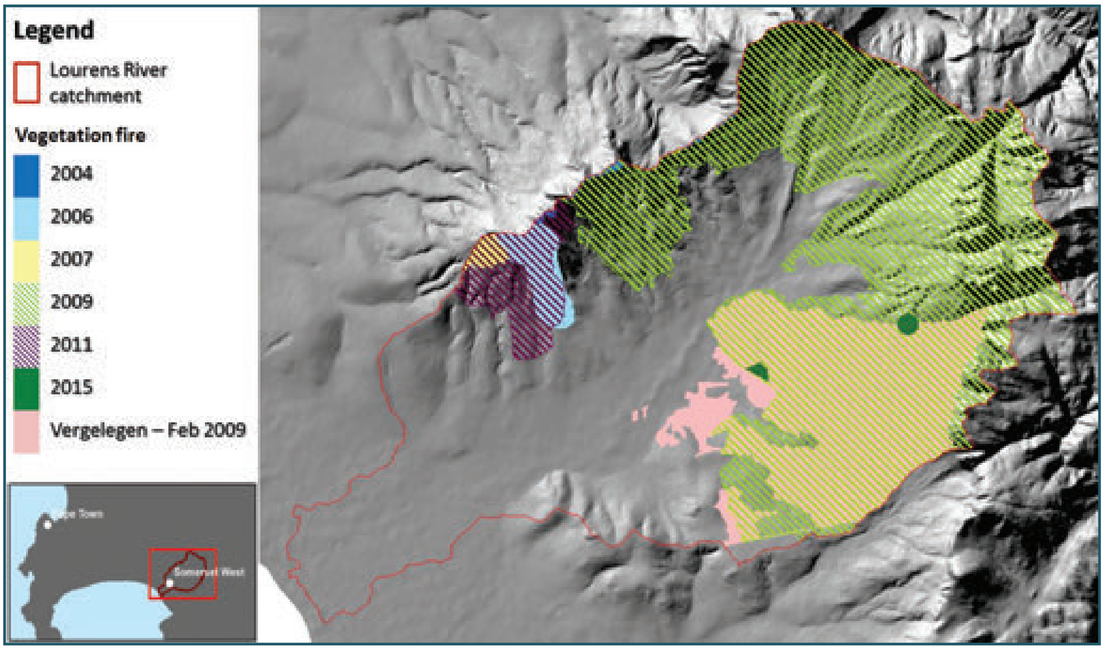


Figure 2.4.2.3: Wildfire burn history in the Lourens River catchment (Source: Schaber, E., 2015)

Modelled impact of land-cover change on run-off in November 2013

Post-flood hydrological analysis indicates that land-cover changes contributed to the intensity of run-off from the slopes around Somerset West during the November 2013 COL disaster (Schaber, 2015). Figure 2.4.2.4 Illustrates the modelled effect of land-use change on flood hydrographs for Lourens River Catchment on 15 November 2013. The lower green-tinted line shows expected river flow levels given run-off under landcover conditions in 1938, while the upper black line shows the flows resulting from the markedly changed land-use conditions in 2010. The model indicates that catchment land-use changes between 1938 and 2010 increased the expected run-off by 64%, from 110 m^3/s to 180+ m^3/s (Schaber, E. 2015).

Rapid run-off rates are reflected in the time of concentration, which is a measure of catchment response time and one indicator of the time it took since it started raining for the flood peak to arrive at the catchment outlet. Complementary research indicated that it took just 74 minutes from the most intense rainfall for the flood peak to arrive in the vicinity of the hospital. This highlights the speed with which the event unfolded.

Such findings on run-off were made possible due to the detailed hydrology and hydrodynamic modelling studies undertaken by the Institute of Water and Environmental Engineering (IWEE) commissioned by the CoCT, after the November 2013 flood (IWEE, 2014).

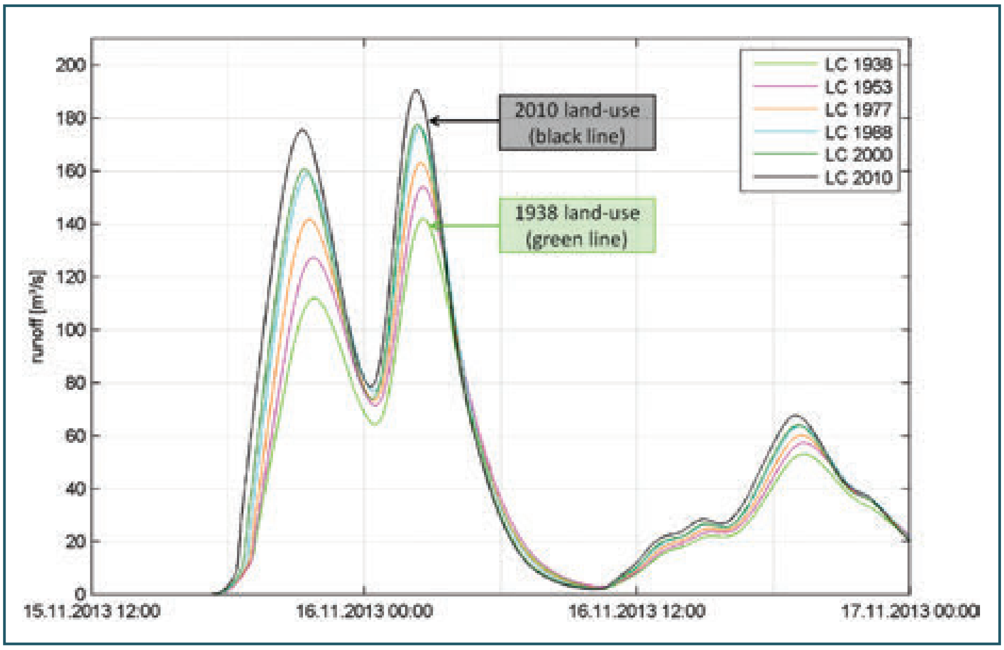


Figure 2.4.2.4: Illustrative effect of land-use change on flood hydrographs for the Lourens River Catchment 15 November, 2013, showing comparative run-off under 1938 and 2010 land-cover conditions (Source: Schaber, E., 2015)

2.4.3 Residential, commercial and infrastructural expansion and densification: challenges for development planning

Alongside changing catchment conditions, this flash-flood event illustrates the planning challenges that face settlements located in flood-prone locations. Somerset West was founded in 1822, but remained predominantly rural until the 1970s. Much of the original settlement was built on the floodplain of the Lourens River, including directly over the flow path of the drained east arm of the River. Over time, the settlement incrementally expanded and densified, illustrated in Figure 2.4.3.1 by the Mediclinic Vergelegen's location between the Lourens River and the flow path of a drained arm of the River (the blue dotted line), exposing the facility to flash floods.

Research findings indicate that the first flood wave resulted from the very intense rainfall over the urban portion of the catchment, resulting in rapid overland flow from the impervious areas down roadways for example. This was exacerbated by blocked storm water drains in the areas that had not been cleared of sediment, rather than a rising river overtopping its banks (see figure 2.4.2.4). Mediclinic staff interpreted the arrival and decline of this first peak as the "end of the flood danger". However, the flood peak which followed when the river did over-top its banks, as the main part of the catchment responded some time later, caught hospital staff by surprise. The emergency escalated rapidly, necessitating evacuation of the hospital.

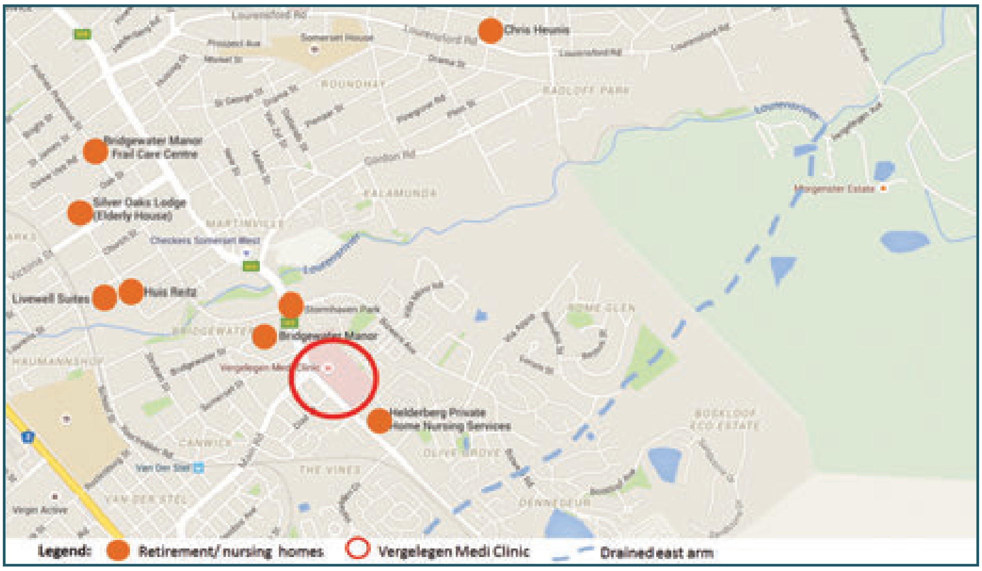


Figure 2.4.3.1: Location of Mediclinic Vergelegen in Somerset West in relation to the Lourens River and its drained east arm.

2.4 Conclusions

This detailed case-study of the 15 November flash-flood in the Lourens River catchment illustrates how incrementally accumulating flood risk factors often go undetected until a life-threatening disaster occurs. In the Western Cape, these same risk factors apply to many other locations that are both exposed to high impact weather conditions as well as to incremental development changes that increase the likelihood of deaths, property damage and financial loss.

This chapter has underlined the sustained efforts by disaster and emergency management personnel to respond under difficult conditions to protect vulnerable people and communities in times of duress. It also indicates modest steps taken to advance flood risk reduction by committed individuals and municipalities. These efforts, while necessary, remain insufficient to off-set powerful flood risk drivers that are embedded in development activities, and that are reflected in repeated and costly financial impacts, especially for farmers, inland municipalities and the province's public infrastructure.

PART III: HIGH IMPACT WEATHER EVENTS: CHALLENGES FOR PREPAREDNESS AND RESPONSE

3.1 Introduction

Findings from the 2011 – 2014 disasters foreground the crucial role that disaster management and other emergency responders play in protecting public safety in times of weather-triggered duress. However, they also indicate serious concerns related to institutional preparedness for and response to future HIWEs. Box 3.1.1 lists four important concerns that emerged in the course of the study.

- The Western Cape Province benefits from **high levels of committed, effective and skilled disaster (risk) management and emergency services** practitioners. However, while a history of cooperation in large-scale disasters has built strong informal relations across services, it may have hindered the formalisation of roles and responsibilities.
- Current **flash-flood forecasting** and communication approaches **are too broad-brush** to give advance warning to specific areas under threat or to accurately inform action. This applies especially to **municipalities in the Karoo and mountainous catchments**.
- **Limited weather radar coverage severely hampers early warning of high impact weather conditions** and prevents full implementation of the National Flash Flood Guidance System – especially for inland municipalities.
- **Social media is a powerful medium in disaster responses**. It has potential to be a formidable resource for informed decision-making and disseminating disaster-related information.

Box 3.1.1: Four important concerns that emerged in the course of the study

Table 3.2.1: Examples of actions taken by disaster management and emergency personnel during the 2011-2014 disasters

Event	Examples
June 2011	Disaster managers in Eden District Municipality worked with local municipalities, Department of Water and Sanitation, South African National Parks (SANParks), the South African Police Service (SAPS) and the Fire and Rescue Service to pre-emptively breach estuaries and evacuate at-risk areas, while coordinating rescues, evacuations and road clearing efforts across the Province.
July 2012	Disaster management authorities in the Central Karoo District Municipality worked with the National Roads Agency (SANRAL), traffic services, private citizens and civil society organisations to free and assist hundreds of road users trapped by snow in Beaufort West, while simultaneously working with the WCDMC, the South African National Defence Force (SANDF) and the Cape Metro's Disaster Risk Management Centre (DRMC) to assist people trapped on farms.
August 2012	Disaster management authorities in the Cape Winelands District Municipality worked closely with the Province's EMS to mobilise search and swift-water rescue capabilities when an ambulance was swept off a bridge in Montagu.
November 2013	Disaster management and Fire and Emergency Services in Overberg District Municipality used inflatable dinghies to evacuate prisoners and prison personnel and their families trapped by flooding at Helderstroom Prison. They also worked with the Department of Education to ensure that matriculants cut-off by flooding at the prison and Struisbaai were able to write their exams. The authorities also used boats to deliver relief to people trapped by flooding in the Stanford area.
January 2014	The SAPS in Laingsburg established a Joint Operations Centre (JOC), contending with intermittent telephone, cell phone and internet reception. The WCDMC received SANDF helicopter assistance to rescue people isolated on farms.

Research results however, also indicate shortcomings in the formalisation of response arrangements. On one hand, findings suggest that experienced disaster managers have developed a wide range of resources and contacts to mobilise in emergencies. For instance, the value of regular simulation exercises and disciplined Major Incident Medical Management and Support (MIMMS) training sessions was repeatedly underlined by those interviewed during the research. On the other, results indicate that these relationships are not always formalised nor regularised by protocols to guide response efforts. This was most apparent in the complex, fast-paced, 'unusual' November 2013 disaster. This event was characterised by simultaneous, dispersed emergencies across the Cape Town Metro and involved a diversity of role-players, including civil society organisations.

Findings also suggest possible fragility in institutional memory due to reliance on individual knowledge and personal relationships. This has potential to undermine institutional capacity as experienced professionals retire or take up positions elsewhere

3.3 Flood risk identification and communication: Serious gaps in weather radar coverage

3.3.1 Close cooperation with SAWS – but warnings inadequate and too broad-brush

Research indicates that there are close collaborative relations between the South African Weather Service disaster management centres across the Western Cape. However, study findings also highlight weaknesses in severe-weather forecasting and warning, and serious gaps in weather radar coverage.

Fieldwork and interviews indicate that current rainfall forecasts in advance of high impact weather conditions are too generic to identify areas most at-risk or to inform effective action under flash-flood conditions. Disaster management and emergency response personnel explained that the coarseness of the SAWS warnings limits their usefulness, particularly in areas with diverse micro-climates such areas as the Overberg and along the Garden Route. Box 3.3.1.1 clearly demonstrates the gap between the broad-brush warning issued and the specific flash-flood management actions that were needed. in the Cape Town Metro in November 2013.

- Although SAWS had issued several alerts warning of an intense cut-off low, these were regional in scale and forecasted "heavy rainfall" across the entire province. This included the Cape Metro, the West Coast, Central Karoo, Overberg, Cape Winelands and Eden District Municipalities (Figure 3.3.1.1).

- In Cape Town, the DRMC responded according to standard procedures for severe-weather alerts. It placed personnel and services on standby, and informed governmental role-players and the public of the approaching storm.

- However, as the DRMC received no advance indication of the possibility of intense rainfall (> 100mm in 3 hrs in the Lourens River Catchment, Somerset West) or of flash-flooding, there was neither anticipatory mobilisation nor commensurate preparedness action in the suburbs most severely exposed.

- This led to an unanticipated, difficult (but successful) evacuation of 121 patients from a flooded hospital in pouring rain in the middle of the night.

Box 3.3.1.1: Implications of broad-brush weather warning in the Cape Town Metropole, 15 November 2013

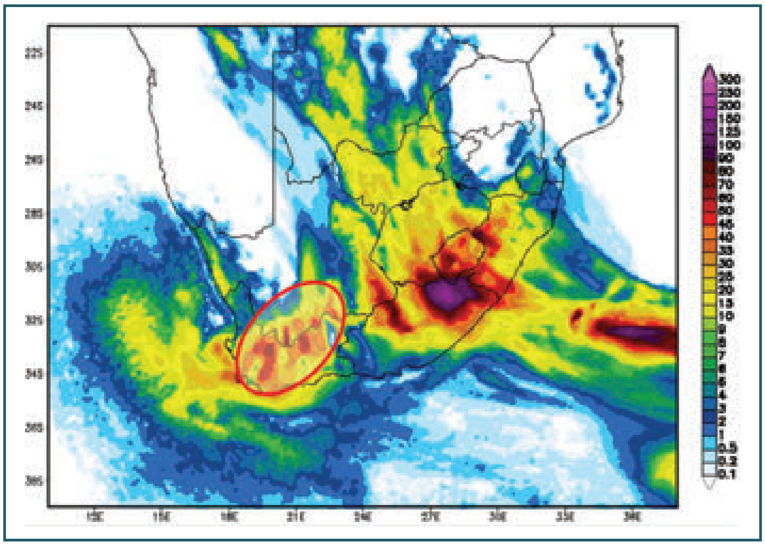


Figure 3.3.1.1: Map issued by SAWS showing probability of precipitation exceeding 50 mm in 24 hours on Friday the 15th of November 2013

3.3.2 'Off the radar' – limited weather radar coverage in the Western Cape

Finer-scale flash-flood alerts, like that needed in November 2013, are substantially informed by access to weather radar information. However, as shown in Figure 3.3.2.1 , current SAWS weather radar coverage in Western Cape is limited to one S-band radar, located in Vlees Bay in Hessequa Municipality (white circle), and a C-band radar in Cape Town, with peripheral cover by a C-band radar located in Port Elizabeth (green circles). SAWS personnel in Cape Town explained that C-band radars have a more limited range than S-band radars and are subject to greater interference. In addition, Cape Town's C-band radar is positioned at too high an altitude to ensure accurate overland rainfall forecasting. SAWS staff added that coverage by both radar types is obstructed by mountainous topography, so that even in the southern Cape, accurate inland flash-flood forecasting is blocked by the Langeberg mountain range. As Figure 3.3.2.2 illustrates, this leaves very little of the Western Cape covered by accurate weather radar, with this confined to a narrow strip of coastline along the Province's southern margin.

This inadequate radar capacity severely constrains accurate forecasting and warning elsewhere in the province, including flood-prone towns in the Karoo. Current weather radar coverage clearly facilitates forecasting along the Garden Route. However, the lack of weather radar capability in the interior means that only those weather systems approaching from the south-east are identifiable, compromising forecasting accuracy.

The implications were clearly illustrated during the events in 2011 and 2012, when weather warnings disseminated by SAWS did not specify areas such as the Langeberg Muncipality, where settlements including Ashton, Montagu and Robertson experienced heavy rainfall and flooding. These events claimed several lives, including that of an ambulance attendant. In both instances, preparedness mechanisms that should have been activated in advance of a HIWE were not triggered, as flash flood warnings were not issued for the Langeberg Muncipality.

The South African Flash Flood Guidance System (SAFFGS)

The SAFFGS is being implemented in Gauteng, around Durban, Port Elizabeth, and Cape Town and the Cape South Coast. It is operated by the SAWS on a 24/7 basis, with active links to Disaster Management Centres in the relevant municipalities and provinces.

The system pre-calculates available hydrological information for each small river basin to estimate the rainfall needed to trigger a flash flood. When rain falls over a river basin, the SAFFG software compares the actual rainfall with the pre-calculated 'flash-flood' value to identify river basins in danger of flooding. This is supposed to enable SAWS forecasters to provide more accurate flash flood warnings to disaster managers.

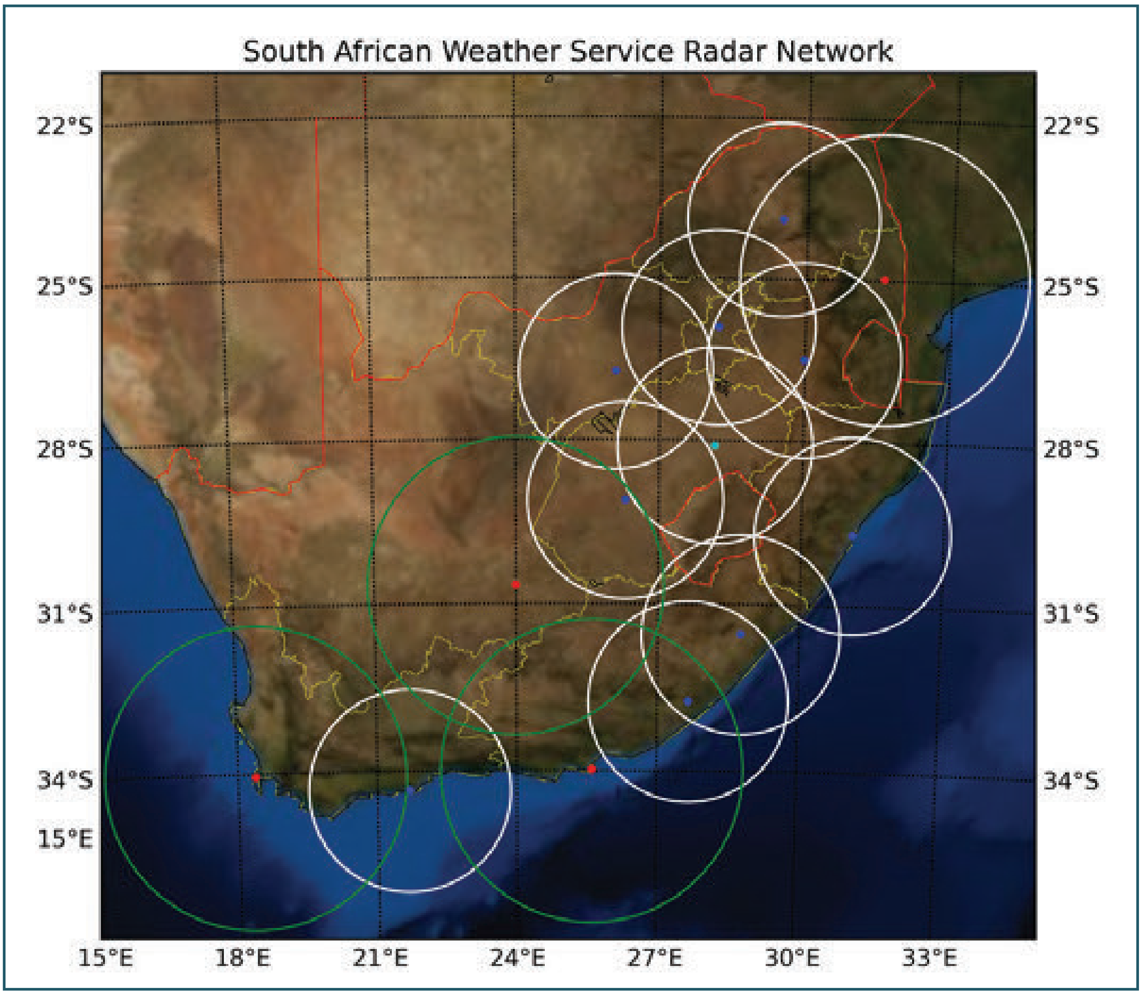


Figure 3.3.2.1: Map showing spatial coverage by SAWS C-Band (in green) and S-Band (in white) weather radars across South Africa (2015)

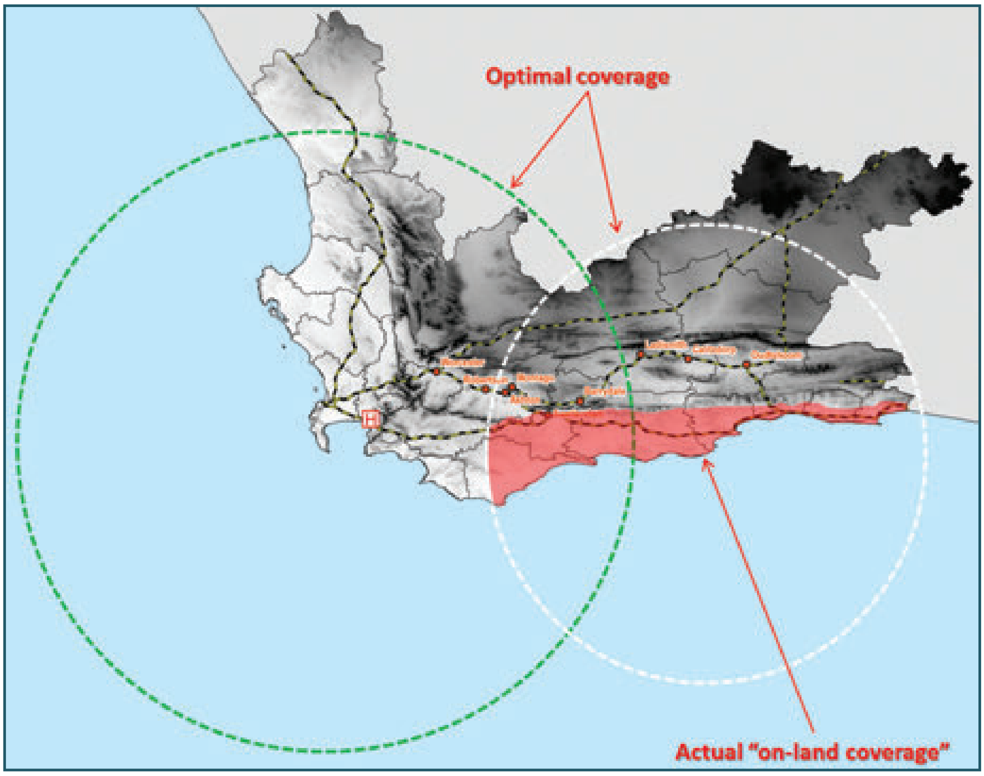


Figure 3.3.2.2: Map of the Western Cape showing optimal weather radar coverage (green and white circles) compared with actual (red shading) weather radar coverage.

3.4 Social media an untapped resource for warning and response

3.4.1 The unexpected impact of social media

A striking research finding was the emergence of social media as a key, but unanticipated factor in the 2013 Somerset West/Cape Town flood response. Research findings show that it substantially influenced both the public's as well as responders' management of the emergency. Social media engagement placed unforeseen demands on disaster management and other authorities. This was particularly evident during the evacuation of the Mediclinic Vergelegen, where the well-meaning but unsolicited arrival of members of the public added an additional layer of complexity for those managing the process.

Analysis of Twitter traffic on the 15th of November shows that a handful of users served to mobilise members of the public. Figure 3.4.1.1 shows the number of Tweets containing keywords relevant to the event. The x-axis shows the time during the day (from 02h00 to 02h00), and the y-axis, the key-word mentions per minute.

- The **22h01** data spike on 15 November followed a Tweet **(red spot)** posted by Premier Helen Zille noting the evacuation of the Mediclinic. Although there was almost no mention of the Mediclinic Vergelegen before this, her message was rapidly retweeted 117 times. Other users soon posted messages asking for assistance with the evacuation, none of whom appear to have been involved in the official response.
- At **22h44** an Eye Witness News Reporter (@ewnreporter) also posted information on the evacuation, with this posting retweeted 43 times.
- At **23h36** and **23h40**, the @JustSportZA account tweeted that help was needed, with this message retweeted 26 times.

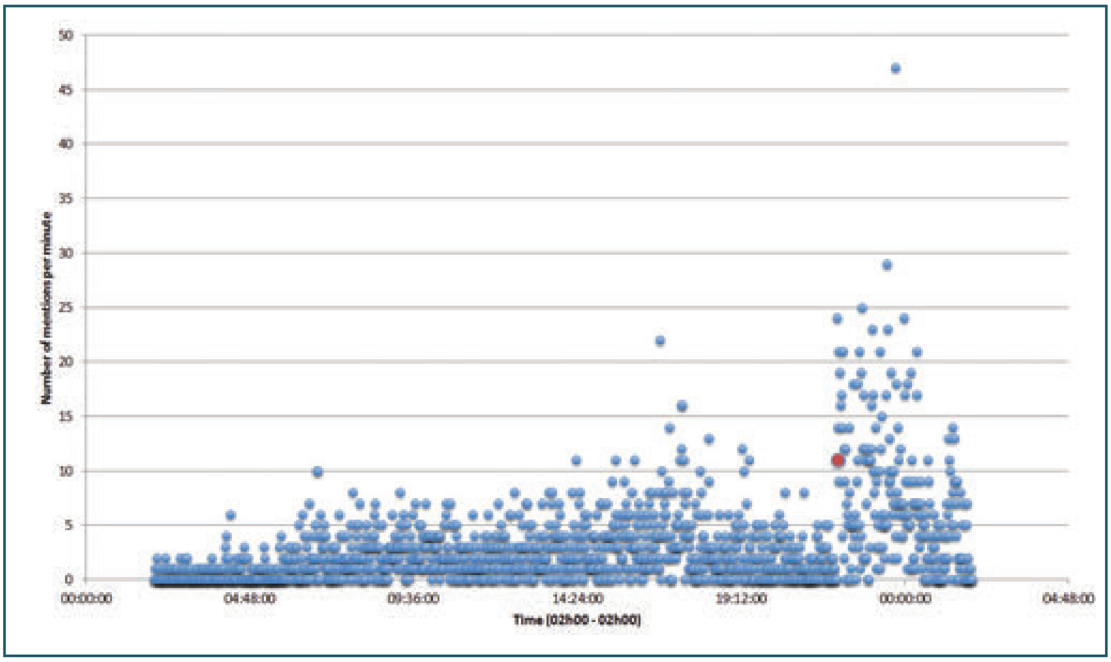


Figure 3.4.1.1: Key word mentions per minute, 15 November 2013 (Source: de la Rouviere, S., 2015)

A noteworthy feature of Premier Helen Zille's engagement was that members of the public approached her directly for information (Figure 3.4.1.2). Rather than seeking information from the CoCT's Twitter platform and website, users messaged her, seeking the contact details for other stakeholders. Tweets posted by the DRMC on the @CityofCT handle achieved some visibility during the event, although postings by more popular or influential users primarily shaped how the public understood and responded to the emergency.

Figure 3.4.1.2: An example of a Twitter exchange involving the Premier on 15 November 2013

3.4.2 Social media – a game changer in emergency management

Emergency response personnel explained that the spontaneous mobilisation of self-despatched, untrained volunteers not only complicated their work but also placed volunteer safety at risk. Yet, research findings strongly indicate that social media is an influential dynamic in emergency situations and should be factored into future responses. The Premier's involvement also shows that members of the public will engage pro-actively in times of duress and expect to be provided with information. Moreover, they will follow high-profile users - irrespective of whether this is beneficial to the official response, or not.

Results indicate that if managed systematically, social media could offer a formidable resource, to both disseminate information and inform decision-making. They show how influential users, such as the Premier can play enabling roles in informing the public and redirecting public interest to the relevant platforms and sources of assistance. Similarly, results underline the roles that media institutions such as @ewnreporter can play both in identifying problems and disseminating information (eg where to report information about floods).

3.5 Conclusion

Study results underline the skilled and committed capabilities of disaster managers and emergency responders in the Western Cape. However, they also reveal important gaps that should be urgently addressed. These include formalisation of roles and responsibilities for geographically dispersed, multi-incident disasters. They also include urgent attention to weather radar coverage gaps that limit the accuracy of high impact weather forecasts and warnings. A pressing priority is the need to strengthen use of social media for improved risk communication. Tapping such resources would not only increase the reach and visibility of information, but could also reduce the pressure on human resources during emergency events.

PART IV: COL DISASTERS 2003-2014: IMPACTS, INSIGHTS AND IMPLICATIONS

4.1 Overview

While this study focused on the high impact weather disasters between 2011 and 2014, RADAR's previous post disaster research enabled a longer view, extending back to 2003. This chapter integrates the 2011-2014 findings with results from eight earlier ex post studies on COL disasters in the Western Cape (Holloway *et al*, 2010) to examine patterns and trends in high impact weather from 2003-2014. Box 4.1 summarises the main findings of this synthesis.

- There is an identifiable **recent increase in the frequency of extreme daily rainfall** associated with cut-off low weather systems.
- Social impacts were wid**e-ranging and poorly documented, including deaths, evacuati**ons and temporary isolation. **Residents of inland municipalities** are at particular risk.
- High impact weather conditions and **damaging floods are not 'rare events'**. They occur almost annually, with ext**ensive and recurrent financial los**ses. From **2003-2014, R 4.9 billion in flood-related damage** was reported by government departments and municipalities.
- Cut-off low associated damage varies seasonally, with average municipal **costs in warmer months more than double those in cooler periods**. Average Septembe**r-February disaster costs were calc**ulated at **R 120.23 million** per event compared with **R 47.6 million** for individual disaster events from March-August.
- The **Langeberg and Laingsburg** municipalities, as well as **Meiringspoort** represent identifiable flash-flood hot-spots, where warning capacity should be urgently prioritised.
- De**spite the almost annual o**ccurrence of severe flooding**, a widely hel**d **perception that 'floods' are disasters** has discouraged the incorporation of flood risk management into IDPs and funding models.

Box 4.1: Summary of the main findings from the study of HIWE 2003 – 2014

4.2 Changing patterns in COL-induced rainfall and river flow peaks

4.2.1 Greater frequency of extreme rainfall associated with COLs

Results from the COL study indicate an increasing frequency of extreme rainfall associated with damaging COL weather systems in the Western Cape (Engelbrecht, C., 2015), corroborating earlier findings by Favre et al. (2013). The six graphs shown in Figures 4.2.1.1 and 4.2.1.2 represent a time series of area-averaged daily rainfall from 1983-2014 associated with COLs that exceeded the 95th percentile (or 'extreme' daily rainfall).

Findings indicate an upward trend in COL-induced extreme rainfall in the more recent record, with the 15 November 2013 COL recording the 4th highest area-averaged rainfall from 1979-2014. Rainfall recorded on 7 January 2014 represented the 11th highest COL area-averaged rainfall from 1979-2014. Analysis results specifically indicate that COL-induced extreme rainfall occurs mainly during June, July and August and to a lesser extent in December, January and February (Engelbrecht, C., 2015). They also confirm that the COL-related disasters considered in this study (eg from March 2003-January 2014) were associated with COLs of at least three days' duration, and not those limited to one-two days.

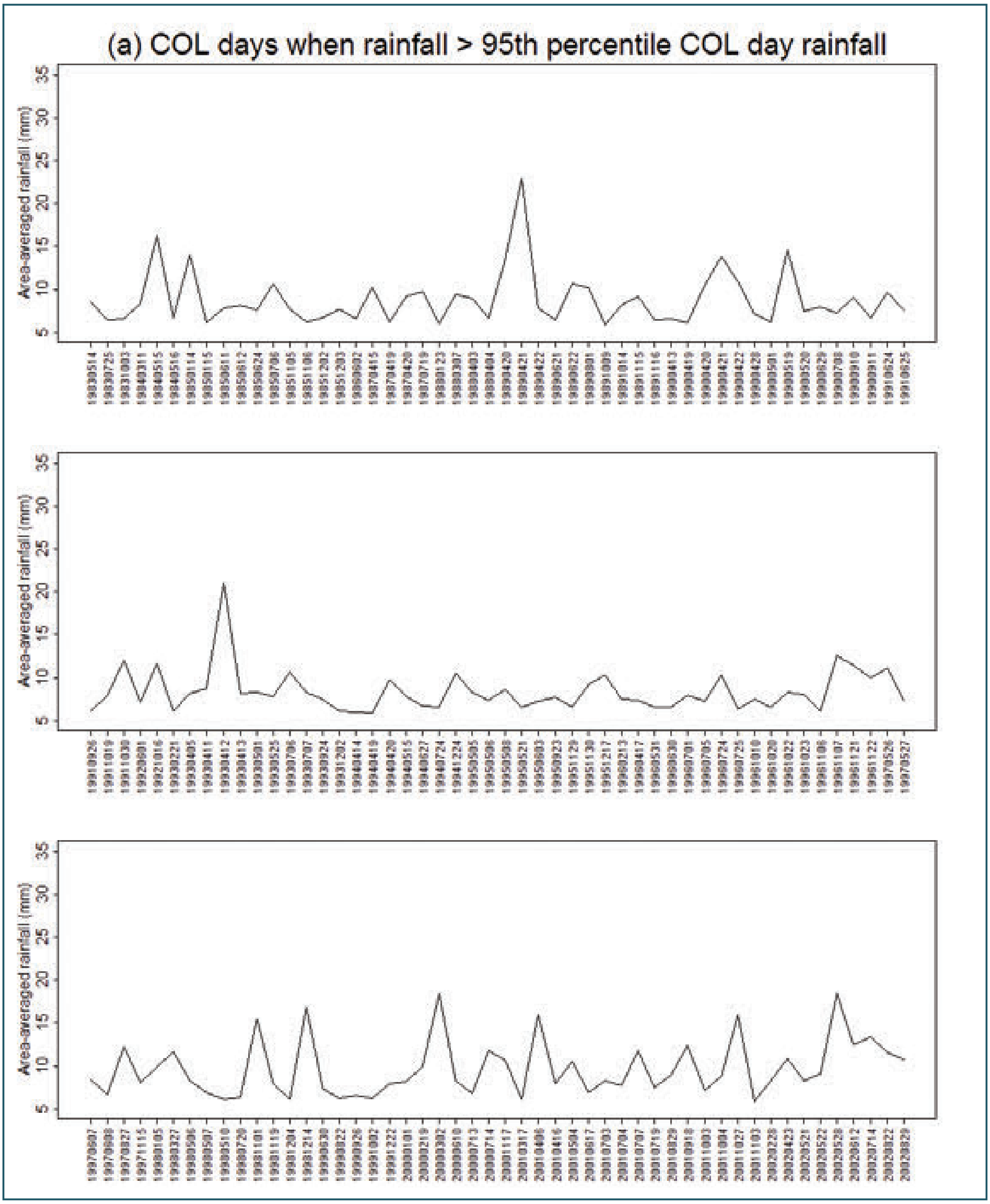


Figure 4.2.1.1: COL induced rainfall days during the period 1983 to 2011 as well as for the case study COL days that exceeded the 95th percentile of all COL induced rainfall days. There are 284 days that qualified. (Source: Engelbrecht, C., 2015)

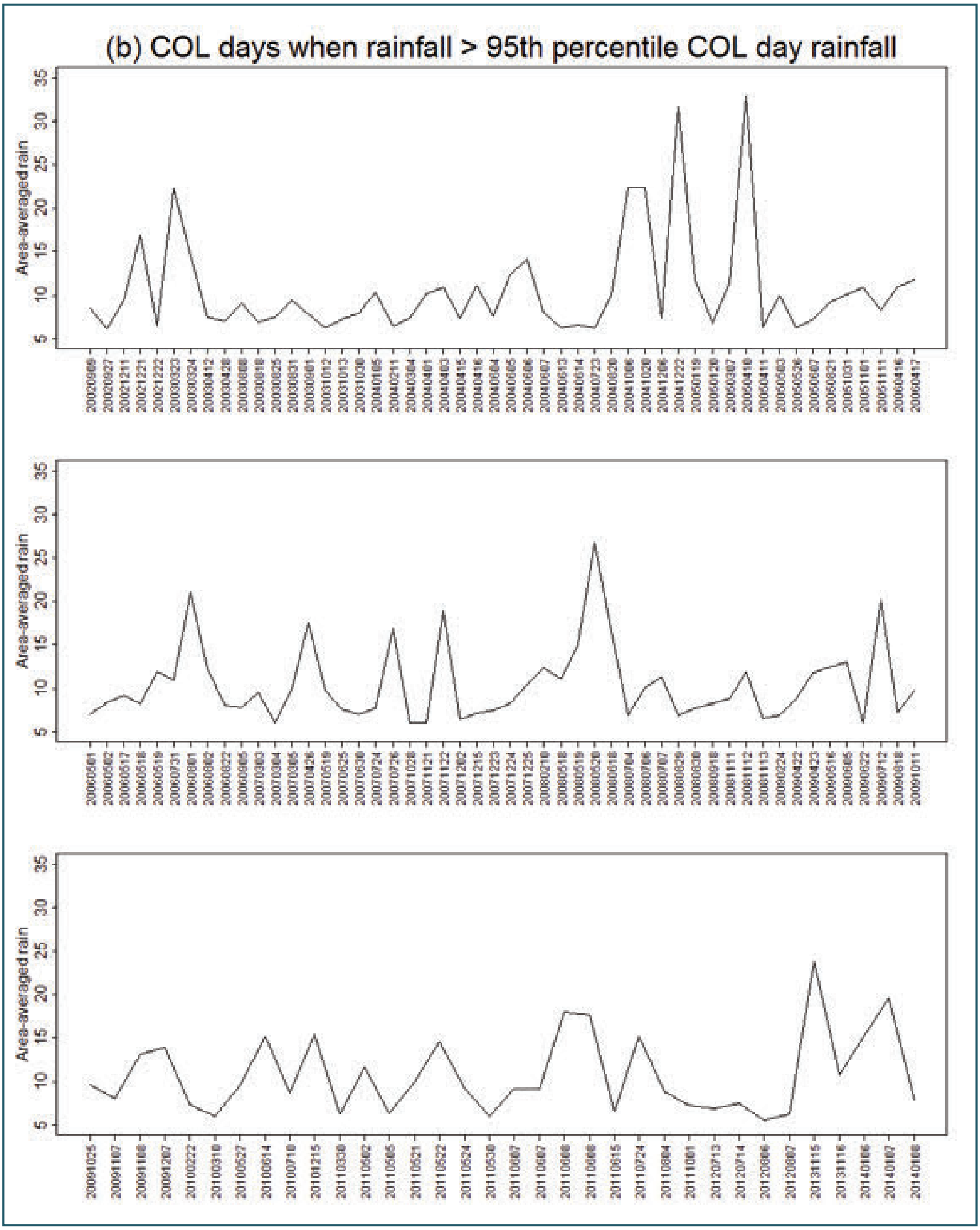


Figure 4.2.1.2: COL induced rainfall days during the period 1983 to 2011 as well as for the case study COL days that exceeded the 95th percentile of all COL induced rainfall days.

Drawing on data presented in Figures 4.2.1.1 and 4.2.1.2, in a 30 year record from 1983-2012, 284 COL-induced rainfall days exceeded the 95th percentile of all COL-associated rain-days. When clustered in five-year groupings, the frequency of COL-induced extreme daily rainfall was seen to increase over time. Table 4.2.1.1 below shows that from 1983-1992, there were 55 days recording extreme COL-induced rainfall. From 1993-2002, these increased to 100 days, and then again to 129 days from 2003-2012.

Table 4.2.1.1: Frequency of occurrence of COL-induced extreme rainfall days May 1983-December 2012 (greater than 95th percentile of all COL rainfall days)

Five-year intervals	Five-Year Frequency	Ten-Year Totals
1983-1987	21	
1988-1992	3	55
1993-1997	49	
1998-2002	51	100
2003-2007	72	
2008-2012	57	129
Total	**284**	

However, findings from the two winter and two summer case studies in 2011-2014 also indicate that heavy rainfall was more densely distributed during the two summer COL events. These were also characterised by high levels of convective activity, associated with higher hourly rain rates compared to the three winter COLs. This attribute was particularly clear during 15 November 2013, contributing to the development and distribution of the intense rainfall that triggered the Lourens catchment floods.

4.2.2 Increased COL-induced flood peaks on some rivers

Consistent with observed trends in COL-induced rainfall, findings from the analysis of flow data from selected DWS river gauges suggest a strong increase in flood-producing storms. For instance, since 2003, one gauge on the Duiwenhoks River (Figure 4.2.2.1 and Table 4.2.2.1) recorded eight of the ten highest flood peaks over its forty year flow history. Similarly, on the Groot River (Figure 4.2.2.2 and Table 4.2.2.2), from 2007-on, the Buffelsfontein gauge measured the ten highest flood peaks since 1980. In contrast, other rivers indicate no change in flood magnitude and frequency. As shown in Figure 4.2.2.3, the Molenaars River in the Du Toitskloof Mountains signals little (if any) change, with larger extreme rainfalls measured earlier in the record

This pattern of differences suggests the frequency and intensity of COLs may have changed across the southern Cape. However, a similar signal of change is not identifiable for the western parts of the province (see Figure 4.2.2.3 for the Molenaars River in the du Toitskloof mountains. Most losses have occurred in the southern region, extending from Cape Town to Bitou, with the exception of substantial damages reported in the Cedarberg District Municipality in 2007.

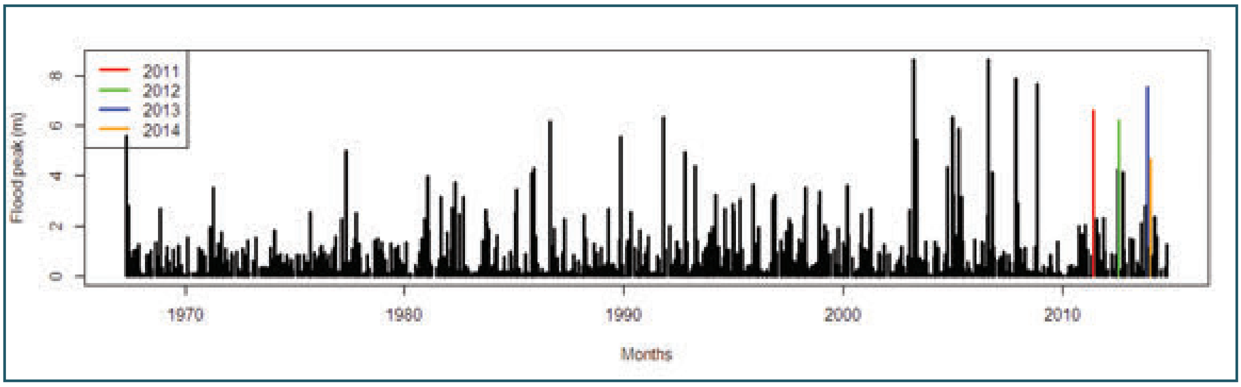


Figure 4.2.2.1: Monthly peak flows on the Duiwenhoks River at Dassiesklip (H8H001), Hessequa Local Municipality.

Table 4.2.2.1: Eight of the ten highest flood peaks for the Duiwenhoks River since 1965, ranked in descending order, occurred from 2003 to present at Dassiesklip(H8H001)

Date	Peak (m)
2003-03-24	8.674
2006-08-23	8.659
2007-11-22	7.888
2008-11-13	7.69
2013-11-16	7.564
2011-06-08	6.629
2004-12-22	6.337
1991-10-30	6.321
2012-08-07	6.231
1986-08-30	6.172

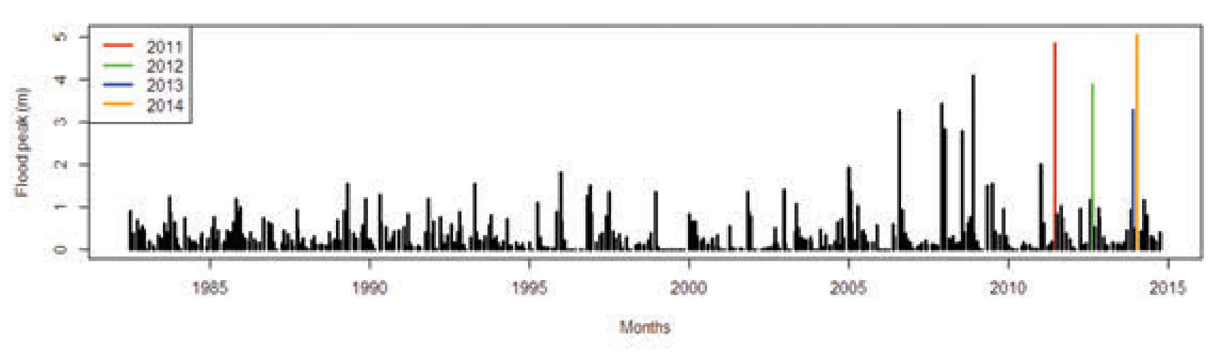


Figure 4.2.2.2: Monthly peaks at for the Grootrivier at Buffelsfontein (J1H019) near van Wyksdorp, Kannaland Local Municipality

Table 4.2.2.2: Eight of the ten highest flood peaks since 1980, occurred from 2007 to the present for the Grootrivier at Buffelsfontein (J1H019), ranked in descending order

Date	Peak (m)
2014-01-08	5.055
2011-06-09	4.859
2008-11-15	4.101
2012-08-08	3.88
2007-11-23	3.425
2013-11-16	3.286
2006-08-02	3.269
2007-12-27	2.831
2008-07-10	2.792
2011-01-01	1.995

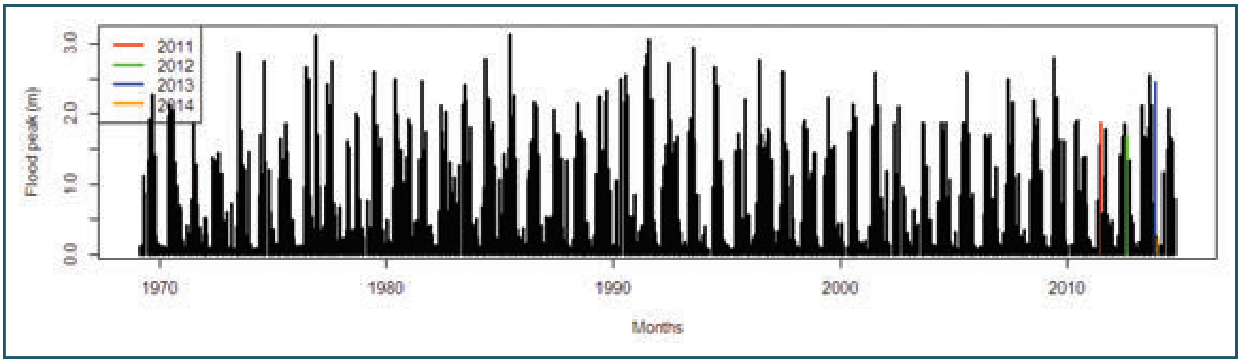


Figure 4.2.2.3: The Molenaars River (H1H018) in the Du Toitskloof Mountains

4.3 Social impacts are wide-ranging and poorly documented

Although there are clear provisions for systematically recording infrastructural damage, regrettably, important social impacts remain unevenly reported. The limited collection of detailed information on household hardship and loss associated with the four most recent COL disasters represents an important gap, as the study findings do not reflect household property damage (eg soaked mattresses and food), or important livelihood impacts (eg due to transport disruptions or ill-health). Despite these constraints, the research team was able to compile information on lives lost and areas affected or evacuated from 2003-2014.

4.3.1 Lives lost

Tables 4.3.1.1 and 4.3.1.2 summarise information on lives lost over the 12 disasters, with 23 deaths reported from 2003-2014. Although the majority of fatalities were attributed to vehicles being swept away or drownings, three deaths in 2012 (in Uniondale, de Rust and Avontuur) were due to hypothermia. Thirteen people lost their lives in the Eden District Municipality, while eight died in the Cape Winelands. COL disasters in August 2006 and July 2012 each claimed the largest number of lives.

Table 4.3.1.1: Lives lost in cut-off low disasters 2003-2014

Municipality	No. of fatalities
Eden district	
Bitou	1
George	7
Hessequa	1
Knysna	1
Mossel Bay	1
Oudtshoorn	2
Eden subtotal	**13**
Cape Winelands	
Breede Valley	4
Langeberg	2
Stellenbosch	2
Cape Winelands subtotal	**8**
Overberg	
Overstrand	1
Overberg subtotal	**1**
Total	**23**

Table 4.3.1.2: Lives lost by year 2003-2014

Event	No. of fatalities
Mar 2003	3
Aug 2006	5
Nov 2007	2
Nov 2008	1
June 2011	1
July 2012	5
Nov 2013	2
Jan 2014	4
Total	**23**

4.3.2 Areas affected and groups evacuated

At least 30 800 people were reportedly affected in the twelve COL disasters (See Table 4.3.2.1). This number includes 18 000 residents of 44 informal settlements in the CoCT who were flood-affected during the November 2013 COL.

Table 4.3.2.1: Numbers of people who were affected or required assistance during the COL disasters 2003-2014

Municipality	Mar-03	Dec-04	Aug-06	Nov-07	Jun-11	July/ Aug 2012	Nov-13	Jan-14	Total
CoCT							18000		18 000
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**18 000**	**0**	**18 000**
Cape Winelands									
Breede Valley									0
Drakenstein							41		41
Langeberg	3 081					1 720	1623		6 424
Stellenbosch							37		37
Subtotal	**3 081**	**0**	**0**	**0**	**0**	**1 720**	**1 701**	**0**	**6 502**
Eden									
George		170	1 274	1 500	520	120			3 584
Hessequa		6			7	28			41
Kannaland					34	68			102
Knysna					7				7
Mossel Bay			320	95	767				1 182
Oudtshoorn					102	100			202
Subtotal	**0**	**176**	**1 594**	**1 595**	**1 437**	**316**	**0**	**0**	**5 118**
Overberg									
Overstand				100					100
Swellendam	371	10							381
Theewaterskloof				700					700
Subtotal	**371**	**10**	**0**	**800**	**0**	**0**	**0**	**0**	**1 181**
Total	**3 452**	**186**	**1 594**	**2 395**	**1 437**	**2 036**	**19 701**	**0**	**30 801**

(Numbers in this table were derived from numerous sources, including correspondence from Eden District Management Centre)

Excluding the CoCT, emergency relief, evacuation or other support was required for 43 settlements or towns across the Western Cape. The majority of settlements requiring relief were located in either the Eden or Cape-Winelands District Municipalities. Evacuees were housed temporarily in community halls.

Unfortunately, detailed research on the other social impacts exceeded the study scope – although previous reports have indicated adverse effects on health and livelihoods, including an increase rate in lower respiratory tract infections in children, and disrupted access to places of work (DiMP, 2004; DiMP 2007).

4.4 Extensive damage costs from almost annual events

4.4.1 Almost R 5 billion in reported direct damage costs

While there was limited loss of life associated with the twelve disasters, direct damage costs were substantial. When reported costs were adjusted to 2010 values, total reported costs associated with the twelve disasters approximated R 4.9 billion. Of this, R 2.3 billion was attributed to agriculture. Non-agricultural provincial damage (primarily losses reported by the Department of Transport and Public Works) comprised R 1.5 billion (29.97%). Municipal damage increased to 35.9% of the total when agricultural costs were excluded.

The November 2007 COL-related disaster was the most costly across the twelve events studied, with an identifiable reduction in losses reported after this event. However, the lower damage costs from 2008-on should be carefully interpreted and not automatically attributed to improved climate risk management. This is because the application of the PSP process from 2011-onwards introduced stringent eligibility criteria for reportable infrastructural damage, and may have "reduced" the number of damage claims – spuriously indicating improved climate risk management.

These new requirements effectively reduced the range of reportable damage categories, and excluded important non-infrastructural losses such as crop damage or livestock deaths. The new criteria also excluded repeat infrastructural impacts that may have occurred in the same location during a flood event in the previous year.

The combined effect of the more narrowly applied eligibility criteria and the nationally-driven PSP process appears to have had a further unintended consequence – specifically to discourage accurate loss recording, especially in resource-constrained municipalities. For instance, prior to 2011, Swellendam Municipality commissioned its own detailed loss reporting. This ceased from 2011-on, following the introduction of the PSP process, resulting in diminished detail in loss and damage reporting.

Table 4.4.1.1: Reported damage costs associated with COL disasters 2003-2014 Adjusted to 2010 inflation values (ZAR)

Event	Municipal	Provincial (excl Agric)	Provincial (incl Agric)	National	Total (excl Agric)	Total (incl Agric)
Mar 2003	11 189 819	134 291 202	279 164 559	22 389 896	167 870 917	312 744 274
Dec 2004	31 842 894	14 264 956	51 444 894	0	46 107 850	83 287 788
Apr 2005	7 853 640	4 883 465	4 883 465	0	12 737 105	12 737 105
Aug 2006	140 514 606	187 870 629	336 683 708	125 152 966	453 538 201	602 351 280
Jun 2007	62 294 365	12 778 790	47 439 623	1 460 983	76 534 138	111 194 971
Nov 2007	380 129 712	567 890 218	781 425 673	29 937 706	977 957 636	1 191 493 091
Jul 2008	25 541 827	21 694 063	52 739 390	3 681 779	50 917 669	81 962 996
Nov 2008	77 127 152	136 483 685	1 041 009 490	20 562 632	234 173 469	1 138 699 274
Jun 2011	70 765 933	154 639 094	275 011 032	2 180 084	227 585 111	347 957 049
July/Aug 2012	15 049 016	30 682 673	362 654 209	32 880	45 764 569	377 736 105
Nov 2013	34 893 218	60 073 207	132 646 439	0	94 966 425	167 539 657
Jan 2014	77 151 587	141 059 004	388 309 261	0	218 210 591	465 460 848
Total	**934 353 769**	**1 466 610 986**	**3 753 411 743**	**205 398 926**	**2 606 363 681**	**4 893 164 438**
Percentage %	**19.1**	**29.97**	**76.7**	**4.2**	**53.27**	

losses of R 178 million. Elsewhere in Eden, George reported R 178 million in damage for six events and Knysna recorded R 142 million for five disasters. The Langeberg Local Municipality[15] in the Cape Winelands District Municipality was affected by six events, with cumulative damage costs of R 23.6 million. Its neighbouring Swellendam Local Municipality in the Overberg District Municipality recorded losses for five events estimated at R 65.7 million.

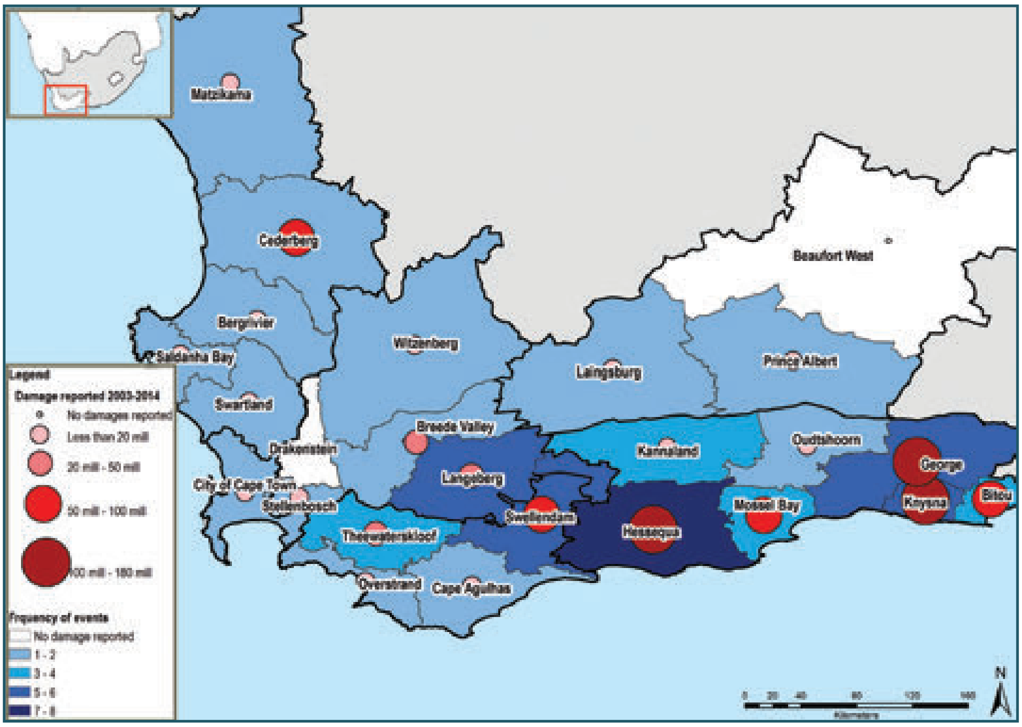


Figure 4.4.1.1: Frequency of high impact COL-related disasters and cumulative municipal financial losses (2003-2014)

4.5 Results challenge perception of floods as occasional 'disasters', delinked from development

Findings from Figure 4.4.1.1 as well as Tables 4.4.1.1 and 4.5.1 challenge prevailing perceptions that floods are occasional 'disasters', delinked from development. They clearly show that damage-inducing storms **are not rare events** in the Western Cape. Table 4.5.1 summarises financial losses reported by municipality, showing average losses per disaster event. For southern Cape municipalities, these can exceed R 20 million per event, while the average damage cost reported for Swellendam was R 13 million.

[15] Previously Breede River/Winelands Local Municipality

Table 4.5.1: Reported municipal damage costs for COL associated disasters 2003-2014

Local Municipality	Total	Frequncy	Ave per event
West Coast District Municipality			
Bergriver	18 527 679	2	9 263 840
Cederberg	51 293 615	2	25 646 807
Saldanha Bay	1 816 669	1	1 816 669
Matzikama	10 279 069	2	5 139 534
Swartland	5 919 161	2	2 959 580
West Coast Total	**87 836 192**		
Cape Winelands District Municipality			
Cape Winelands DMA	2 111 988	2	1 055 994
*Langeberg	**23 626 994**	**6**	**3 937 832**
Breede Valley	23 942 724	2	11 971 362
Stellenbosch	263 589	1	263 589
Cape Winelands Total	**49 945 295**		
Overberg District Municipality			
**Cape Agulhas	19 940 566	3	6 646 855
Swellendam	**65 652 018**	**5**	**13 130 404**
Overstrand	4 646 639	2	2 323 319
Theewaterskloof	20 324 936	3	6 774 979
Overberg Total	**110 564 158**		
Eden District Municipality			
Bitou	59 879 078	4	14 969 770
**George	**178 417 578**	**6**	**29 736 263**
Hessequa	**177 893 059**	**8**	**22 236 632**
Kannaland	17 775 886	3	5 925 295
Knysna	142 325 297	5	28 465 059
Mossel Bay	86 522 650	4	21 630 662
Oudtshoorn	12 114 018	2	6 057 009
Eden Total	**674 927 566**		
Central Karoo District Municipality			
Prince Albert	517 383	1	517 383
Laingsburg	4 107 038	1	4 107 038
Central Karoo Total	**4 624 421**		
Cape Town Metro			
Cape Town Metro	6 456 136	1	6 456 136
Metro Total	6 456 136		
Mun & Metro Total	**934 353 768**		

*** Previously known as Breede River-Winelands**
****Includes DMA**

4.6 Seasonal differences in severity of recorded disaster losses

Research findings also indicate a surprising seasonal influence on realised loss outcomes. Table 4.6.1 compares municipal damage costs for cooler (March-August) and warmer (September-February) months. It shows that approximately 64% of reported municipal damage costs were attributed to COL weather events in the warmer months, compared with 36% in cooler periods. Warmer-season events were 1.8 times more costly than those in cooler months (R 601.1 million, compared with R 333.5 million). Table 4.6.1 and Figure 4.6.1 underline this difference in the seasonality of COL-associated losses. On average, reported municipal damage costs for warmer season COLs are R 120.23 million per event, compared with R 47.60 million per cooler season event. Moreover, reported average municipal damage costs for warmer season COLs are a staggering 2.53 times higher than those recorded in the cooler months.

Table 4.6.1: Average municipal damage costs per COL by seasonality, comparing warmer and cooler season events in the Western Cape (2003-2014)

	Frequency	Total Damage Cost	Average Damage Cost
Warmer	5	601 144 563	120 228 913
Cooler	7	333 209 205	47 601 315
Total	**12**	**934 353 768**	**77 862 814**

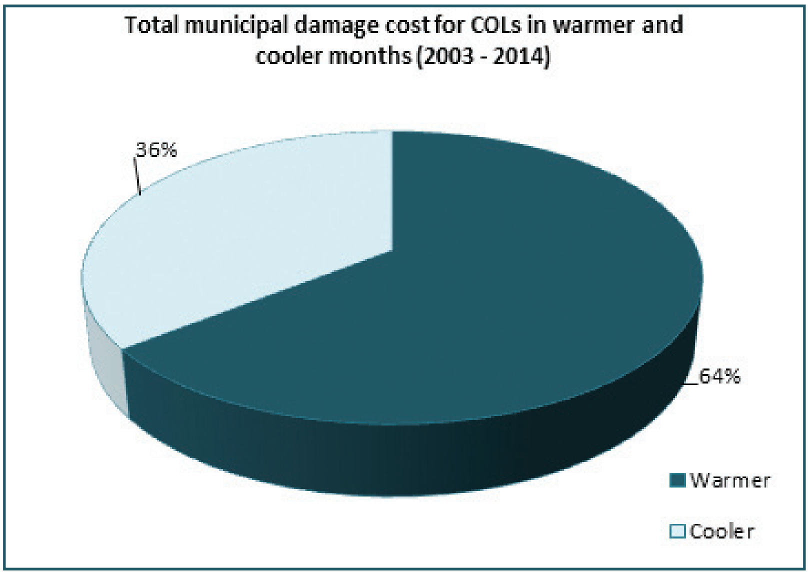


Figure 4.6.1: Pie-chart illustrating the seasonal differentiation of reported COL- associated municipal damage costs in the Western Cape 2003-2014

These findings have important implications for the management of high impact weather risk in the Western Cape. The prevailing assumption is that loss-triggering severe-weather events occur primarily in winter, with contingency planning, risk reduction measures and preparedness gearing up for the cooler months (for example see Favre et al., 2013). However, results from this study indicate a seasonal bias to more costly warm-weather events. They also signal major risk perception and practice gaps, underlining the need for year-round prevention and preparedness actions. This is particularly so given the prospect of warmer and more variable weather conditions in the future.

Table 4.6.2: Reported municipal financial losses for COL disasters 2003-2014 in the Western Cape, distributed by warmer and cooler periods

	Warmer months (Sep - Feb)			Colder months (Mar - Aug)			Total		
Local Municipality	**Total**	**Affected**	**Ave**	**Total**	**Affected**	**Ave per event**	**Total**	**Affected**	**Ave per event**
West Coast District Municipality									
Bergriver	0	0	0	18 527 679	2	9 263 840	18 527 679	2	9 263 840
Cederberg	0	0	0	51 293 615	2	25 646 807	51 293 615	2	25 646 807
Saldanha Bay	0	0	0	1 816 669	1	1 816 669	1 816 669	1	1 816 669
Matzikama	0	0	0	10 279 069	2	5 139 534	10 279 069	2	5 139 534
Swartland	0	0	0	5 919 161	2	2 959 580	5 919 161	2	2 959 580
Subtotal	**0**			**87 836 192**			**87 836 192**		
Cape Winelands District Municipality									
DMA	2 111 988	2	1 055 994	0	0		2 111 988	2	1 055 994
***Langeberg**	**16 869 521**	**3**	**5 623 174**	**6 757 473**	**3**	**2 252 491**	**23 626 994**	**6**	**3 937 832**
Breede Valley	23 942 724	2	11 971 362	0	0		23 942 724	2	11 971 362
Stellenbosch	263 589	1	263 589	0	0		263 589	1	263 589
Subtotal	**43 187 822**			**6 757 473**			**49 945 295**		
Overberg District Municipality									
**Cape Agulhas	12 086 926	2	6 043 463	7 853 640	1	7 853 640	19 940 566	3	6 646 855
Swellendam	**58 130 505**	**3**	**19 376 835**	**7 521 513**	**2**	**3 760 756**	**65 652 018**	**5**	**13 130 404**
Overstrand	4 646 639	2	2 323 319	0	0	0	4 646 639	2	2 323 319
Theewaterskloof	20 324 936	3	6 774 979	0	0	0	20 324 936	3	6 774 979
Subtotal	**95 189 006**			**15 375 152**			**110 564 158**		
Eden District Municipality									
Bitou	43 301 420	1	43 301 420	16 577 658	3	5 525 886	59 879 078	4	14 969 770
****George**	**129 578 178**	**3**	**43 192 726**	**49 127 962**	**3**	**16 375 987**	**178 706 141**	**6**	**29 784 357**
Hessequa	**116 792 768**	**5**	**23 358 554**	**61 100 292**	**3**	**20 366 764**	**177 893 059**	**8**	**22 236 632**
Kananaland	12 442 937	1	12 442 937	5 332 949	2	2 666 475	17 775 886	3	5 925 295
Knysna	**90 416 720**	**2**	**45 208 360**	**51 908 577**	**3**	**17 302 859**	**142 325 297**	**5**	**28 465 059**
Mossel Bay	57 004 151	2	28 502 075	29 518 499	2	14 759 250	86 522 650	4	21 630 662
Oudtshoorn	2 668 388	1	2 668 388	9 445 630	1	9 445 630	12 114 018	2	6 057 009
Subtotal	**452 204 562**			**223 011 567**			**675 216 129**		
Central Karoo District Municipality									
Prince Albert	0	0	0	517 383	1	517 383	517 383	1	517 383
Laignsburg	4 107 038	1	4 107 038	0	0		4 107 038	1	4 107 038
Subtotal	**4 107 038**			**517 383**			**4 624 421**		
Cape Town Metro									
Cape Town	6 456 136	1	6 456 136	0	0	0	6 456 136	1	6 456 136
Subtotal	**6 456 136**	**1**	**6 456 136**	**0**	**0**	**0**	**6 456 136**	**1**	**6 456 136**
Total	**601 144 563**			**333 497 768**			**934 642 331**		

4.7 Flash-Flood Hotspots

4.7.1 Flash-flood exposed… and vulnerable

Research findings indicate at least three flash-flood hotspots where improved warning capacities are urgently needed to protect lives and avert unnecessary evacuations under dangerous weather conditions. These include:

- Langeberg Municipality (Cape-Winelands)
- Laingsburg Municipality (Central Karoo)
- Meiringspoort, through the Swartberg Mountains (Eden)

Although flash-flood conditions escalate quickly in these three areas, the locations are not protected by weather radar, and rapidly become isolated and inaccessible. In these sites, there is also documented evidence of inadequate weather warnings, road closures, lives lost or repeated helicopter evacuations (eg helicopter rescues in Meiringspoort in 2014 and 2015).

Specifically, each site is characterised by:

- past and/or current evidence of flash-flood *exposure.*
- high *vulnerability* to loss of life due to compromised weather warnings (weather radar-blind locations), combined with prospects of rapid closure/inundation of road access routes and isolation.
- limited access to additional *capacity* due to road and air inaccessibility.
- evidence already of *realised flash-flood risks* in the form of deaths and/or life-saving land, water or air evacuation.

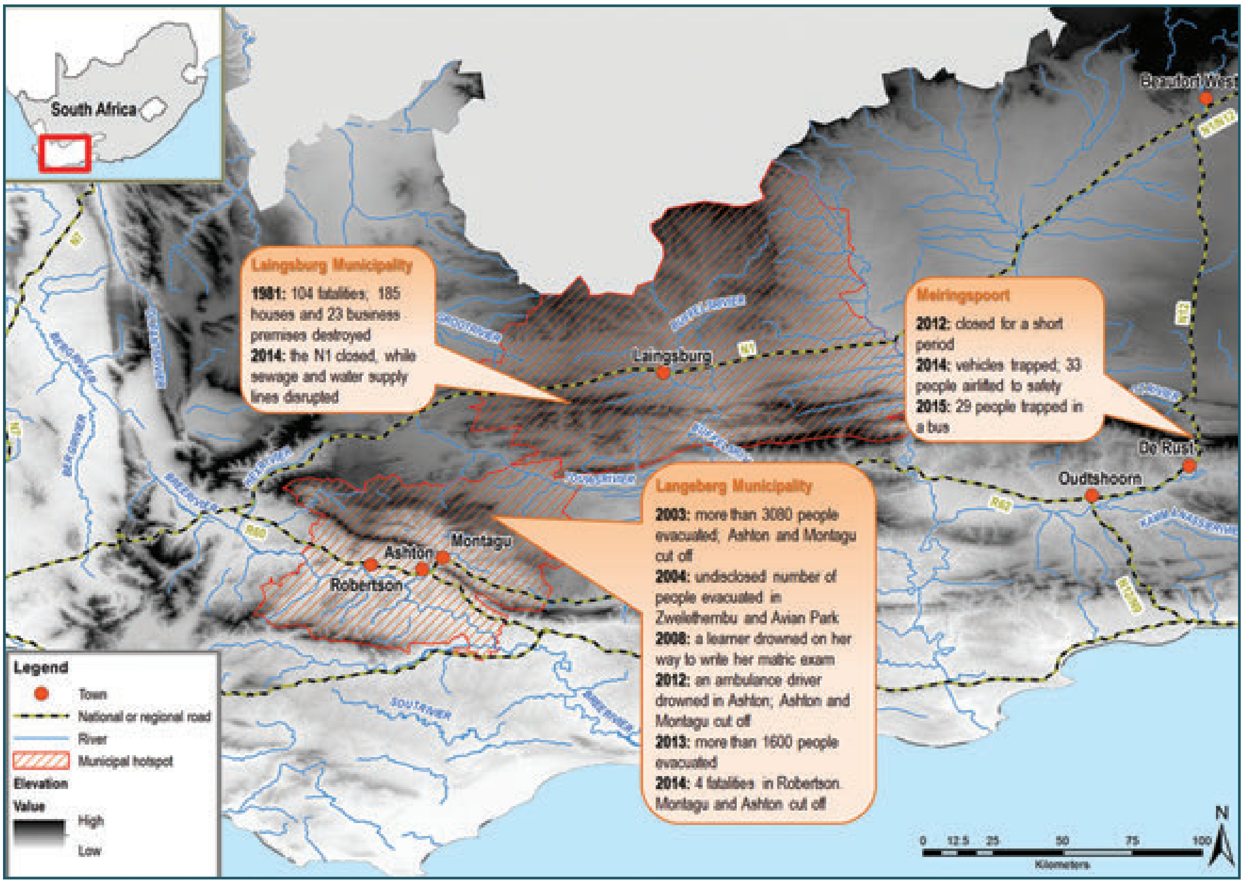


Figure 4.7.1.1: Location of priority flash-flood hotspots; Langeberg, Laingsburg and Meiringspoort

Flash-flood hotspot 1: Langeberg Municipality

Montagu has a long history of flooding, with eight severe floods recorded from before 1867 until the largest flow measured in March 2003. This was followed by a further flood disaster in 2008, and then annual events from 2011 to 2014. The town's flash flood risk is primarily due to Montagu's location. The town lies at the confluence of two major river tributaries (the Keisie and Kingna Rivers) while the elongated and lobed catchment shape increases the likelihood of flooding. Access routes, including the R60 (to Ashton) and the R62 (to Barrydale), cross both rivers close to the river channel and are frequently closed by flooding. River flows soon inundate the town's low-level bridges.

There is a history of severe flood impacts. Thirteen people died during flooding in 1981, while in 2012, an ambulance attendant died when her vehicle left the road in a flooding river, with the vehicle being swept away and trapped by fast-flowing flood waters. This incident occurred in pre-dawn darkness when visibility was very low. Floods have recurrently damaged infrastructure, including roads, bridges, electricity supplies and sewage pipes and plants and in 2003, forced the evacuation of 500 households, as well as the local primary school. In 2012, the Montagu Springs resort sustained substantial damage and was closed for repairs and reconstruction, reportedly reducing local tourism. Rock climbing-related tourism was also affected due to trail closures. The resort was damaged again in 2014.

Flash-flood hotspot 2: Laingsburg Municipality

Laingsburg's location also exposes it to flash-flood threats. The Buffels, Wilgenhout and Baviaans rivers converge as they flow into the town. Although these are ephemeral drainage channels, the thin soils, the large catchment above the town and river confluence increase the chance of infrequent but endangering floods. This convergence occurs at a gap in a ridge, which also creates a natural choke point. The January 1981 'Laingsburg Flood' was a wrenching disaster for the Karoo community in which 104 people died, while 185 houses and 23 business premises were destroyed.

The January 2014 flood disaster was also associated with severe flooding, although not of comparable magnitude. The N1 was closed, with sewerage and water supply lines disrupted between sections of the town when fast-flowing waters flooding severed sections of pipeline crossing the Buffels River. Telecommunication links with surrounding areas became intermittent or failed. The poor weather precluded helicopter reconnaissance and interventions, which could only occur once the weather had cleared substantially.

Flash-flood hotspot 3: Meiringspoort

Meiringspoort is a crucial link and major transport route between the Central Karoo and the Klein Karoo. The pass enables travellers on the N12 national road to travel through the Swartberg Mountains via a 25 km route that crosses the Groot River 25 times, over low-level bridges. Although the road primarily runs adjacent to the riverbed, it is also situated in the riverbed in several places. The flood record dates back to 1859, with more than nine severe flood events recorded between 1859 and 2001 (Ross and Murray, 2001). The road was severely damaged in several floods through to the early 1990's.

Although the road is now constructed to high standards and able to resist flood damage, during intense convective storms over the Karoo, there is a high likelihood of road-users becoming trapped in the pass. The route was closed during the 2012 floods, while 33 were people airlifted to safety in January 2014. Vehicles and a bus were trapped again in March 2015, when 29 people required rescuing.

There is an additional concern when the Buffels River floods in Laingsburg – which results in N1 traffic being diverted through Meiringspoort. Given the pass's exposed and vulnerable location, this practice could transfer and even increase flash-flood risks for road users. This is because the intense weather systems that trigger flooding in Laingsburg are also likely to cause flash-flooding in Meiringspoort.

An urgent need for targeted warnings

- The recurrence of flash-floods in these areas underscores the urgency for impact-based forecasting in the Western Cape. It also foregrounds the need for integrated early warning systems (EWS) at hotspots that combine SAWS warnings, an enhanced version of the SAFFG, radars (where feasible), automatic weather stations, real-time river gauges, cameras, community EWS, and in specific critical basins, complex hydrological modelling.

- This would enable specific warning information on intense upstream rainfall to be communicated to exposed groups downstream so they can take action. For example, in the event of heavy rainfall in the Groot River catchment, Meiringspoort could be closed promptly and the pass cleared of both traffic and sightseers before the river flooded. Similar warnings are needed in the Buffels River catchment above Laingsburg and its surrounds, as well as in the Langeberg District Municipality, especially for Montagu and the Cogmanskloof pass

- Evacuations from Meiringspoort suggest that more could be done to reach members of the public and tourists regarding flooding in such high-risk locations. Avenues for disseminating information could include radio, television and social media, as well as the distribution of SMS. warnings to accommodation providers and Tourist Bureaus. During the 2009-2011 drought, for example, the Eden District Municipality negotiated with Vodacom to send bulk SMS messages to residents providing them with information updates.

Box 4.7.1.1: Need for targeted warnings

4.8 Flood risk management weakly integrated into IDPs

Despite almost annual flood damage in the province, findings indicate that flood risk management is poorly reflected in municipal planning as well as infrastructural developments and maintenance. Despite recurrent losses, and as illustrated in Part II, the persistence of developmental flood risk drivers, there is an entrenched perception that endangering floods are occasional 'rare' events, delinked from development and are the sole responsibility of "disaster management".

Study results suggest that the misperception that HIWEs are isolated and unusual phenomena reinforces a reactive approach to flood risk management. This also discourages municipalities (and other spheres of government) from recognising and proactively addressing the developmental flood risk drivers through risk-aware planning, environmental interventions, construction, and in the maintenance and upgrading of infrastructure. In addition, the prospect of changing rainfall intensities and extremes, along with landscape changes in many catchments, has specific implications for the design, maintenance and upgrading of road and storm-water infrastructure, including bridges and culverts.

According to the acting head of the Roads Department's Regional Roads Management Directorate, much of the Province's road and bridge network was built in the 1950s, and complies with out-dated design-criteria that are already inadequate for current conditions. Similarly, several of those interviewed during field work noted that much of the province's drainage infrastructure is out-dated, inadequately maintained or simply not designed to meet prevailing demands.

Such challenges contribute to the generation of the large, recurrent losses reported by provincial and municipal authorities presented in this report. Moreover, the prospect of more intense or frequent storms foregrounds the urgency for greater emphasis on prospective risk reduction, including more resources for upgrading current structures, as well as risk-aware design of new infrastructure. Changing climate and environmental conditions also underline the need for critical research into design parameters so these are 'fit for purpose' given future rainfall exposures.

4.8.1 Problems with repair and financial disbursement processes

Research findings suggest that the introduction of the PSP verification process in 2011 may have had the unintended consequence of delaying access to emergency and recovery grants. Field research indicates that the lengthy PSP-linked damage verification processes pose real challenges for municipalities under local pressure to restore essential services. For instance, some municipalities reportedly forfeited their access to recovery funding by making interim repairs to essential municipal infrastructure prior to the PSP assessment – causing them to be ineligible for subsequent recovery funding.

Study findings also suggest that the criteria for recovery funding vary between disasters; for instance, infrastructure damage funded following one event may not necessarily be considered for another. In addition, results suggest that the lengthy damage verification processes involved in accessing disaster-related funding may be “out of synch” with the Western Cape’s risk profile, characterised by frequent high impact weather exposures.

This is a particular challenge in smaller under-resourced local authorities, which do not have or allocate a budget to make interim repairs. In Laingsburg, for instance, permanent repairs to water supply infrastructure damaged in January 2014 remained outstanding in September 2015, with reported implications for supply and quality. Similarly, in Kannaland, the first tranche of funding requested and approved following the 2012 floods was only released in May 2014. And, in Hessequa, funding for damage incurred in June 2011 only became available in 2013, with the municipality just commencing repairs in September 2014. Hessequa’s recurrent exposure to flooding meant that between June 2011 and September 2015, the municipality had sustained additional losses associated with the 2012, 2013 and 2014 COLs.

4.8.2 Weak integration of flood risk considerations into development funding

The persisting view that flood losses are ‘disasters’ (delinked from development) also encourages a continued dependence on disaster funding rather than planned investment financing streams. Research findings suggest that even repeatedly flood affected municipalities and provincial departments seldom incorporate flood risk reduction into integrated development plans (IDPs) – or seek conditional grants to bolster resilience to climate risks.

This continuing dependence on disaster grants rather than other development funding instruments also erodes a sense of local responsibility for risk reduction, including the need to ‘build back better’. These obstacles undermine aspirations to strengthen local and provincial resilience to disasters, and drive an avoidable drain on municipal (as well as provincial and national) resources.

4.9 Conclusions

This section combined findings from the 2011-2014 disaster study with those from previous reports between 2003 and 2008. The results underline the high frequency of high impact weather events for many municipalities and their cumulative costs. They also foreground the urgency to shift prevailing perceptions of ‘floods’ as infrequent disasters.

Findings demonstrate that flood risk management is a central development priority for many municipalities that should be purposefully incorporated into development plans and funding models. Results also underscore the importance of prospective risk reduction, including more resources for upgrading current infrastructure, as well as risk-aware design of new developments.. This more deliberate focus on resilience building to recurrent weather shocks is fully consistent with both the Sendai Framework on Disaster Risk Reduction and Agenda 2030 for Sustainable Development.

PART V: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Impact summary

From 2003-2014, there were twelve disasters associated with 14 identifiable COL weather systems in the Western Cape. This signals that high impact weather conditions and damaging floods are not 'rare events'. They occur almost annually, with extensive and recurrent financial losses. From 2003-2014, R 4.9 billion in flood-related damage was reported by government departments and municipalities. Of this, R 2.3 billion was attributed to agricultural costs (refer to Table 1 following the Executive Summary).

COL associated damage varied seasonally, with average municipal costs in warmer months more than double those in cooler periods. Average September-February disaster costs were estimated at R 120.23 million per event compared with R 47.6 million for individual disaster events from March-August.

From 2003-2014, Hessequa Local Municipality in Eden reported damage for eight of the 12 events and cumulative losses of R 178 million. George reported R 178 million in damage for six events and Knysna recorded R 142 million for five disasters.

Social impacts were wide-ranging but poorly documented, and included deaths, evacuations and temporary isolation. 23 lives were reportedly lost, with more than 30,800 people affected or evacuated. Outside of the Cape Town Metro, the Langeberg Municipality reported the largest number of residents affected or evacuated (6,400). Research findings indicate that inland residents are at increased flash-flood risk, especially in the Langeberg and Laingsburg municipalities. Meiringspoort also represents an identifiable flash-flood hot-spot.

Critical facilities and essential services are at-risk. In the 2012 and 2013 COL-induced disasters alone, losses included an ambulance attendant on duty and a hospital evacuation, while wind/rain damage were reported for 23 schools within the CoCT.

From 2011, the national introduction of more rigorous infrastructural damage assessment procedures for recovery reconstruction has reduced the range, specificity and accuracy of reported losses. This has weakened the quality of municipal and provincial disaster risk surveillance, especially for non-infrastructural and recurrent impacts.

5.1.2 Changes in COL-induced rainfall

The COL weather systems were associated with heavy rainfall as well as other potentially damaging conditions, including snow and hail. There is an identifiable recent increase in the frequency of extreme daily rainfall associated with COL weather systems. This is also associated with record flood peaks in several rivers during the past decade. COLs occurring in the warmer months have potential to be particularly damaging.

5.1.3 Developmental conditions continue to drive flood risk

Despite the almost annual occurrence of severe flooding in the Western Cape, a widely held misperception that 'floods' are disasters has discouraged the incorporation of flood risk management into IDPs and funding models.

There are also developmentally-driven flood risk factors that continue to escalate the likelihood of endangering floods. These include shortcomings in integrated catchment and river management that increase flood exposure, especially the build-up of sediment of riverbeds around bridges and culverts. They also include inadequate removal of alien vegetation and debris from rivers and floodplains.

Incremental changes associated with development and agricultural practices have also increased flood exposure and vulnerability by altering catchment conditions. For instance, residential, commercial and infrastructural expansion and densification in flood-prone areas have not only placed homes, facilities and infrastructure in harm's way, but also impeded the flow of natural watercourses and overland run-off during heavy rain.

5.1.4 High impact weather responders and forecasters are under pressure

The Western Cape Province benefits from high levels of committed, effective and skilled disaster (risk) management and emergency services practitioners. However, while a history of cooperation in large-scale disasters has built strong informal relations across services, it may have hindered the formalisation of roles and responsibilities.

Stake-holder feedback and spatial analysis of social impacts indicate that current flash-flood forecasting and communication approaches were too broad-brush to give advance warning to specific areas under threat or to accurately inform action. This applied especially to municipalities in the Karoo and mountainous catchments, where the Province's complex terrain makes it difficult to provide flood warnings with the level of detail required.

Constrained weather radar coverage in the province also severely hampers early warning of high impact weather conditions and prevents effective implementation of the National Flash Flood Guidance System, particularly in the Western Cape. This especially applies to inland municipalities where there are tight time-frames for evacuation and life-saving response, but vast distances to cover and major resource constraints.

High impact weather warning capacity could be more effective however, if social media were better harnessed. This is a powerful medium in disaster responses, with potential to be a formidable resource for informed decision-making and disseminating disaster-related information.

5.2 Recommendations

5.2.1 Improve COL and flood risk understanding as well as on-going surveillance

It is recommended that the WCDMC consult with appropriate national, provincial and municipal authorities to:

- Assess and address sedimentation levels in flood-prone areas on an ongoing basis. This includes the impact of sediment accumulation on flow capacity for bridges and culverts carrying regional and district roads across flood-prone river channels.
- Engage with the DWS to evaluate progress of rectification processes to reduce safety risks at various large and medium dams. This particularly applies to the Karoo where sediment loading and retention are high. Where progress is slow or delayed, increased downstream flood exposure must be identified and communicated to the affected parties.
- Identify critical facilities and infrastructure exposed to flooding, as well as areas at risk of isolation during flood events, such as Hout Bay. Contingency plans need to be established to assist in strengthening and streamlining future responses to flooding in these localities.
- Specifically identify hospitals and health facilities that are potentially flood-exposed. Provincial EMS should consider and investigate the scope for making flood-risk assessment a requirement for hospitals

- Revisit and harmonise current approaches to disaster risk assessment as well as post-disaster loss estimation in the province, to improve the range, accuracy and spatial specificity of losses. This information should proactively inform and update purposive resilience programming within integrated development planning processes.

5.2.2 Strengthen institutional capacity to manage COL-induced flood risks

It is recommended that the WCDMC consult with appropriate national, provincial and municipal authorities to:

- Reinforce the need for prospective flood risk management. Flood-risk should be explicitly incorporated into planning, infrastructural developments and maintenance regimes. Resilience planning and funding mechanisms should be prioritised for high-risk areas.
- Deepen institutional memory related to HIWEs and their effects within district and local disaster management authorities to build more robust disaster management capacity.
- Urgently address gaps in the provisioning of emergency response vehicles, particularly in flash-flood-prone and rapidly isolated areas such Langeberg Municipality. Emergency response capabilities in these areas should also be enhanced.
- Explore the role of Neighbourhood Watches and similar institutions as local resources. DRM and response planning processes should identify local capacity and engage proactively to strengthen planning and response (especially to increase responsiveness in the case of intense, rapid onset and fast-paced weather events).
- Assist in clarifying the roles and responsibilities in the case of emergencies facing private health facilities. While EMS is mandated and best placed to manage responses concerning health facilities, the respective roles, and chains of command should be identified and planned for.

5.2.3 Invest in flood resilience building to protect development gains

It is recommended that the WCDMC consult with appropriate national, provincial and municipal authorities as well as the private sector to:

- Ensure that new infrastructure is designed to withstand current risk conditions, as well as possible future upward trends in weather extremes and climate variability. (Design parameters for bridges, culverts and other infrastructure should be critically re-evaluated to ensure that they are appropriate for current and future conditions).
- Ensure that flood prevention and preparedness, including cleaning of drains are implemented year-round (not just before winter rainy season).
- Increase oversight of alien clearing processes, to ensure that cleared vegetation is removed properly from the riparian zone, as specified by the DWS.
- Support DoA efforts to:
    - enable farmers to reduce sediment by encouraging and deepening improved farming and land care practices.
    - advance river protection efforts as well as holistic system-level river management processes.

5.2.4 Improve disaster preparedness and capacities to ‘Build Back Better’

It is recommended that the WCDMC consult with SAWS to:

- Collaboratively and urgently address gaps in weather radar coverage, especially for the Province’s inland areas. This includes new and additional radars so the Flash Flood Guidance System can function protectively and to enable impact-based forecasting.

- Explore mechanisms to introduce integrated flash flood early warning systems at hotspots that combine SAWS warnings, an enhanced version of the SAFFG, radars (where feasible), automatic weather stations, real-time river gauges, cameras, community EWS, and in specific critical basins, complex hydrological modelling.
- Provide more spatially specific impact-based forecasts to provide finer-scale information that captures meteorological variability between areas, and improves forecast information at the local level, to fine-tune pre-emptive responses.

It is recommended that the WCDMC consult appropriate national, provincial and municipal authorities, especially local disaster management officials to:

- Explore risk communication mechanisms that more effectively target populations in areas exposed to flooding, especially those in informal settlements. In Eden District Municipality, this should include communities living along the Keurbooms River and tourists and others likely to travel through flooding hotspots such as Meiringspoort.
- Explore new mechanisms for disseminating warnings and other information to the public and tourists regarding flash flooding in known hotspots such as Meiringspoort. (These could include alerting tourist bureaus and information centres and key accommodation providers, as well as broadcasts on local and provincial radio stations).
- Improve the effectiveness of social media, including:
    - incorporating social media systematically into awareness and flood risk communication strategies.
    - Establishing a social media platform to provide information and engage the public.
    - Assisting municipal disaster management officials to develop social media communication strategies and capacity.
    - Complementing rather than duplicating local-level engagement by disaster management and municipal authorities, so that messaging is consistent and unified.
    - Optimising opportunities presented by influential users to raise the profile and reach of information.
    - Expediting post-disaster recovery and reconstruction funding processes to support risk reduction imperatives, particularly in less-resourced local municipalities.
    - Developing guidelines to 'build back better' as urged by the Sendai Framework for Disaster Risk Reduction. (There needs to be greater emphasis on risk reduction in the repair of damaged infrastructure to strengthen its resilience for flood and other high impact weather exposures).

It is recommended that the WCDMC consult with Provincial EMS in connection with potentially flood-exposed medical facilities to:

- Sensitise senior hospital managers to environmental and climate conditions that stand to create unexpected emergencies.
- Advise managers of both private and public health care facilities in areas potentially exposed to flooding, to undertake risk assessments to inform appropriate risk reduction efforts and planning.
- Develop evacuation protocols that establish criteria for proactive action and decision-making. These should be based on a strengthened relationship between disaster management authorities and provincial EMS.
- Plan and prepare for communication and electricity failures/interruptions.

5.3 Recommendations to the DoA

As stressed in previous post-disaster studies within the Western Cape, the agricultural sector sustains unacceptably high recurrent costs due to exposures to high impact weather, flooding and drought. This study shows that 56% of total costs reported by government entities from 2011-2014 were attributed to agriculture.

It is urged that the DoA urgently strengthen its institutional capacity for agricultural risk management. Specifically, the DoA should review the recommendations outlined in the draft Department of Agriculture, Forestry and Fisheries (DAFF)-commissioned Feasibility study on the decentralisation and institutional capacity development for DRM within DAFF (DAFF, 2014) and actively consider the following:

- “Establish a dedicated DRM unit for agriculture in each province. The unit functions within the respective provincial department of agriculture and becomes part of its hierarchy, similar to the DRM within DAFF. In such a case the unit must be correctly located in the structure so that it has the mandate and ability to coordinate DRM activities across all sectors. These units must also be staffed and funded to achieve their objectives” (DAFF, 2014:14).
- “Funding should be made available for DRR and disaster response activities as per the DMA and NDMF. Specifically 1.2% of each sub department’s budget as required by the NDMF (see page 104) should go to contingency fund for disaster response activities at both levels. This percentage allocation would ensure alignment with the Disaster Management Act and NDMF. For operational budgets it is advised that provincial and national departments along with Provincial and National Treasuries take responsibility for funding provincial units” (DAFF, 2014:8).
- “DAFF should urge the NDMC to develop and put guidelines in place as per the NDMF to eliminate red tape for disaster relief funding within the sector. Provincial units and affected groups should also be made aware of the correct procedures to follow to access funding from Department of Cooperative Governance (DCoG) -NDMC” (DAFF, 2014:8).

Appendix 1: Reference list

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