Methodology for Linking Extreme Flood EventS AND the Cost of Damage to Water Security Infrastructure

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ABSTRACT: Extreme flood events feature amongst the most destructive and dangerous natural hazards in many countries around the world. Damage from the destructive power of extreme flood events on key infrastructure is aggravated by an increasing vulnerability of growing populations in the river flood plains. The risk of damage to infrastructure from extreme rainfall and flood events is greater in drier areas than in areas that usually receive high rainfall. This research paper examines both the scientific and financial approaches for linking extreme flood events and the cost of damage to water security infrastructure in the Upper Vaal Water Management Area (WMA), South Africa. The key parameters driving the relationship between extreme flood events and the cost of damage will be identified. Theoretical and simulated extreme flood events from three separate sub-catchments in the Upper Vaal WMA will be used to determine the predicted cost of damage to water security infrastructure in the catchments. The outputs will be compared with the actual cost of damage to water security infrastructure as a result of recorded extreme flood events. Reliability of the results or findings will be achieved by comparing outputs from selected catchments. The outcomes of the analysis will be used to determine the risk factor which should be taken into account when designing water security infrastructure. In addition to the risk factor, the researcher will develop a process framework for linking extreme flood events and the cost of damage to water security infrastructure.

1 BACKGROUND

This paper emanates from doctoral research which is currently being conducted. The objective of this paper is to present research work which will be conducted to develop a process framework for linking an extreme flood event to the cost of damage to water security infrastructure. The research will examine parameters driving the relationship between extreme flood event and the cost of damage to water security infrastructure. For the purpose of this research water security infrastructure refers to dams, levees, and water control structures (e.g. stormwater networks). The extremeness of a flood event will be defined in terms of the basin size-discharge relationship and the probability of high water levels and their duration (Papp, 2000).

2 PROBLEM STATEMENT

There is currently no process framework linking extreme flood events to the cost of damage to water security infrastructure. Most of the publications by economists, financiers, investors and engineers, either focus on the economic side of infrastructure investment or the scientific and engineering side of infrastructure. There is a grey area in terms of integrating the economic, scientific and engineering sides of the infrastructure investment and management. The lack of the process framework to link these fields was one of the short-comings the researcher and other colleagues experienced during their tenure at the National Treasury of South Africa between 2010 and 2013. This view was also confirmed by infrastructure investment research work conducted by renowned South African economists (Calitz, 2011) and engineering scientist (Smithers, 2012).

Extreme flood events feature amongst the most destructive and dangerous natural hazards in many countries around the world (Petersen, 2009). Damage from the destructive power of extreme flood events is aggravated by an increasing vulnerability of growing populations in the river flood plains (Petersen, 2009). Extreme flood events cause extensive damage to infrastructure related to water, energy, roads, transport, and telecommunications and property. The damage can extend to the loss of human life. The risk of damage to infrastructure from extreme rainfall and flood events is greater in drier areas than areas that usually receive high rainfall (World Bank, 2001a)

3 METHODOLOGY

Both qualitative and quantitative research methods will be used in this research. The qualitative research method will be used to gain an improved theoretical understanding of extreme flood events and the cost of damage to water security infrastructure in South Africa and the rest of the world. The quantitative research method will be used to analyse hydro-meteorological and cost related data assembled from the Upper Vaal Water Management Area. The research will propose a four-pillar holistic model for determining the criteria and process framework (refer to Figure 1). Two pillars of the criteria and process framework that will not be investigated in detail are the institutional and legislative framework. The financial and technical pillars are the two main pillars of the criteria and the process framework that will be investigated thoroughly.

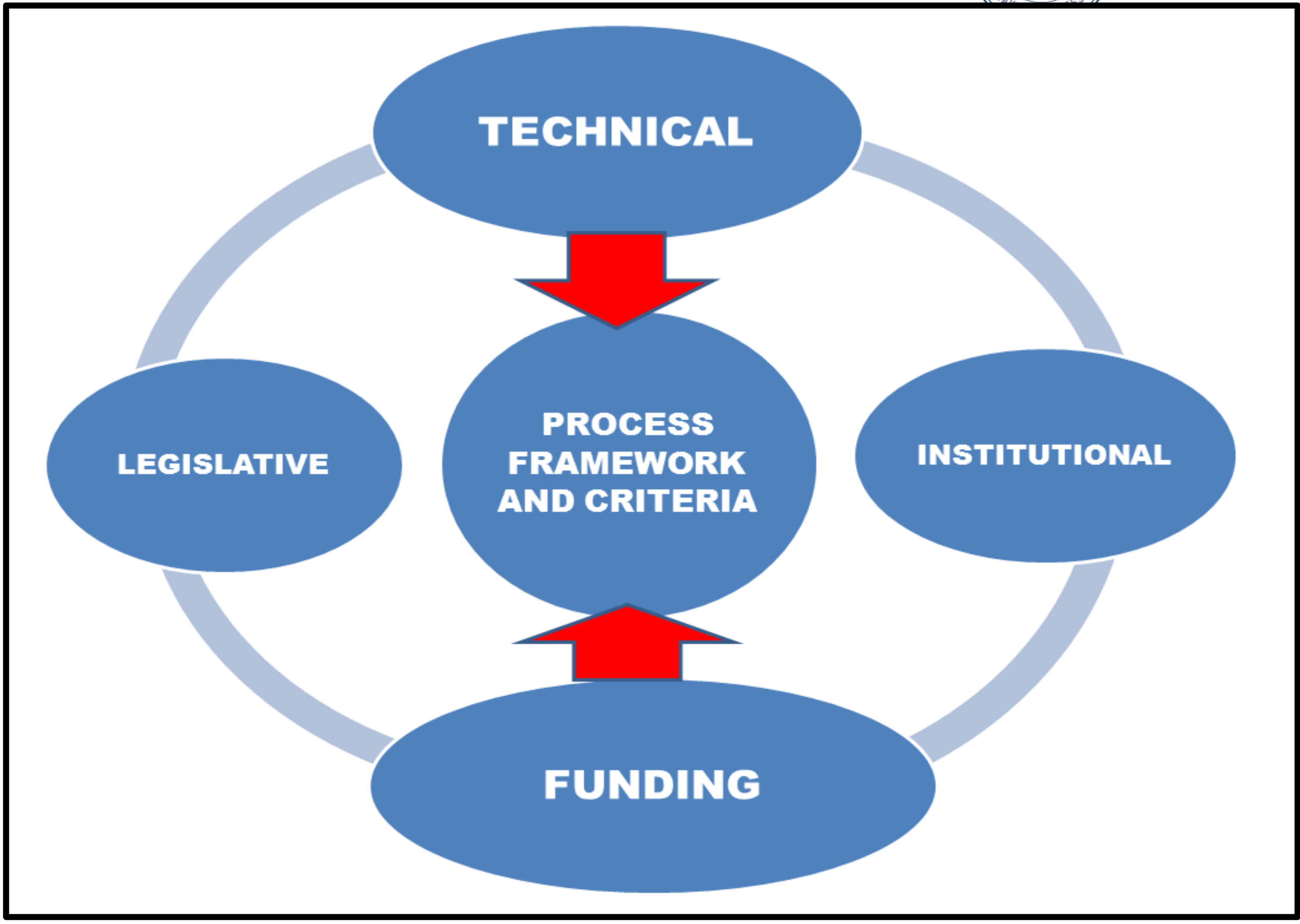

Figure 1 Pillars of the process framework

3.1 Technical pillar

The Upper Vaal Water Management Area has a number of quaternary catchments as shown in the basemap (Figure 2). The quaternary catchments to be used in the study will be selected based on the availability of rainfall data (refer to Figure 3 for rainfall distribution, population distribution (Figure 4)), flow gauging stations and dams towns or urban centres with a large network of water control structures, land cover (Figure 5), recorded extreme flood events and availability of data on the cost of damage to water security infrastructure.

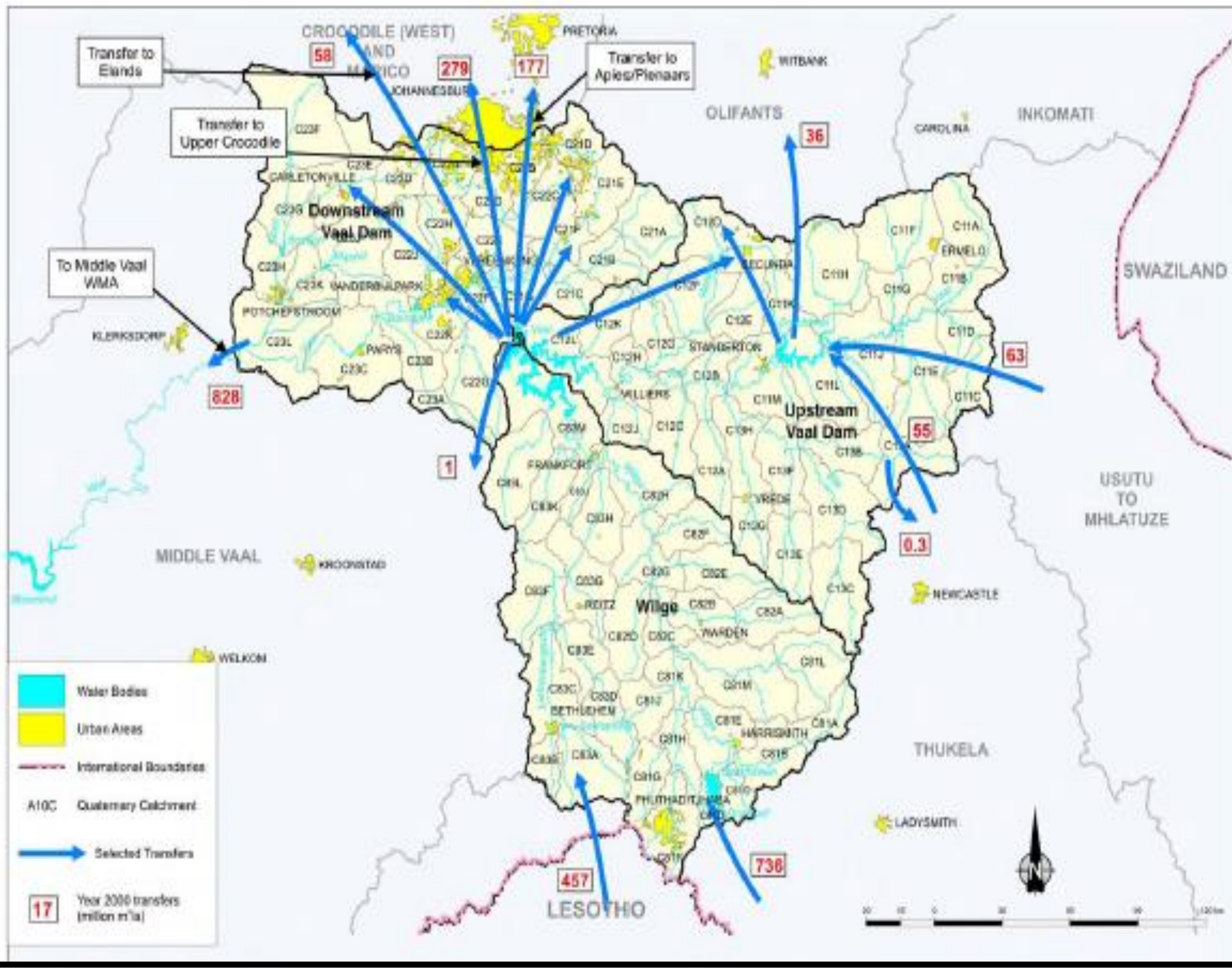

Figure 2 : Basemap (Source: (Department of Water Affairs and Forestry, 2003))

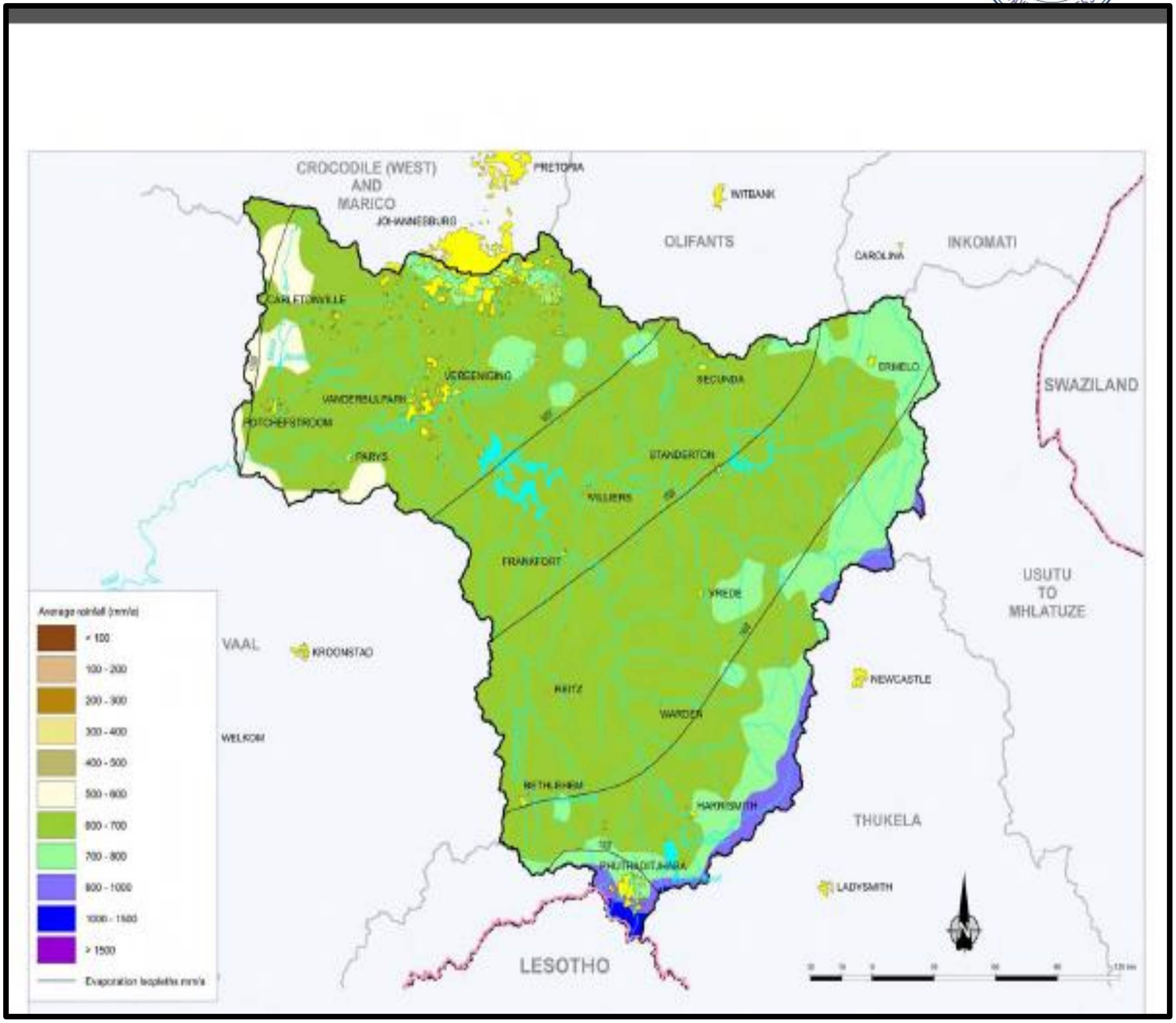

Figure 3 : Rainfall Map (Source: (Department of Water Affairs and Forestry, 2003))

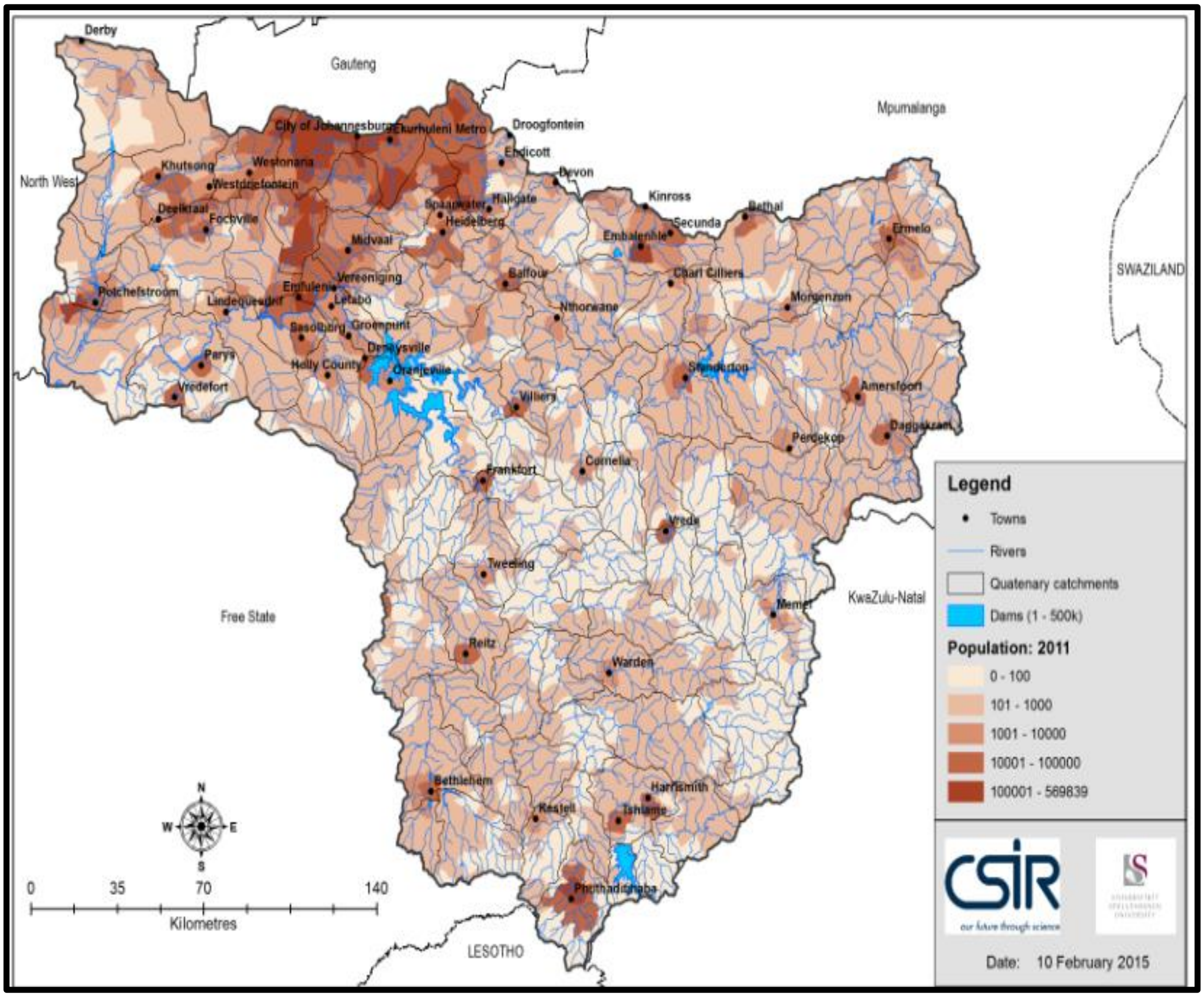

Figure 4 : Population distribution (Source: Council for Scientific and Industrial Research (2015))

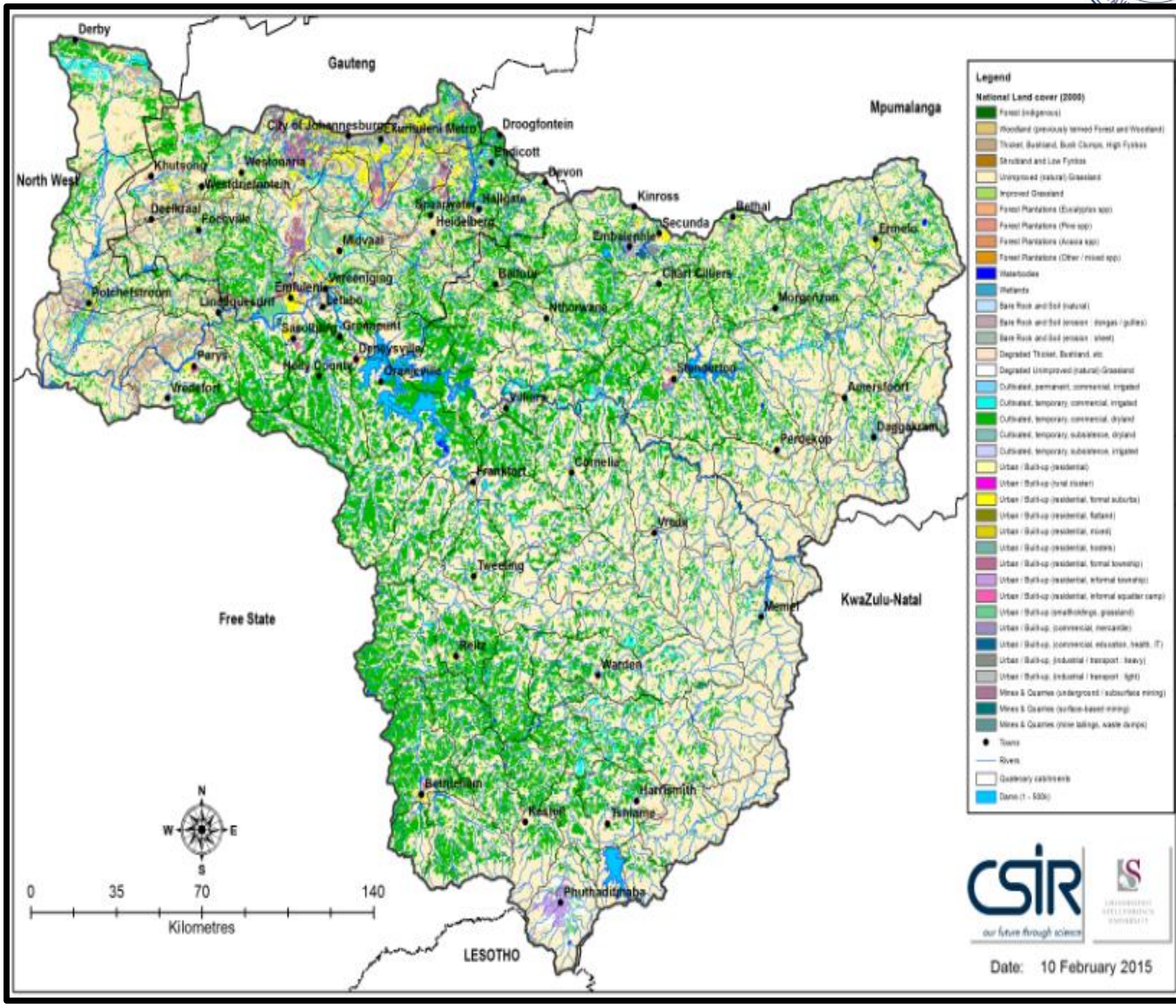

Figure 5 : Land cover map (Source: Council for Scientific and Industrial Research (2015))

The measured data on extreme flood events and cost of damage to water security infrastructure will be obtained from the government and private institutions operating in the Upper Vaal Water Management Area. This data will be used to select appropriate quaternary catchments. A total of three quaternary catchments will be selected. Analysis of parameters driving the relationship between extreme flood events and the cost of damage to water security infrastructure will be conducted per catchment. The analysis of the parameters in the three catchments will be compared to establish any consistencies or variations.

3.2 Financial pillar

The relationship between the estimated cost of damage as a result of an extreme flood event will be determined using the approach developed by (Olsen et.al, 2013) who investigated and compared three commonly used methods for calculating Estimated Annual Damage (EAD) based on the damage-return period simulations. Based on the analysis per catchment and comparative analysis in all the catchments, risk factors will be determined. Sensitivity analysis of the risk factor will be determined using the outcomes from each of the quaternary catchment. The outcomes of the abovementioned analysis will assist in drawing conclusions and recommendations on the key parameters driving the relationship between extreme events and water security infrastructure.

Furthermore, the research will give direction on how the risk factor should be taken into account when designing water control structures to minimize negative impact.

4 DATA COLLECTION AND ANALYSIS

Data collection processes started in January 2015 and it is scheduled for completion on October/November 2015. The assembled data will be analysed using statistical methods to check its integrity and reliability.

5 CONCLUSIONS

It is envisaged that the outcomes of this research will benefit planners and developers, hydrologists, road infrastructure planners, local and national authorities, town and city managers, risk managers, insurance companies and infrastructure investors.

6 REFERENCES

Calitz, J.P., 2011. Development and Assessment of a Refined Probabilistic Rational Method for Design Flood Estimation in South Africa. Unpublished Masters Dissertation Degree. School of Bioresources Engineering and Environmental Hydrology. University of KwaZulu-Natal. 1-2.

Council for Scientific and Industrial Research (CSIR). 2015. Population Distribution and Land Cover Maps. 2015.

Department of Water Affairs and Forestry. 2003. Upper Vaal Water Management Area : Overview of Water Resources Availability and Utilization. Report No. WMA 08/000/00/0203.
http://web.mit.edu/urbanupgrading/upgrading/caseexamples/ overview-africa/alexandra-township.html [Geo-2-341].

Olsen, A.S., Zhou, Q., Linde, J.J., Ambierg-Nielsen, K., .2013. Estimating Damage Costs of Urban Pluvial Flooding as a Means of Improving Climate Change Adaptation Investments. P95-96. International Conference on Flood Resilience: Experiences in Asia and Europe, 5-7 September 2013 Exeter, United Kingdom. 95-96.

Papp, F., 2000. Extremeness of Extreme Floods. Extraordinary Floods – Proceedings held at Reykjavik. Iceland. Publication No. 271.2002.

Petersen, G., .2009. Managing Extreme Flood Events. Analysing, Forecasting, Warning, Protecting, and Informing – Case Studies from the Risk Management for Extreme Flood Events (REMAX) Projects. 9-10.

Smithers, J.C., .2012. Methods for Design Flood Estimation in South Africa. ISSN 1816-7950 (On-line) = Water SA Vol. 38 No. 4.

World Bank. Upgrading Urban Communities, Version 2001. 2001a. Spotlight on Alexandra, South Africa. Massachusetts Institute of Technology.