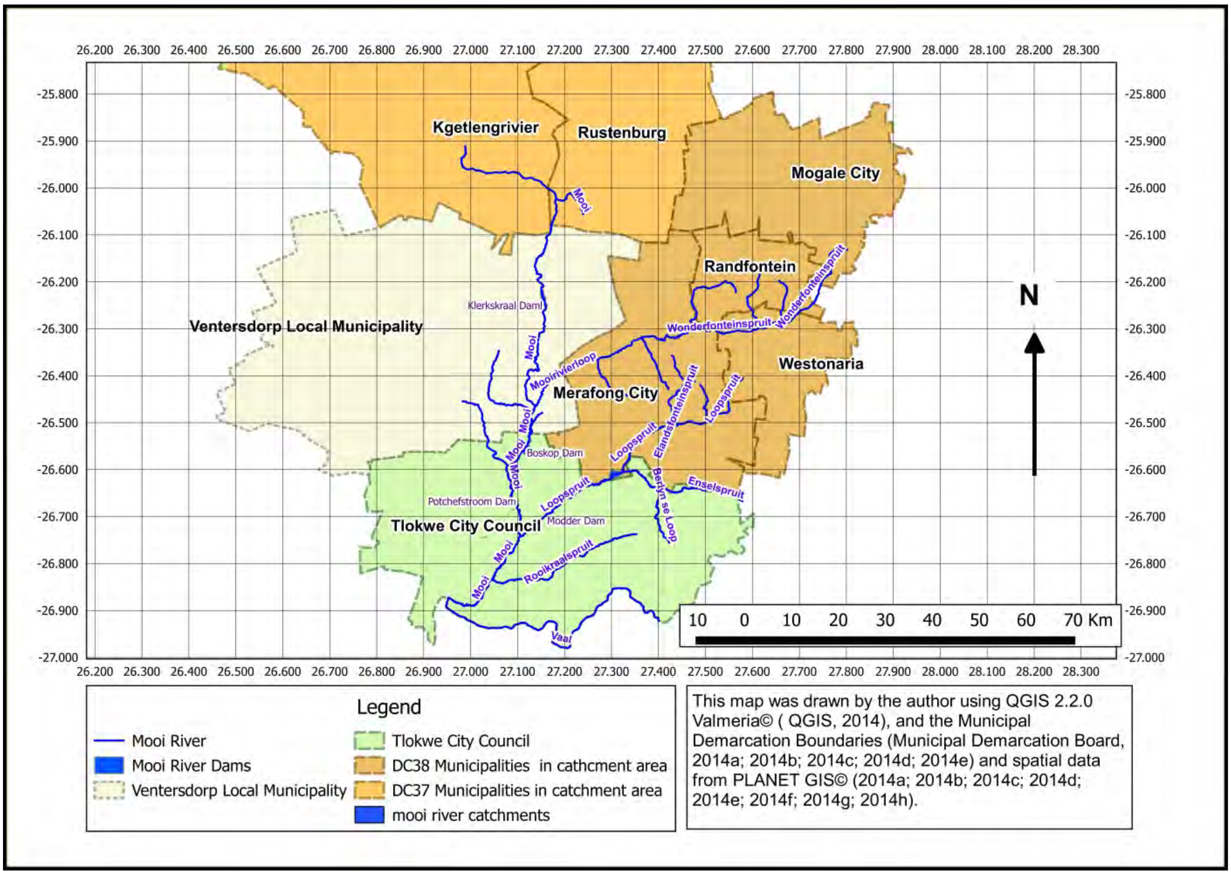
Chapter 1: Orientation and Problem Statement

1.1 Introduction

The Tlokwe Local Municipality, situated in the North West Province, South Africa is responsible for the management of potential disasters (Section 54 of Act 57 of 2002) and consequences thereof, and realizing its Constitutional (Act 108 of 1996) and legislative obligations within its municipal boundaries. The Disaster Management Act 57 of 2002 and Government Municipal Systems Act 32 of 2000, for example, require both reactive interventions, and proactive interventions that can mitigate the impact of possible hazards. When considering the above, the Tlokwe City Council Local Municipality (Tlokwe Local Municipality) is both obliged and responsible for avoiding, reducing and effectively managing the consequences of potential disaster that may arise. The problem the local municipality encounters is that its major source for domestic water is the Mooi River (Van Eeden *et al*., 2009a:195), of which the catchment extends over two provinces and a number of Local municipalities (See Map 1).



Map 1 The municipalities' and districts outside the Tlokwe City Council through which the Mooi River flows

Activities in the catchment, both upstream and beyond the borders of the local municipality, which include active and suspended mining (Van Eeden, *et al*., 2009b; Masondo & Evans, 2011; Hanlon, 2010: Online), industrial and agricultural activities as well as urbanization, are the potential source of hazards that could affect the Tlokwe Local Municipality (See: Appendix A.1 and A.2). These hazards together with other natural and anthropogenic hazards, including both point and non-point sources of pollutants (Heath *et al*., 2009:11) have the potential to result in short-, medium- and long-term disasters. The Tlokwe Local Municipality needs to and is obliged to effectively manage these potential shorts-, medium- and long-term risk of disasters within the municipal catchment area that can result from hazards that arise from within and beyond its catchment area. Although, many of the impacts on the catchment arise beyond the boundaries and the control of the municipality, this does not relieve the municipality from the responsibility to develop tools to manage the risks. Therefore, in this study the above complex real-world systems problem is discussed, and an attempt to provide a possible solution for the effective management of the risk of disaster by the Tlokwe Local Municipality, through predominantly qualitative research methodologies and application of systems theory, including modelling, is considered (O'Brien & Marakas, 2006:339,400; Daellenbach, 1995:50; Narayanan & Nath, 1993: 63).

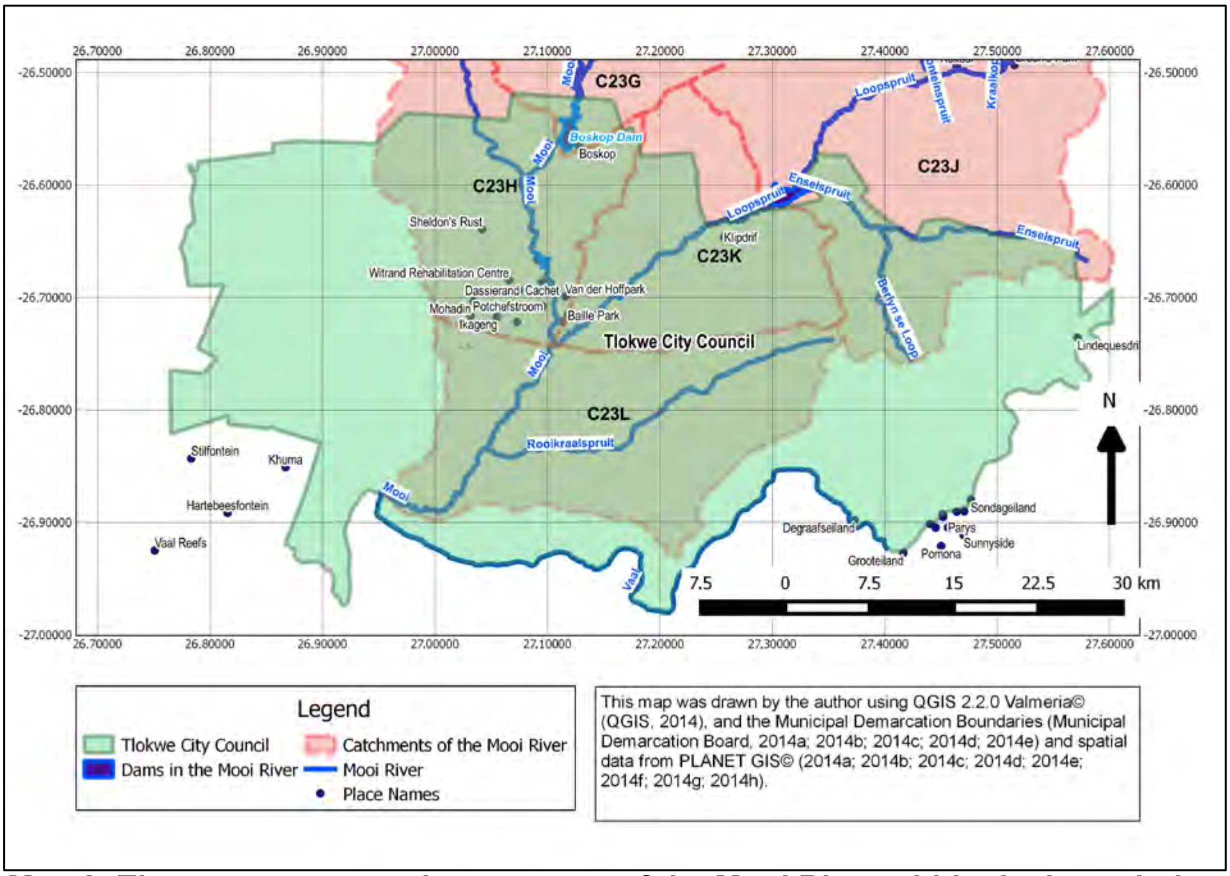
In the first section of this chapter a discussion referring to recent literature and research highlighting, the potential of certain activities to result in hazards that could impact on the quality and quantity of water in the catchment area of the Mooi River, and that could result in potential disasters, are provided. This is followed by a concise discussion on the use of Information and Communication Technology (ICT) as a potential tool in the management of disasters and the application of a GIS as potential tool to assist in disaster risk management and the management of disaster. Contextualisation and defining of the general terms and concepts as used in the study then follow. This is to provide greater insight into crucial disaster management terminology. Concepts that require in-depth discussions are discussed separately in the appropriate chapters. The research problem is then defined, formulated and demarcated. The research objectives for the study based on the problem are formulated. Key research questions arising from the research objectives are identified and formulated as research goals, which are addressed in the study. The methodologies used to address the research objectives and goals are then concisely outlined. These are followed by a brief discussion of the data accessing, processing and analysis methodologies used.

The discussion and orientation are provided in the following paragraph.

1.2 Discussion and Orientation

Recent reports (DWAF, 2009; Manders *et al.*, 2009; Coetzee, *et al*., 2009:Online; Hobs and Cobbings, 2007a:Online; Hobbs and Cobbing, 2007b:Online; Nengovhela, *et al.*, 2007:Online; NNR, 2007; Coetzee *et al*, 2006; Krige, 2006a; Krige 2006b) public debates, and wide-spread media interest (SAPS, 2013:Online; ENVIROADMIN, 2011:Online; Gross, 2011:Online; Salgado, 2011:Online; Waldner, 2011; Bernstein, *et al*., 2010:Online; Boon, 2010; Davies, 2010; Day, 2010:Online; FEDUSA, 2010:Online; Heyns, 2010:Online; Jagals, 2010:Online; Lesufi, 2010; SAPA, 2010; Sechemane, 2010:Online; UASA, 2010a:Online; UASA, 2010b:Online; Munshi, 2008), on the impact of mining in the West Rand, Acid Mine Drainage and subsequent toxic pollution (Bega, 2012:Online; Bega, 2011:Online; DWA, 2009) caused by heavy metals such as uranium, culminated in the formation of an Inter-Ministerial Committee on Acid Mine Drainage (IMCAMD, 2010:Online) in 2010. In December 2010, the report "Mine water management in the Witwatersrand Gold Field with special emphasis on Acid Mine Drainage" was prepared by a team of experts, and was presented to the IMCAND and subsequently released to the public in 2011. The report, highlights the threat and potential threats of acid mine drainage; these include contamination of groundwater used for human consumption, increased seismic activity, negative ecological impact and localised flooding (IMCAMD, 2010:Online). Acid mine drainage is mainly the result of the cessation of mining activities, which in turn leads to the cessation of the pumping of underground-water, resulting in the flooding of the mining voids and decanting of the mine water on the surface (McCarthy, 2011:Online; Keet, 2010:Online; Coetzee, 2009:Online). Acid mine water forms as the un-pumped water filling the voids is exposed to the pyrites on mined rock surface (Ochieng *et al.*, 2006:Online). Although, the latter impacts mainly on the mined-out areas of the West-, East- and Central Rand Basin and not the Far West Rand Basin. There is valid concern that this problem could extend to the Far West Rand Basin as mines reach the end of their economically sustainable life, and are forced to close (Van Vuuren, 2011:Online; Zorab, 2010:Online). The possible negative impact of mine closures in the catchment area of the Mooi River on the groundwater and on the water resource quality in the Mooi River catchment area is of great concern (Coetzee, 2009:Online). This is but one example of a source of potential anthropogenic hazards that can significantly affect the Mooi River catchment.

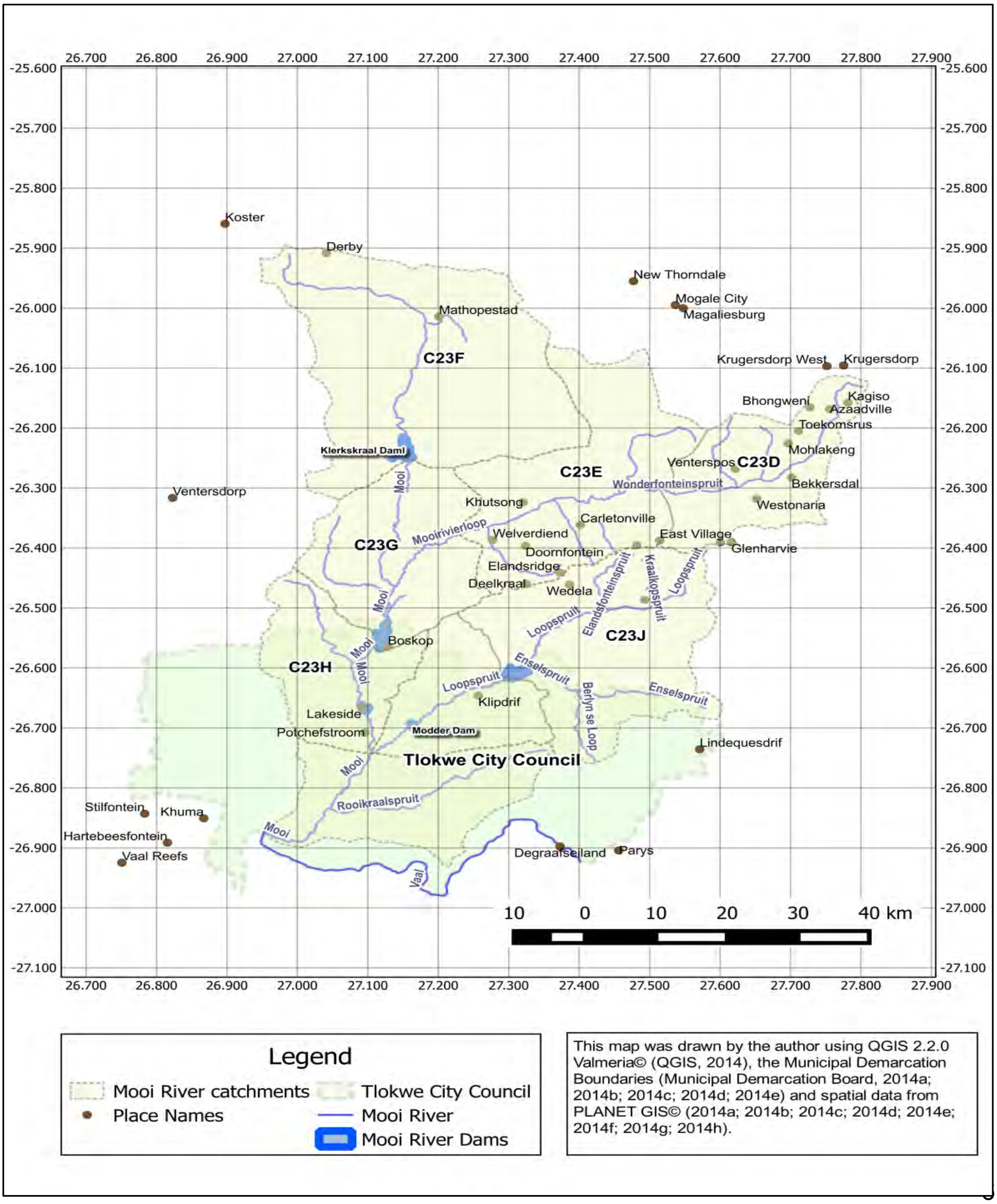
Map 2 below provides a spatial representation of the Mooi River and the quaternary catchments of the Mooi River, that is C23G, C23J, C23H, and C23K that overlap within the Tlokwe Local Municipality Boundaries, and quaternary catchment C23L that lies within the Local Municipalities boundaries.



Map 2: The quaternary catchment areas of the Mooi River within the boundaries of the Tlokwe Local Municipalities

Although treated water of good quality is provided for by the Local Municipality for domestic use to the majority of the communities in the townships of Potchefstroom, including Dassierand, Baillie Park, Central CBD, South, Miederpark, Grimbreekpark, Ikageng, Ext 7, Ext 11, Sarafina, Mohadin and Promosa. The remaining smallholdings and farms, including rural and farm schools source untreated water from the ground, surface and canals, and are themselves, responsible for water treatment. The Tlokwe

Local Municipality's main water resources, the Mooi River (See Map3) and its integrated groundwater systems, could be impacted upon by factors related to deep-level mining discussed above, as well as urbanisation, industrialisation, alluvial-, pit- and surface mining and environmental degradation.



Map 3: The quaternary catchment areas of the Mooi River in relationship to the Tlokwe Local Municipality.

Many of these activities occur outside the boundaries and jurisdiction of the Local Municipality (See Map 3) and in most instances outside the provincial boundaries and jurisdiction of the North West Province (Van Eeden, *et al*., 2009a:195). As can be seen in Map 3, the Mooi River Catchment includes the quaternary catchments of C23D, C23E, C23F, C23G, C23H, C23J, C23K and C23L of which only portions of the quaternary catchment area's C23H, C23G, C23J and C23L fall within the Tlokwe Local Municipality. The Tlokwe Local Municipality and its water resources are continuously exposed to both the risk of anthropogenic hazards and natural hazards from with its boundaries and those originating from hazards in the portions of the catchment areas beyond its boundaries.

The concern of anthropogenic hazards including mining and industrial induced hazards are illustrated by the extent of research and reports outlined in Table 1 that have been conducted in the catchment area in respect of these potential hazards.

Table 1: Summary of recent studies and reports

Year	Authors	Focus and findings	Comments
2005	Van Dyk, A. A.	Assessment of the cumulative impact within the Kromdraai catchment area: Focusing on the points of discharge.	Identifies various point of sources and their inputs on the Wonderfontein Spruit, Mooi River and Loop Spruit.
2006	Coetzee, H., Winde, F. & Wade, P.W.	Impact of mining on water quality and availability in the Wonderfontein catchment area.	Focuses on radio isotopes and heavy metals
2005	Le Roux, E.	On means to improve the quality of raw water supply to Potchefstroom	Proposes various alternatives including a new canal from Gerhrad Minnebron Eye and a new dam
2007	NNR	Technical report on the Radiological impact of mining activities on the public in the Wonderfontein catchment area.	Focuses on radio isotopes and heavy metals
2006b	Krige, W.G.	Assessment of the possible impact of water pumped from	15 Ml /day of treated water must be pumped from the Western

Year	Authors	Focus and findings	Comments
		the western basin mining void on the Wonderfontein Spruit	Mining void to reduce the impact on the Tweelopie Spruit at the Cradle of Mankind
2008	Opperman, I.	The remediation of surface water contamination in the Wonderfontein River	Focuses on the creation of artificial wetlands to assist in sedimentation and water purification
2009	Department of Water Affairs and forestry (DWAF)	Proposed remediation plan for the Wonderfontein catchment area.	Identifies areas that require urgent intervention in the Wonderfontein Spruit and proposes remedial action that should be taken.
2010a	Winde, F.	Uranium pollution of water resources in mined-out and active Goldfields in the Wonderfontein Spruit catchment area.	Analyses approximately 3400 unpublished Uranium – concentration of water samples gathered between 1997 and 2008
2010b	Winde, F	Investigates the extent of Uranium pollution	Focuses on the potential impact of drinking water
2010a & 2010b	Winde, F. & Stoch , E.J.	Investigates the possible impacts of future mining, re-watering and dewatering in the dolomite aquifers.	Focuses on the impact of mining on the dolomite compartments and the water resources within the Wonderfontein Spruit catchment area
2010	Gold Fields	Environmental impact report:	Gold Fields is proposing to reclaim and process 13 of its existing tailings storage facilities removing seven from dolomite ground.

Recent reports indicate potential hazards resulting from poor control by certain responsible authorities and license holders over the discharge of wastewater into the water resource of the catchment area for example; it has recently been acknowledged that more than one third of local municipalities do not have the capacity to maintain waste treatment systems (Waldner, 2011:Online; DEAT, 2007:Online). Another example is the recent breach of a tailings dam in December 2010 where unknown quantities and qualities (that is pollutants) of slurry was released into the catchment Area (Bega, 2010:Online; Child, 2010:Online). Hazards resulting from urbanisation are for example the formal and informal development upstream of the Wonderfontein Spruit catchment that is a tributary of the Mooi River at Singobville, Azaadville, Kagiso and Bekkersdal on or near the banks of the Spruit. The Bekkersdal graveyard for example is less than 200 meters from Donaldson dam (As measured from a Google Earth© satellite image of Bekkersdal).

All of these hazards have the potential to impact negatively not only on Potchefstroom's only water supply but on the entire water catchment area within the Local Municipality boundaries and the many communities that are within its boundaries. The resulting potential disasters from these hazards could have a negative impact and in some instances devastating socio-economic infrastructural and environment impacts.

Municipalities in accordance with the South African Constitution (Act 108 of 1996) are obliged to, in many instances, not only protect but also realise the rights enshrined in the Bill of Rights, and are required to adhere to legislative obligations. Examples of legislation include those prescribed in the Disaster Management Act 57 of 2002 and Government Municipal Systems Act 32 of 2000, that require both reactive interventions, and proactive interventions that can mitigate the impact of possible hazards. Therefore, in the case of the Tlokwe Local Municipality, there is a need to advance human rights and freedom by ensuring access to the basic rights, for example the right to water (section 27 of the South African Constitution Act 108 of 1996) and reduce the consequence of disasters by proactively managing the risk of disaster. This study considers an Information Systems solution to enable the Tlokwe Local Municipality to enhance its effectiveness in managing Disaster Risk and disasters. The possible role of an information system solution is discussed below.

Information reduces uncertainty, improves effective planning and decision-making, and reduces the probabilities of unexpected outcomes in a decision situation (Davis & Olson, 1985:200). It can therefore be argued that the effectiveness of management is dependent on the accessibility to quality management support and decision support information, and the ability to effectively utilise that information. The use of current information and communication technology (ICT) as a tool to assist managers in accessing and processing quality information is discussed below.

The event of Globalization, rapid changes in Information and Communication Technology and the World Wide Web (WWW)(WC3,2011:Online) that ushered in the 21st Century, have provided global access to a perceived unlimited supply of data and electronic information, and affordable technology solutions that provide fairly accurate in time modelling of the real-world systems and events (Wadhwa, 2011:Online; Cogbum, 1998:Online; Cook, 2013:Online). The first significant impact of the information era is that most information on an entity (for example, buildings, rivers, bridges, persons, schools, etc.) is available in digital format. For example, municipal accounting systems are electronic, census data systems (StatsOnline, 2012:Online); most official records are now kept in an electronic format (SA-SAMS, 2014); most research reports are available in electronic format, for example plans and maps are digitised and are therefore in digital format. The challenge, therefore is tracing the data, determining the quality of data and ensuring that the data is maintained, thereby ensuring the optimal utilization of official data (Rob & Coronel, 2004:776). The second significant impact of the information era is the rapid development in technology. This includes Global Position Systems (GPS) (Jordan, 2006:Online), the transmitting of signals by satellites from remote sensors (National Seismic Center USA (USGS, 2012a:Online)), Global Seismographic network (USGS, 2012b:Online), Wireless Technologies (cellular phones, IPods, Palm Tops, GPS wrist watches, etc.) which can be and are being used to assist in disaster management (Iwai & Kameda, 2009:Online). The third significant impact of the information era is the combination of technology and data to monitor events in time, for example Weather Forecast (Weather SA, 2013a:Online), Visual Broadcasts, River Flows for example daily unverified data (DWAF, 2013:Online) & Dam Levels for example weekly updates (DWAF, 2013b:Online), Emergency Updates (US Department of Homeland Security 2013:Online; National Weather Services: 2014:Online).

In respect of disaster risk reduction and disaster management, the above technologies have the potential as effective tools:

- To enhance accessibility to sufficient information, for example historical data on river flow peaks, flood levels, geological formation types such as dolomite and existing global knowledge base on good practices, online and in–time information of events, through the WWW and other collaborative applications such as Face Book. These can assist in risk reduction planning, establishment of early warning systems and avoiding or reducing the impact of disasters.

- To communicate with previously inaccessible communities, for example training of isolated communities through teleconferencing and satellite video streaming that allows for interactive remote sessions. This could help in the effective preparation of communities and reducing their susceptibility as the result of lack of information, to assist in reducing disaster risks and increase their effectiveness in responses to disasters.
- As an early warning of impeding disasters and, for example, warning of expected increase of water levels in rivers and dams through remote satellites sensors, online and in-time warning from remote weathers stations, presence of threatening hazards such as veld fires using modern telecommunication technology.
- To enable communities to contact disaster response teams when needed when there is a risk of a disaster or a disaster has occurred so that immediate interventions are possible. Modern telecommunication technology has made it possible to communicate when traditional communications structures are non-functioning or not available.
- To enable the authorities to contact remotely affected communities in the event of a disaster, so that effective response, rescue and recovery can be conducted to minimize the impact of a disaster.

Information and communication technology can also enhance the effectiveness of disaster risk management and disaster management of complex river catchment systems, for example, that of the Mooi River which extends across numerous municipal boundaries (see Map 1, Map 2, Map 3 Appendix A.1 and Appendix A.2), with a sensitive ecosystem that is exposed to a myriad of potential hazard sources.

Spatial information in the form of GIS in this case could enable contextualisation of the spatial locality of the potential hazard sources in relation to the catchment inflows.

Presently, a class of Decision Support Systems (DSS), namely Geographical Information Systems (GIS) that integrates computer graphics, and uses a geospatial database, to provide maps and other graphical displays is used in supporting spatial decisions. Applications include: urban planning (Ormsby *et al.*, 2009; O'Brien & Marakas, 2006:331); disaster management (Samadi & Delavar, 2009:Online;

Zanariah, *et al.*, 2009:Online; Harman, *et al.*, 2008; Kumar, *et al.*, 2008:Online; Vargas, *et al.*, 2008:Online); water resource management (Katiyar, *et al.*, 2008:Online; Elkrai, *et al.*, 2003:Online; Vijaindra, *et al.*, 2003:Online; Lim, *et al.,* 2003:Online;); wetland research and monitoring (Musinguz, *et al.*, 2006a:Online; Musinguz, *et al.*, 2006b:Online; Sinthumule, 2006:Online;); monitoring and research in respect of air and water pollution (Veerabhadram, 2003:Online) sustainable development, global warming and climate change (Bac-Bronowicz & Maita, 2007:Online; Sharifan & Alaghmand, 2007:Online;). The above are a few examples, of the successful application of geospatial information systems to provide management support and decision support information to managers, decision makers and knowledge workers, where problems occur within a geospatial location. For example, catchment area, transport routes, towns and specific communities and have a geospatial context for example, flooding of river, multi-vehicle pileup, transporting and handling of highly toxic waste, etc. that must be considered. In respect of disaster risk management and disaster management Spatial information can assist in reducing the impact of potential disasters in that it can be utilised in planning to avoid, mitigate or prepare for potential disasters, and too effectively manage disaster response and recovery. A GIS potential as a disaster risk reduction and disaster management application also include the following:

- The application allows for simulations of potential disaster so that the potential impact can be determined, and the action required to reduce or avoid the impact of potential disasters can be planned (Goodchild, 2012:Onine; US Department of Homeland Security, 2005:Online).
- The application can be used to spatially identify potential risks and communities, infrastructure and ecologies spatially related to the risk (Gruber, 2009:Online; Organization Of American States, 2005:Online).
- The application can assist it effective spatial planning which will reduce the risk of disaster and promotes sustainable development (Bunch, *et al*., 2012:40; Sutanta, *et al*., 2009:Online).
- The application can assist in identifying spatially potential vulnerabilities (Roy & Blaschke, 2014:Online; Sharma, 2012:Online; Babiker, *et al*., 2005:127).

- The application can assist in crowd management (Deshpande & Gupta, 2014:Online; Vij, 2009:Online).
- The application can be used as an evacuation planning tool (Laghi, *et al.,* 2007:1-84; Cova, *et al.*, 2005:603-617)
- The application can be used to for disaster preparedness and emergency response to disasters (Simons, 2008:Online; .Laurini et al, 2005:1-18).
- The application can be used as a disaster management planning tool (Nair, 2012:vii; Stimson, 2010:1-5; Strydom & Braune, 2005:28-34; Dash, 1997:135-146)
- The application can assist in spatially determining the impact of a disaster (Peterson, 2014:Online)

It can be argued, therefore, that utilisation of a Geospatial Information Technology as one of the tools in the solution mix, should be considered when addressing a spatial problem that is under investigation. Taking the above into consideration, the utilisation of geospatial information is recommended as a part of the solution to address problems that are geospatially linked and have a geospatial context.

The problem is the need for the Tlokwe Local Municipality to effectively manage the potential short-, medium- and long-term risk of disasters that could arise from potential natural and anthropogenic hazards originating and influencing the Mooi River Catchment within the Municipality's geographical area of responsibility. These occur within a geospatial area (river catchment area, municipal area) and within certain geospatial context (physical location of activities resulting in potential hazards, and physical location of vulnerable communities, ecosystems and economical infrastructure). This not only allows, but also requires the consideration of geospatial information in any decision support or management information solution. The focus in this study is therefore on the effective utilization of a GIS as a means to enhance the ability of the Tlokwe Local Municipality to prevent, mitigate and manage any disaster that could arise within its water catchment areas. The study is limited in it that it will only focus on determining the requirements for the conceptual design of Geographic Information System for the Mooi River catchment area.

As the study focuses on disaster management and related activities, there is a need for the reader to be familiarized with these terms and the context in which they will be used in the study. Conceptualisation, description and definition of the terms used in the text are provided in the next paragraph.

1.3 Definition of terms

The definitions and the clarification of concepts as used in this study are provided below.

1.3.1 Coping Capacity

Coping capacity is the combination of all the strengths and resources within a community, society or organization that can reduce the level of risk, or the effect (impact) of a disaster (UNISDR, 2004:16). The coping capacity is therefore the ability of the community, society, organization and systems to use the skills and resources available and its ability to cope with and to mitigate the adverse consequences of disaster (UNISDR, 2009:12;).

1.3.2 Disaster

According to section 1 of the Disaster Management Act (Act 57, 2002), a disaster is defined as a progressive or sudden, widespread or localized, natural or human caused occurrence which causes or threatens to cause, death, injury or disease; damage to property, infrastructure or environment; or disruption of the life of the community; and is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using their own resources. Van Niekerk *et al.,* (2002:12) similarly define a disaster as a serious disruption in the functioning of a society, causing or threatening to cause wide-spread human, material, economic or environmental losses and impacts, which exceed the ability of the affected community or society to cope using its own resources. Twigg (2007:1) defines disaster as the occurrence of an extreme hazard event that affects vulnerable communities, causing substantial damage, disruptions and possible casualties, and leaving communities unable to function normally without outside help, assistance and support.

All of the above definitions acknowledge firstly, that a disaster is the result of an occurrence of a phenomenon (hazards) that can be natural, for example, the devastating torrential floods and rainstorms (Rourke & Jones, 2011:Online), major earth quakes (Quinn, 2011:Online; McCurry & Branigan, 2011:Online) or the result of human intervention for example, nuclear (The Manhattan Project, (Belli, 2014:Online)), the Chernobyl nuclear power plant accident, (USNRC, 2013:Online), Three Mile Island accident (World Nuclear Association, 2001:Online), the Fukushima Daiichi nuclear power plant accident following the Japanese tsunami in 2011(CNN Library, 2014:Online), chemical (Lamb, 2009:Online), portions of a city without access to potable water as a result of human errors as was the case in Potchefstroom resulting in millions of rands lost in income (Botha, 2013b; Botha, 2013c:3). Secondly, to become a disaster the hazard must have a significant impact on the functioning of society. This could include the loss of life, and/or injury, and/or disease, and/or damage to property, and/or infrastructure, and/or environmental degradation. Thirdly, the extent (impact) of the disaster (impact) must exceed the ability (coping capacity) of the community to function and /or recover without external assistance. Fourthly, disasters can be progressive, sudden, localized or widespread. Disasters can, according to the Disaster Management Act (57 of 2002) be classified according to the extent of the geographical area affected as well as the coping ability of the different spheres of government affected. Accordingly, disasters can be classified as local disasters, provincial disasters and national disasters.

1.3.3 Disaster Risk

The scientific concept of risk implies the measurement of the probability of an outcome (event), and the extent (negative consequences) of the outcome (event) (UNISDR, 2009:25; Visser & Erasmus, 2007:196). This implies that risk has two components, the probability (frequency) of the event, and the probable resulting consequence of the event.

Thus risk = probability (frequency) X consequence (magnitude of the impact)

The concept risk in respect of disasters, refers to the probability (likelihood) of the harmful impact (consequence) that includes losses (deaths, injuries, negative impact of livelihoods, loss and destruction of properties) and degradation to the environment, resulting in the interaction between hazards and the human coping ability (Vulnerability including resilience) (Coppola, 2011:28; UNISDR, 2004:6).

Based on the above, risk can be seen as a function of the potential hazards and the vulnerability of the humans to be affected.

Thus risk = hazard x vulnerability

Disaster Risk includes the probability of the event (disaster) occurring and the potential impact of the event (disaster). Therefore, analysing the risk will enable the prioritization and the focusing of resources most effectively on potentially the most devastating hazard with the highest probability of occurring. The formula below is used (Coppola, 2011:28; Twigg, 2004:20):

$$\text{Thus (disaster) risk} = \frac{\text{(Hazard (probability x potential impact)) x Vulnerability)}}{\text{Coping Capacity}}$$

1.3.4 Disaster Risk Management

Disaster Risk Management is the process of using administrative decisions, organizations, operational skills and capacities to implement policies, strategies, and coping capacities of the society and the community (UNISDR, 2009:35), so as to prevent (avoid) or lessen the impacts of hazards. These hazards include natural, technological or other human initiated hazards and the related disasters (GTZ, 2002:19).This process comprises of all the actions (programmes, project and other measures) and activities, including structural and non-structural measures to avoid (prevent) or to limit (through mitigation and preparedness) adverse effects of hazards (UNISDR, 2004:2; GTZ, 2002:Online).

1.3.5 Disaster Risk Reduction

According to UNISDR (2004:17), Disaster Risk Reduction is defined as the conceptual framework of elements considered with the possibilities to minimize the vulnerability and risk of disasters throughout society, to avoid (prevent) or to limit trough mitigation and preparedness the adverse impacts of hazards, within the broad context of sustainable development. In a later definition, UNISDR (2009:10) refers to disaster risk as a practice of reducing disaster risks through a systematic effort to analyse and manage the casual factors of disasters, including through the reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

When considering the two definitions it can be noted that the first provides for a conceptual framework, that is, a model that can be used to understand and assist in the reducing (preventing and limiting) the potential impact of a disaster. In the second, the systematic analysis and management of causal factor of a disaster and its relationship to sustainable development is recognized (Mansourian, *et al*., 2004:Online).

Based on the above, Disaster Risk Reduction as used in this mini-dissertation is described as, a systematic effort using a conceptual framework, to analyse the hazards and vulnerabilities, and manage, including the lessening of vulnerability by improving livelihood strategies (Steinmann, 2005:Online), wise management of land and the environment, the causal factors of a disaster, so as to prevent or reduce the impact of disaster.

1.3.6 Early warning

Early warning can be defined as the set of capacities needed for the provision of timely and effective warning information, through identified institutions, that allow individuals, communities and organisations exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response (UNISDR, 2009:Online; UNISDR, 2004:3).

1.3.7 Hazard

Hazards can be defined as a physical event, phenomenon or human activity that has the potential to cause the loss of life, injury, health impacts, damage to property, loss of livelihood, social and economic disruptions and or environmental degradation (Coppola, 2011:28; UNISDR, 2009:17; UNISDR, 2004:24; Twigg, 2004:14,15). Hazards are therefore not disasters but they do have the potential to give rise to disasters and are potential threats that have a natural or anthropogenic origin.

1.3.8 Mitigation

Mitigation in the context of a disaster is referred to the measures (action) undertaken to limit (minimize) the impact of hazards (Twigg, 2004:13; UNISDR, 2004:17). These measures can be structural or/and non-structural.

1.3.9 Preparedness

Preparedness refers to the specific measures taken before the onset of a disaster, with the aim of effectively preparing for and reducing the impact of a potential hazard, it includes early warning systems, planned precautions that can be taken, and providing for the appropriate disaster response (IFRC, 2007:6).

1.3.10 Resilience

Resilience is the antitheses of vulnerability (Twigg, 2007:1), and is the capacity of the systems, community or society to adapt to the potential adverse effects of hazards, by resisting or changing in order to reach and maintain an acceptable level of functioning and structuring (UNISDR, 2004:17).

1.3.11 Vulnerability

According to section 1 of the Disaster Management Act (52 of 2002), vulnerability is defined as the degree to which an individual, a household or an area may be adversely affected by a disaster. For the purpose of this study, vulnerability refers to those social, political, economic, technological, global, and environmental factors including characteristics and circumstance, that increase the susceptibility of people including individuals, groups or social economic structures likely to be affected by the potential negative (damaging) impacts of hazards (IDSR, 2004:13; Twigg, 2004:13; Twigg, 2007:1; IDSR, 2009:30).

Vulnerability is, therefore, the human dimension of disaster, resulting from various factors (Twigg, 2004:16), including economic for example, recessions (Brigugilo, 2011:Online; Silbert, 2011:Online), social for example, marginalized groups, cultural and religious for example, the tradition at a funeral for all attending to wash hands in the same bowl of water that increases the likelihood of the spread of contagious water borne diseases such as cholera, demographic including age transitions, migration and urbanization, civil unrest and war, (DANIDA, 2000:Online), vulnerable groups for example older people have reduced physiological resilience and are subjected to degenerative diseases, younger children are more susceptible to contagious diseases, psychological for example, behaviour and stress coping abilities, and environmental degradation (TERI, 2003:Online). Therefore, all individuals, communities and societies may to a lesser or greater extent be susceptible, but many have sufficient coping capacity for example access to medication, more sound infrastructures better, appropriate knowledge and skills, effective social support structure, food and water reserves, risk transfer such as insurance on assets and health, etc. required to minimize the effect of these vulnerabilities. Unfortunately, the poor do not always have access to these factors that can improve their coping capacity and decrease their vulnerability, and therefore are more often the group that is most negatively impacted during a disaster.

In the case of disasters therefore, the extent of susceptibility and resilience depends on the ability of the community to anticipate, resist, and recover from the impact of a hazard.

1.3.12 Water Resource

In accordance with the National Water Act 36 of 1998 (Section (1)(xxvii)), a water resource includes the watercourse, surface water or groundwater aquifer. The water course refers to (Section (1)(xxiv)) a river or spring; a natural channel in which water-flows regularly or intermittently; a wetland, lake, or dam into which or from which water-flows; any collection of water that the Minister may, by notice in the Government Gazette, declare to be a watercourse; and includes where relevant, its beds and banks.

The above summarises some of the important terminology to be used in the study. In the chapters that follow, a few of the concepts will be discussed in more detail. In the next section the research problem is addressed, a possible solution is provided, the aim and demarcation of the study are stated, and research objectives are formulated, based on the research aims.

1.4 Addressing the problem

1.4.1 Problem Statement

The problem under investigation is the need for the Tlokwe Local Municipality to; effectively manage the potential short-, medium- and long-term risk of disasters that could arise from potential natural and anthropogenic hazards originating in the Mooi River catchment area that could affect the catchment areas within the jurisdiction of the Local Municipality. The lack of effective risk management tools is of concern in the context of the water catchment management of the Mooi River, which is the main water supply of the Tlokwe local Municipality. An example of the complexity of the problems in respect of the surface-water and groundwater catchment was emphasized during a District Disaster Management Forum Committee meeting held on 24 April 2014, in Matlosana when a presentation was made by AGES (Potgieter, 2014) on the dolomitic formations found in the Tlokwe Local Municipality. Risk of subsidence or sinkholes are related to the fluctuation in water levels of the dolomitic compartments. The problem concerning the water levels in the Tlokwe Local Municipality is that it can be influenced by the activities of the dolomitic compartments above the Turfontein/Boskop compartment, which fall beyond the Local Municipality boundaries. The implication is that Tlokwe Local Municipality management systems and tools for, disaster risk management, disaster preparedness and disaster response must consider the effectors of disaster risk within and beyond the municipal boundaries.

1.4.2 Possible solution

As a solution to the problem, an effective GIS is considered, that will enhance the ability of the Tlokwe Local Municipality to effectively manage the potential short-, medium- and long term risk of disasters that could arise in the Mooi River Catchment.

1.4.3 Aim of this study

The aim of this study is to determine the requirements for a conceptual model of a GIS that will enhance the ability of the Tlokwe Local Municipality to effectively manage the potential short-, medium- and long-term risk of disasters that could arise within the Local Municipality.

1.4.4 Demarcation of the study

Firstly, although all activities in the quaternary catchment areas of the Mooi River can and do affect the catchment area of the Tlokwe Local Municipality. This mini-dissertation focus is limited to the potential hazard sources that could affect quaternary catchments with specific reference to C23D of the Mooi River (see Map 3 and Appendix A.3). Secondly, this study only identifies the requirements for the conceptual phase of the logical model.

1.4.5 Key research questions

Information providing the theoretical foundations for determining the needs for the conceptual model in the study is acquired by addressing the following research questions:

1. What are the Constitutional and legislative obligations in respect of the management of disaster risks in water catchments areas and of water resources?
2. What are potential natural and anthropogenic hazards, that are specific to a water catchment area in general and those affecting the Tlokwe Local Municipality? Which are the potential vulnerable communities, ecologies and socioeconomic infrastructures that can be negatively impacted upon by hazards arising in the catchment area?
3. What is a GIS and what type of spatial information is required for effective Disaster Risk Management?
4. What are the requirements for a conceptual model of an effective GIS that will enhance the Tlokwe Local Municipality's ability to manage the risk of disasters related to the water catchment area of the Mooi River?

1.4.6 Research objectives

Each of the above research questions in this study is then formulated and addressed as a research objective. The following research objectives are accordingly formulated from the research questions:

1. To Identify and conceptualise the Constitutional and legislative obligations in respect of disaster risk management in general and specifically those governing the disaster risk management in the water catchment area for the Mooi River and its related water resources that could impact directly or indirectly on the Tlokwe Local Municipality catchment area of the Mooi River.
2. To identify and conceptualise the generic hazards that are related to water catchment areas (including the related groundwater compartments) and those specific to the Mooi River catchment area that can impact directly or indirectly on the Tlokwe Local Municipality section of the catchment area.
3. To identify the requirements, for an effective conceptual model of a GIS for Disaster Risk Management in the Tlokwe Local Municipality's municipal area.
4. The aim is to identify and conceptualize the requirements for an effective conceptual model of a GIS for disaster risk management in the Tlokwe Local Municipality's municipal area.

The above process of addressing the problem is outlined in Figure 1, below.

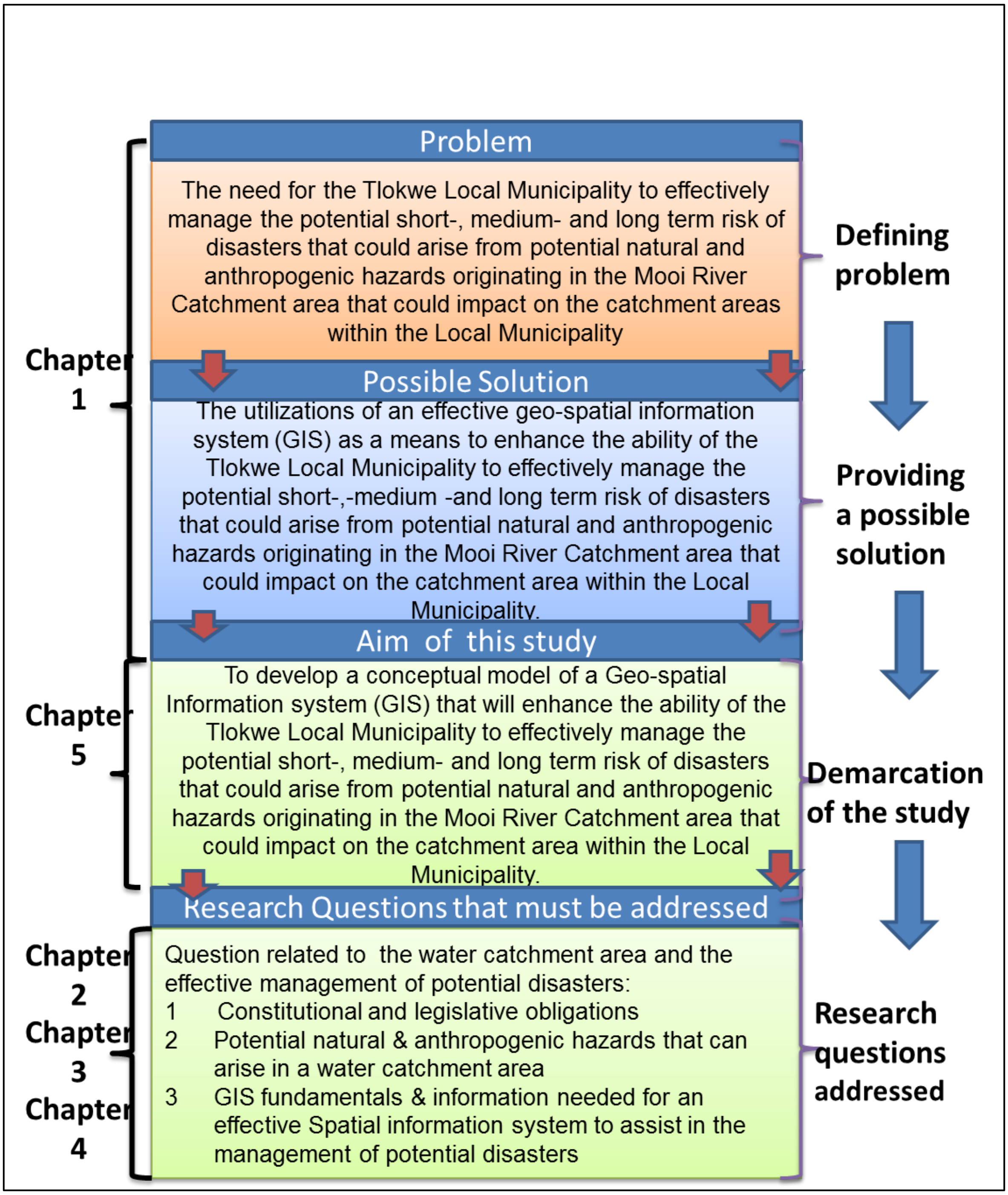


Figure 1: Addressing the problem

A concise overview of the research design used in the study to address the above research questions is outlined in the paragraph below.

1.5 RESEARCH DESIGN

The establishment of an effective spatial information system has been identified as a possible solution in addressing the ability of the Tlokwe Local Municipality to effectively manage the potential short-, medium- and long-term risk of disasters that could arise from potential natural and anthropogenic hazards in the catchment area of the Mooi River. Based on the postulated solution, the focus of this study is therefore on the determining of the requirements needed to conceptualize an effective geospatial information system that will assist the Tlokwe Local Municipality in effectively managing the risk of potential disaster and reduce the impact of potential disasters. Therefore, the important components of the system is the legislative context, the spatial data, the information and models that will be required to assist in decision support and all aspects of managing, including planning, organising, directing, control, monitoring and communication (WWW.SMARTDRAW.COM, 2013:Online; Thorn, 2011:Online; Nieman & Bennett, 2006:91,93,99,103,107; Van der Waldt & Du Toit, 2005:16,222-223). A logical process or design methodology (Figure 2) is to firstly, identify the main constitutional, legislative and policy obligations and processes in respect of Disaster Management in the water catchment area and water resource management. Secondly, it is necessary to determine the geographical area and features of the water catchment area, water resources and potential sources of hazard for which the spatial information will be required. Thirdly, it would be necessary to determine the nature of the Decisions Support System (DSS) and Management Support System in the case of this study, a spatial information system, namely a GIS.

In determining and mapping of the main geographical features for the spatial information component, and determining the information requirements for the Decision Support System and the Management Support component, qualitative methods were used. This included the use of available maps and document studies (De Vos *et al*., 2008:315; Struwig & Stead, 2007:101). In this study, the documents sourced in the documents study include official documents (Government and International Agencies), mass media and archived material (archived international and national officially government sanctioned and private reports and research documents). Throughout this study, in an attempt to enhance the validity and reliability of data, where possible, various data sources are compared through triangulation (De Vos *et al.*, 2008:315; Struwig & Stead, 2007:102).

Figure 2 below provides a conceptualisation of the research design approach that is discussed above.

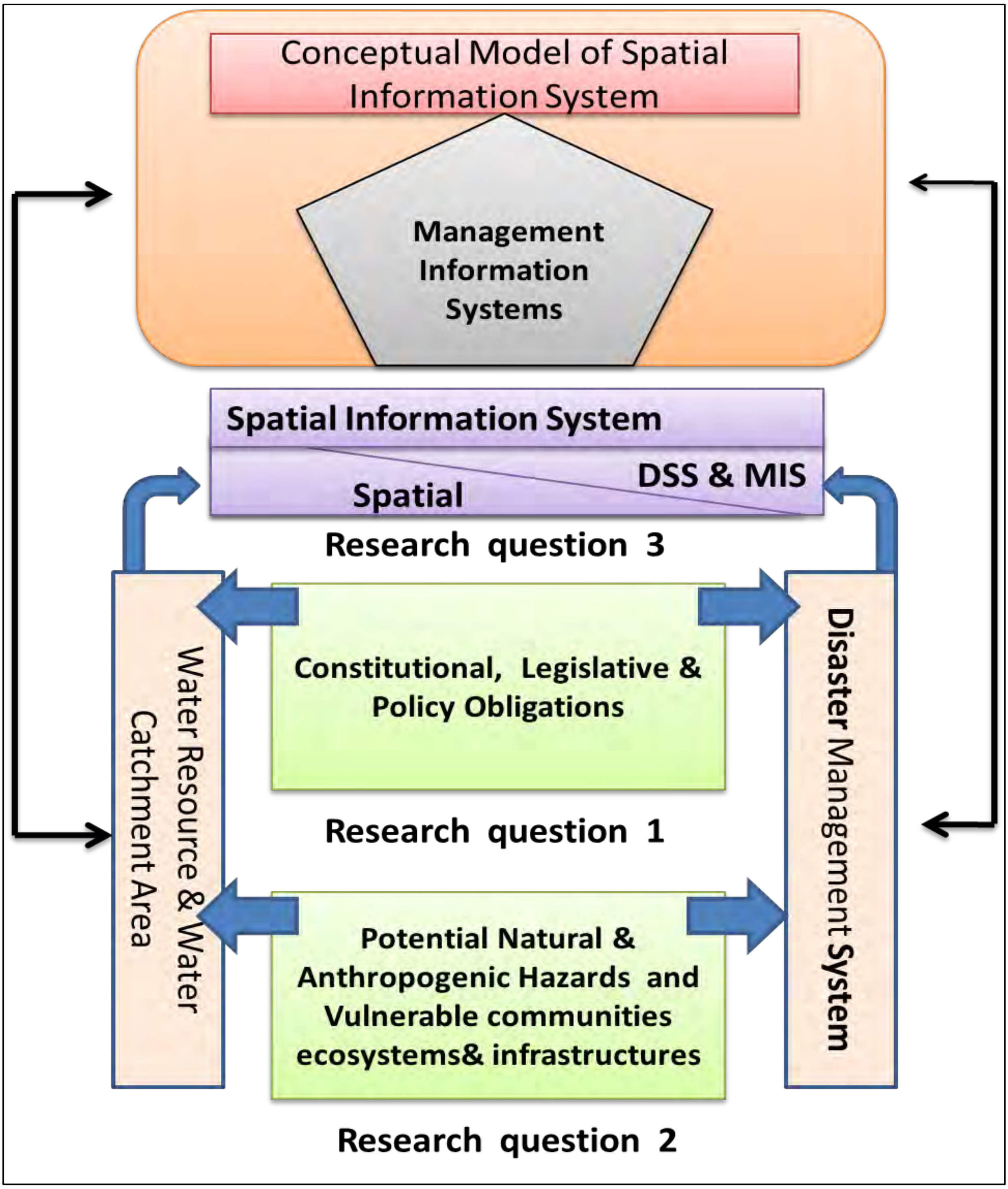


Figure 2: Research Design

1.5.1 Data Collection and Data Sources

In providing the preliminary base map for the study, spatial data from the following sites where used:

> www.demarcation.org.za (Municipal Demarcation Board. Only available in PDF format)
> www.google.earth.com (Google Earth)
> www.maplibrary.org (Map Library uses old demarcation)
> www.planetgis.co.za (Planet GIS)
> www.dwaf.gov.za (Department of Water Affairs and Forestry)

The objective of the systems is to assist with the effective Disaster Risk Management and Disaster Management. The system therefore must provide data that will assist in the Management and Decision Support in respect of Disaster Management.

In this study, the following sites where used to acquire information in respect of Disaster Management and Disaster Risk Management:

> http://www.unisdr.org (The United Nations home page for the International Strategy on Disaster Management)
> http://www.ndmc.gov.za/Home.aspx (The South African National Disaster Management Centre),
> http://www.disaster.co.za/ (The Disaster Management Institute Of South Africa)
> http://www.ifrc.org/ (International Federation of Red Cross and Red Crescent Societies)
> http://www.disasternews.net/ (Disaster News Network)
> http://www.emforum.org/ (Emergency Management Forum)
> http://www.teers.org/ (The Environmental Emergency Management Response Services Canada)
> http://www.naturalhazards.org/ (NaturalHazards.Org)
> http://www.fema.gov/ (Federal Emergency Management Association: USA)

The management of the water catchment area and disaster risk is informed by constitutional and legislative obligations, and are influenced by the nature and risk of potential hazards and the impact thereof. These three components are addressed as research questions 1, 2 and 3, and are respectively formulated as research objectives 1, 2 and 3. The design methodology used in Research Question 1, which addresses the Constitutional and legislative obligation in respect of disaster management and water resources, is mainly qualitative of nature. This involves the study of relevant, laws, regulations and applicable case studies, and published legal opinions, all of which are forms of document studies (De Vos *et al.*, 2008:315; Struwig & Stead, 2007:101). In this study, the following sites where used to acquire information in respect of Constitutional and Legislative information in respect of Disaster Management and Water Resources:

http://www.enviroleg.co.za/Acts.htm (Copy of most National, Provincial and Local Legislation and Regulations relating to health, hazards water and environmental affairs)
http://www.saflii.org/content/south-africa-index (South African legal Information Institute: Provides information on legislations and related cases in respect of Southern African Countries)
http://www.constitutionalcourt.org.za/site/home.htm (The home page of the Constitutional Court of South Africa: Provides Judgements on cases that served before the Constitutional court)
http://www.justice.gov.za/sca/ (The Supreme Court of Appeal: Provides Judgement on cases that served before the Supreme Court of Appeal)
http://www.parliament.gov.za/live/index.php (Parliament of the Republic of South Africa Home Page: Link to all Acts and Bills)
http://www.acts.co.za/ (Acts online: Provide South African Acts with amendments)

The design methodology used in Research Question 2, which addresses hazards and vulnerability in the Tlokwe Local Municipality Water Catchment Area (Mooi River) is predominantly qualitative in nature. This involves the study of official documents (Government and International Agencies), mass media and archived material (Archived international and national officially government sanctioned and private reports and research documents), indirect observations and unobtrusive measures using literature, satellite images and maps to trace the water catchment areas, water resources, and trace possible sources and impacts of hazards, and a secondary analysis of data previously collected (De Vos *et al.*, 2008: 315, 319; Struwig & Stead, 2007:101).

.This study utilises a technological application, namely a geo-spatial information system. This technological application is addressed as Research Question 3. The design methodology used in Research Question 3, which addresses the question of the concept GIS and the type of information that will be required for an effective spatial information system, is qualitative in nature. This involves the study of official documents (Government and International Agencies), mass media and archival material (Archived international and national officially government sanctioned and private reports and research documents) (De Vos *et al*., 2008:315; Struwig & Stead, 2007:101). Fourthly, the final part of the research design is requirements for the conceptual (Logical) model of the Spatial Information Systems. System Development methodologies (Stair & Reynolds, 1999; Whitten *et al*., 2004) are utilised to determine the requirements for a conceptual model of the system.

The source of all data used is provided in as much detail as possible, and the processing of all data and sources used in the creating of the spatial database of the water catchment is recorded in the study. A conscious attempt is made to avoid any action or data that will affect individuals' rights.

The Constitutional, legislative and policy obligations in respect of disaster management, water catchment areas and water resource are provided in the next chapter.