DEVELOPMENT OF A WATER MANAGEMENT DECISION MODEL FOR LIMPOPO PROVINCE, SOUTH AFRICA

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DEVELOPMENT OF A WATER MANAGEMENT DECISION MODEL FOR LIMPOPO PROVINCE, SOUTH AFRICA

BY

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PHILOSOPHIAE DOCTOR

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	Professor A. Stroebel

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DECLARATION

I declare that this thesis hereby submitted for the degree of Doctor of Philosophy in Sustainable Agriculture at the University of the Free State, is my own independent work and has not been submitted for the purposes to any other university. I further cede copyright of this thesis in favour of the University of the Free State.

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Khathutshelo Alfred Tshikolomo **Date**

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DEDICATION

For the conception and completion of this study, I am thankful to the Almighty God who provided life, good health, peace and wisdom, without which there could have been no study. My father, Thomani Phanuel Tshikolomo (late) and my mother, Nkhanedzeni Tshavhungwe ignited an ever burning desire for education in my life and this inspired me to conduct this study. My wife, Humbulani was very supportive throughout the study and her encouragement made it possible for this work to reach completion. Our three children, Wavhudi, Thikho and Masana were able to go on without some of the privileges as I could not provide due to my deep commitment to this study.

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ABSTRACT

The study was conducted in the Limpopo Province with a focus on the Limpopo and Luvuvhu-Letaba Water Management Areas. The main issues investigated were (1) water resources, mainly runoff and storage capacity of the target Water Management Areas and municipalities, and the water gain and loss of the Middle Letaba Dam, (2) water management issues, mainly perceptions of municipal water managers on the water resource and its uses, and their perceptions on stakeholder participation, and (3) household water supply and requirement. A water management decision model was proposed based on the results of the investigations.

The results of the investigations revealed that: (1) The Limpopo WMA has a MAR of 611.4 million m^3 for possible development of new dams compared to only 365.2 million m^3 for the Luvuvhu-Letaba WMA, and related results were recorded for municipalities in these WMAs. The storage volumes of the Middle Letaba Dam were very small compared to design capacity; (2) The municipal water managers lacked knowledge on water resources and were relatively more knowledgeable on water use. Water management decisions were made by government based stakeholders while community based stakeholders had little influence on water management decisions; (3) There was a lack of access to safe water sources, only half (50.1%) of households obtained water from street taps. The quantity of water fetched ranged from 25 to more than 200 litres per household per day and the amount fetched was more for households located near the water sources. As a result of scarcity, water was mostly used for basic activities such as drinking, preparing food and bathing. Half (51.7%) of the households fetched less water than the 25 litres per capita per day supply standard which itself did not meet the average requirement of 37.5 litres per capita per day; and (4) A water management decision model was proposed based on the framework of the Congruence Model. The proposed model stated the main challenges faced by the water sector in the study area and assessed the capacity of the service organisations to address them by analysing the congruence between the challenges and the capacity. All assessed water service organisations only had moderate capacity to address the challenges. The lack of filling of some posts was the most significant constraint to the effectiveness of the organisations.

It is therefore recommended that: (1) The Limpopo WMA be the focus for possible construction of new dams, especially the Mogalakwena, Lephalale and Mokolo catchments in the WMA as they showed to have more available mean annual runoff for possible development of new dams. Although the Luvuvhu-Letaba WMA was shown to be well developed in terms of storage dams, the Mutale Catchment had more available mean annual runoff for possible development of new dams. Regular investigations of runoff and dam storage capacity should be conducted as the current status will change due to changing rainfall patterns and dam siltation. Water should be transferred to the Middle Letaba Dam from other catchments in order to maintain this dam at a full level and consequently to improve the supply of the resource to planned areas; (2). Municipal water managers should be trained on water resources and to a lesser extent on resource uses for them to make relevant decisions on the management and use of the resource. Community based stakeholders should be involved in water management decisions and should be capacitated to be reliable sources of water information; (3) The Department of Water Affairs should reconsider the 25 litres per capita per day as a supply standard as it does not suffice for the average requirement of 37.5 litres per capita per day proposed in this study. (4) Guided by the proposed water management decision model, service organisations should improve their capacity to address water sector problems.

Key words: water management area, municipality, water resources, rainfall, runoff, dam storage capacity, water supply, water use, stakeholder participation, congruence model, water service organization, water management decision model.

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CHAPTER 1

1 INTRODUCTION AND BACKGROUND

1.1 Introduction

This introduction outlines the issues discussed in the rest of the chapter, namely: (1) an overview of national water resources to provide the context in which the study area exists; (2) a description of the study area (geographic, socio-economic, and environmental description) with an analysis of the macro-environment and identification of water related problem areas that guide the focus of the research project; (3) the purpose of the study, presenting the study objectives which respond to the problems experienced by the water sector in the study area; and (4) outline of the thesis which serves as a guide to the reader.

1.2 Overview of national water resources

South Africa is located in a predominantly semi-arid part of the world. The climate varies from arid in the west to humid along the eastern coastal area. The country mean annual rainfall is about 450mm which is well below the world average of about 860mm while evaporation is comparatively high (DWAF, 2004a). As a result, the country's water resources are scarce. According to DWAF (2004a), the combined flow of all the rivers in South Africa is approximately 49 000 million m^3 per annum and is less than half of that of the Zambezi River alone.

The view that South Africa is a water scarce country was supported by CIWA (1970) who projected that the country's water requirement would exceed resource supply in 2000. According to Weaver (1990), the country's water requirement will only exceed supply in 2020 while Odendaal (1992) argued that this will occur sometime between 2020 and 2030. Muller (2002) and Inocencio *et al.* (2003) predicted that South Africa is likely to run out of water in 2025. It may be concluded from these projections that the water resources in our country are not inexhaustible.

It was in fact affirmed by Greeff (2010) that there is not enough water for South Africa's current and planned socio-economic development. Efficient management of the water resources is therefore crucial to sustain future water supply. According to Greeff (2010), efficient water management should consider the nexus between our scarce water resources, potential climate change impacts, and issues of long term food security. Informed by these links among the water resources, impacts of climate change and issues of food security, efficient management of water resources should promote sustainable development.

Four of South Africa's main rivers are shared with other countries. These shared rivers are the Limpopo, Inkomati, Pongola and Orange River. The four rivers together drain about 60% of the country's land area and contribute about 40% of its total surface runoff (DWAF, 2004a). As stated by DWAF (2004a), these four rivers contribute to approximately 70% of our country's gross domestic product (GDP). Judicious joint management of these rivers between South Africa and the neighbouring countries with which they are shared is of paramount importance for regional peace and stability.

It is clear from the above discussion that South Africa is a water scarce country and has to manage the available water resources efficiently. The fact that 60% of the country's land area is drained by shared rivers suggests that management of the water resources should be compliant with relevant international protocols. The national resource scarcity and the occurrence of shared rivers constitute an important context for managing water resources in the study area.

1.3 Description of the study area

1.3.1 Geographic description

The study was conducted in the Limpopo Province of South Africa. Selection of study sites within the province was based on two geographic aspects, (1) Water Management Areas and their river catchments, and (2) district and local municipalities. The geographic description of the study area will therefore be made in terms of these aspects.

(a) Water Management Areas and their river catchments

The province has four Water Management Areas (WMAs) located in it. The Limpopo and the Luvuvhu-Letaba WMAs are fully located while the Olifants and the Crocodile West and Marico are partially located in the province (Figure 1.1). The two WMAs that are fully located within the province entirely represent the province and were the focus of the study.

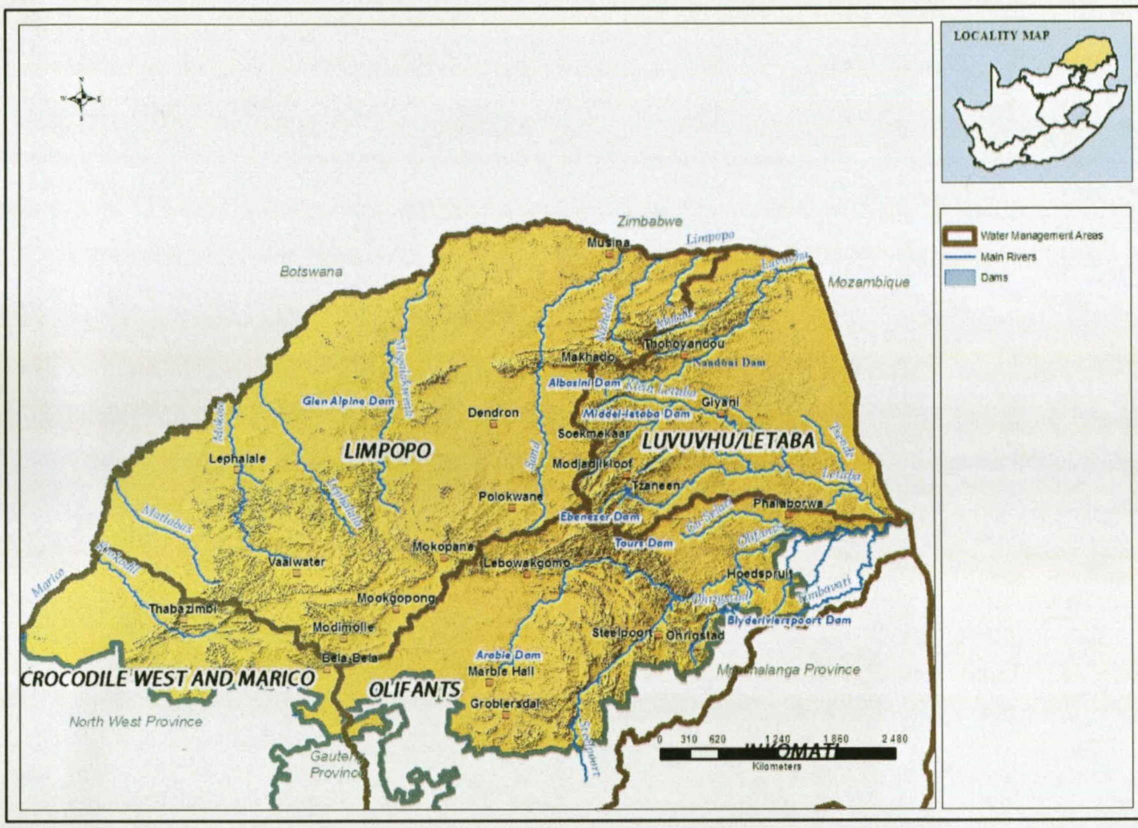


Figure 1.1 Map of Limpopo Province showing the Water Management Areas (brown lines) and the main rivers (blue lines) (DWAF, 2004a)

The main river catchments within the WMAs targeted by the study are the Matlabas, Mokolo, Lephalale, Mogalakwena, Sand, Nzhelele and Nwanedi in the Limpopo WMA and the Mutale, Luvuvhu, Klein Letaba, Middle Letaba and Groot Letaba in the Luvuvhu-Letaba WMA (Figure 1.1). The river catchments are discussed to different extents in the various chapters of the study.

(b) District and local municipalities

The province is politically divided into five district municipalities (referred to as districts), the Vhembe, Waterberg, Capricorn, Mopani and Sekhukhune District (Figure 1.2). The study covered four of the districts with only Sekhukhune excluded.

Figure 1.2 Map of Limpopo Province showing the Water Management Areas (brown lines), district (grey lines) and local municipalities (different colour shadings)

The districts are politically divided into local municipalities (referred to as municipalities) with each district having between four and six such municipalities. The number of municipalities selected for the study is 10 with four (Makhado, Thulamela, Musina and Mutale) in Vhembe, three (Letaba, Tzaneen and Giyani) in Mopani, two (Polokwane and Aganang) in Capricorn and one (Lephalale) in Waterberg District.

Of the 10 municipalities selected for the study, five are in the Limpopo WMA, namely: Makhado and Musina in Vhembe District, Polokwane and Aganang in Capricorn and Lephalale in Waterberg District. The other five municipalities included in the study are in the Luvuvhu-Letaba WMA, the Thulamela and Mutale in Vhembe and the Letaba, Tzaneen and Giyani in Mopani District.

Investigations in the study will focus on different combinations of the geographic aspects of water management areas (with their river catchments), districts and municipalities. Some of the investigations will be limited to only one of these WMAs and only some of the catchments, districts and municipalities.

1.3.2 Socio-economic description

In order to provide a comprehensive socio-economic description of the Limpopo Province, its socio-economic environment was properly scanned. Environmental scanning is the acquisition and use of information about events, trends, and relationships in an organisation's external environment, the knowledge of which would assist management in planning the organisation's future course of action (Auster and Choo, 1993; Choo 1998). Organisations scan their socio-economic environment in order to understand external forces of change so that they may develop effective responses which secure or improve their position in the future.

Meaningful scanning of the socio-economic environment should be guided by some framework that highlights pertinent issues to be targeted by the scan. The PESTEL framework was adopted for guiding the scan of the socio-economic environment for this study. Pertinent issues highlighted in the PESTEL framework are the Political, Economic, Social, Technological, Environmental and Legal factors (Fahey and Narayanan, 1986). Guided by the PESTEL framework, the socio-economic description of the study area follows.

(a) Political situation

In accordance with the constitution of the Republic of South Africa (RSA, 1996), the Limpopo Province has a legislature with 49 seats. In the fourth legislature of 2009, 43 seats were won by the African National Congress (ANC), 4 by the Congress of the People (COPE) and 2 by the Democratic Alliance (DA) (IEC, 2009). The legislature elects the Premier from the majority party. The Premier appoints the Members of the Executive Council from among members of the provincial legislature (RSA, 1996). The executive council runs the provincial government within the mandate of the ruling party.

In the same way that the provincial legislature elects a premier, the municipal council elects a mayor who is referred to as executive mayor for a district municipality. The mayor appoints the mayoral committee from among the members of the municipal council, and the committee serves as the executive of the municipal government (RSA, 1996).

The political leaders of these spheres of government influence strategic direction and hence the allocation of budgetary and other resources. The political system also exerts influence through the legislature and municipal councils who approve government strategic and annual plans and also play an oversight role of ensuring that the plans are properly implemented (RSA, 1996). The communities in the study area are mostly active politically and have an influence on their political parties who hold the government to account.

The water programmes run by the provincial and municipal governments include facilitation and funding infrastructure development. The building of dams is an important strategy for improving water supply in the study area. Dams are mostly funded by the national Department of Water Affairs with provincial and municipal governments leading local facilitation (RSA, 1998a). Reticulation infrastructure and water services are mostly funded by municipalities (RSA, 1997).

The availability of adequate well maintained water infrastructure has a strong influence on the supply of water (Randall, 1981; Backeberg and Groenewald, 1991).

Major dams in the study area are the Mokolo, Doorndraai, and Nzhelele in the Limpopo WMA and the Albasini, Vondo, Nandoni, Middle Letaba, Nsami, Ebenezer and Tzaneen in the Luvuvhu-Letaba WMA (DWAF, 2003; DWAF, 2004b). The dams store water in the wet season when and where the marginal value of the resource is low and reallocates it to the dry season when and where the marginal value is high (Keller *et al.,* 2000). [a] Prior to building more dams in the Limpopo Province, planners should know the quantity of water that can be stored in the existing dams and the amount of water that could remain available for future storage, and these were investigated in this study.

The extent of development of infrastructure in the Limpopo Province varies from one locality to another. The general trend is for urbanised areas to have better infrastructure than their rural counterparts although access to services provided by such infrastructure is influenced by the economic status of individuals (DANIDA, 2000). Although the issue of water reticulation infrastructure is important for water management in the study area, it is not the focus of this study and will not be further investigated.

(b) Economic condition

Limpopo is one of the poorest provinces in South Africa (RSA, 2000). The province only contributes 6.9% of the GDP (Stats SA, 2008). The poverty is affirmed by the lack of infrastructure, including water reticulation infrastructure. According to Stats SA (2009), only 18% of households had piped water inside the house compared to 47.2% nationally. The smaller number of households with piped water suggests a lack of infrastructure for water services and affirms RSA (2000) that the province is poor. As a result of poverty, most households are registered as indigents in order to qualify for social grants and free services such as water services (Stats SA, 2011a). Up to 57.9% of households in the province receive grants compared to the national figure of 28.4% (Stats SA, 2011b).

With this state of poverty, increased development of the water resource could make it possible for new economic development projects to be initiated. Further development of the water resource may only be possible if relevant stakeholders have adequate knowledge about the resource and its current use. It is only when the stakeholders are knowledgeable that they will be able to make informed decisions about the prospects of further development of the resource for future use. Among the critical stakeholders for the water sector are the municipal water managers. The responsibilities of the municipal water managers are to broaden as the Department of Water Affairs continues with its restructuring in which most implementation functions will be transferred to municipalities for the department to focus on policy issues (DWAF, 2007).

Although the water managers report directly to municipal managers (administrative head of district or municipality), they also report indirectly to the mayors of their municipalities. The water managers advice both the municipal managers and the majors on water issues and have a lot of influence on water management decisions. The managers' knowledge of their water resources is therefore crucial for them to make informed resource management decisions. [b] There is a lack of information about these managers knowledge of the water resources and hence it was necessary for this study to conduct some focussed research on this issue.

(c) Social situation

The social environment includes social services such as health and education (Barnett and Casper, 2001), communication networks and the participation of people in decision making. On the issue of health services, Limpopo Province has 40 public hospitals distributed in the five districts of Capricorn (9 hospitals), Mopani (8), Sekhukhune (7), Waterberg (8) and Vhembe (8) (OTP, 2009). In addition to the shortage of health professionals, the hospitals mostly have dilapidated infrastructure with old equipment which result in poor services.

With regards to education, the province still faces challenges of poor classroom infrastructure and shortage of educators and equipment for learning areas such as mathematics and science.

The shortage of classroom infrastructure has made the Department of Education introduce mobile classes (Nduvheni, 2007). In terms of the educational status of the population, 19.4% had no schooling compared to only 9.4% nationally. Some 5.9% of the population had primary education compared to 7% nationally, 12.5% had grade 12 compared to 18% nationally, while 6.4% had tertiary education compared to 8.8% nationally (Stats SA, 2009). The above statistics indicate that the province is educationally under-developed compared to the national situation.

Other than the written media, communication of water sector information would require access to media such as radio and television. With a population of 5.2 million, Limpopo Province has a radio listenership of 3.3 million and a television viewership of 2.7 million (MDDA, 2009). The population is therefore well exposed to information communicated through both radio and television media.

Water sector information communicated through radio and television should reach the majority of the population and may promote public participation in resource management decisions. The participation of all relevant stakeholders in water decisions is important for broader community acceptance of the decisions. The National Water Act (Act No. 36 of 1998) provides for the formation of institutions such as the Water Users Associations (WUAs) and Catchment Management Agencies (CMA), (RSA, 1998b) to allow for stakeholder participation.

Communities in the province occasionally embark on public protests against the government's performance in delivering water services. These protests may be indicative of poor participation of the communities in water management decisions. There is a lack of information on major stakeholders of the water sector in the province and their level of participation in resource decision making. To address the stakeholder information gap, this research project conducted a focussed investigation of the existing stakeholders and their level of participation in resource management decisions.

(d) Technological situation

Associated with poor economic development and low educational status, the province has low capacity to generate relevant technologies to respond to water challenges. The low capacity to generate technologies is also associated with lack of research capacity. Factors associated with the lack of capacity to conduct research include the scarcity of research skills and requisite infrastructure. It is important for the province to build research capacity in order to generate appropriate technologies to respond to the challenges faced by the water sector. Initiatives to develop research capacity should be focussed at the two universities in the province, the University of Limpopo and the University of Venda as they already have some basic resources.

Water sector problems for possible research should include those related to the hydrology of catchments and reservoirs. Reservoir problems demanding research would include that of the Middle Lataba Dam that seldom fills up. The dam is one of the large reservoirs in the province and its persistent low water levels contribute to the problem of shortage of water supply. The area planned to be supplied from this dam has experienced frequent shortages of water.

The shortage of water supply from the Middle Letaba Dam has resulted in a situation where the limited water available is reserved only for household use. Other planned uses such as irrigation are not supplied and therefore multi-million rand worth of irrigation infrastructure installed in some farming projects is not used. Major investments in irrigation infrastructure were made at the Homu and the Middle Letaba Irrigation Schemes. These schemes have scaled down agricultural production because of shortage of water. [d]It is not clear whether the Middle Letaba Dam will ever fill up to its capacity and allow for increased supply of water to target communities. It was therefore necessary to conduct a focussed investigation of the hydrology of this dam. There may be more cases in the province that require research intervention and development of responsive information and technologies, and this necessitates some improvement of research capacity.

(e) Legal situation

Similar to the situation in the broader South Africa, the legal environment of the Limpopo Province is characterized by having some of the undesired water decisions taken under the 1956 Water Act (RSA, 1956) continuing to apply. This results in frustration among users who would like the changes stated in the Water Act of 1998 (RSA, 1998b) to be implemented. This delay in implementing certain aspects of the Water Act of 1998 creates disgruntled water users.

Among the major problems caused by the 1956 Water Act (RSA, 1956) is the inequitable allocation of water. Such inequitable allocations results in certain areas such as most rural communities and some uses being under-supplied while other areas and uses have more water than they need. Some of these inequitable allocations continue to apply even though there is a new Water Act of 1998 in place (RSA, 1998b) and this result in some communities lacking water for household use while others have the resource for luxury consumption.

Unfortunately, there is not much information on household water supply in the study area, more so for rural households. In some cases there may be information but that is mostly outdated information as new water schemes are developed annually. Some water taps are often dry due to shortage of supply from the storage while some reticulation systems with abundant supply from storage are non-operational due to poor maintenance. Estimation of water supply to the households based on availability of infrastructure may therefore be misleading. With this dearth of information on water supply to households in the study area, the study included an investigation of household water supply with a focus on rural households.

1.3.3 Environment

Rainfall and evapotranspiration are the major factors of the environment that influence the availability of water resources in an area and are therefore the focus for this discussion.

(a) Rainfall

Rainfall is the fundamental driving force and pulsar input behind most hydrological processes (Schulze, 1995). The rainfall of Limpopo Province is highly variable from one place to another and this has led to a climate that is semi-arid in some parts and sub-humid in other parts of the province. The rainfall of the study area was calculated based on the rainfall figures of the ten municipalities selected for the study (Table 1.1) obtained from the South African Weather Services (SAWS, undated) for weather stations located in those municipalities.

Table 1.1 Mean monthly rainfall (mm) distribution of sampled municipalities in the study area (SAWS, undated)

Month	Municipalities in WMAs and their mean monthly rainfall (MMR)										MMR
	Limpopo WMA					Luvuvhu-Letaba WMA					
	Makhado	Musina	Lephalale	Polokwane	Aganang	Letaba	Thulamela	Tzaneen	Giyani	Mutale	
Jan	134	58	76	82	109	185	74	131	115	93	**106**
Feb	157	57	78	60	79	184	108	147	119	105	**109**
Mar	109	39	56	52	51	120	75	115	70	58	**75**
Apr	40	27	21	33	30	54	47	42	30	26	**35**
May	20	10	3	11	9	18	15	17	15	11	**13**
Jun	11	4	8	5	3	9	17	11	2	6	**8**
Jul	11	1	3	3	6	8	14	10	7	7	**7**
Aug	11	1	4	6	3	9	11	11	5	8	**7**
Sep	28	12	10	17	12	17	39	17	25	19	**20**
Oct	71	24	43	43	44	53	93	66	37	33	**51**
Nov	93	49	53	85	88	96	76	87	76	60	**76**
Dec	122	57	80	81	87	150	128	109	86	91	**99**
MAP	**807**	**339**	**435**	**478**	**519**	**902**	**697**	**762**	**588**	**515**	**604**
	516					**693**					**604**

As shown in Table 1.1, more rainfall is received during summer months and less is received during winter months. The rainfall season begins in spring with an average across the area of 20mm in September where three municipalities recorded ≥ 25mm. By October the rainy season has begun and all stations are receiving more than 50mm on average with Thulamela recording the highest monthly rainfall of 93mm. The mean across the area increased through November (76mm) and December (99mm) with January and February representing the peak rainy months with more than 100mm each. Thereafter the mean rainfall across the area declines through March (74mm), April (35mm), May (13mm), June (8mm), and then July and August are the months with the lowest rainfall of 7 mm each.

Considering the municipal mean annual rainfall (MAP in mm per annum), Letaba (902mm) > Makhado (807) > Tzaneen (762) > Thulamela (697mm) > Giyani (588) > Aganang (519) > Mutale (514.9) > Polokwane (478) > Lephalale (435) > Musina (339). Generally, the municipalities in the Luvuvhu-Letaba WMA have higher MAP (all > 500 mm) than those in the Limpopo WMA where three have MAP<500 mm. The average MAP for the Limpopo WMA was 516 mm while that of the Luvuvhu-Letaba WMA was 693mm. The average rainfall of the province is estimated at 500 - 600mm per annum which is low compared to the world average of 860mm per annum (DWAF, 2004a). With this rainfall pattern, the question is how much water is actually available for use in the study area?

(b) Evapotranspiration

Evapotranspiration (ET) is the major loss of water from a hydrologic system (Schulze, 1995). Methods of estimating ET include evaporation pans, monitoring soil water under controlled conditions, and applying known rates of potential ET to an area based on its land use and vegetative cover (Webb, 2005). The ET of the study area was calculated based on the ET figures of the ten study municipalities based on ET data obtained from the SAWS (undated) for weather stations located in those municipalities (Table 1.2).

Table 1.2 Mean monthly evapotranspiration (ET mm) of sampled municipalities in the study area (SAWS, undated)

Month	Municipalities										Mean ET
	Limpopo WMA					Luvuvhu-Letaba WMA					
	Makhado	Musina	Lephalale	Polokwane	Aganang	Letaba	Thulamela	Tzaneen	Giyani	Mutale	
Jan	175	166	155	161	157	132	158	133	150	161	**155**
Feb	146	144	130	153	136	112	133	112	127	136	**133**
Mar	141	140	129	149	133	105	132	123	124	130	**131**
Apr	111	111	108	108	111	86	107	86	96	108	**103**
May	93	96	84	92	92	70	93	73	84	88	**86**
Jun	75	78	77	78	81	60	83	60	72	74	**74**
Jul	82	84	84	85	88	65	85	65	74	82	**80**
Aug	110	107	113	107	113	81	109	81	93	104	**102**
Sep	143	126	144	134	141	99	137	101	120	122	**126**
Oct	163	154	163	164	169	118	152	118	141	152	**149**
Nov	164	162	165	161	168	120	155	120	143	153	**151**
Dec	171	167	166	161	171	129	160	129	147	166	**157**
Annual ET	1572	1534	1517	1552	1559	1176	1501	1199	1372	1475	**1446**
	1547					**1345**					

As shown in Table 1.2, ET is generally lower during the winter months of May to July where the mean monthly ET ranged between 74mm and 86mm. The ET is higher during summer months of November to January with mean monthly ET ranging between 151mm and 157mm. The study area losses more water through ET during summer months despite this being the season in which more rainfall is received.

Considering municipal ET (mm per annum), Makhado (1572.3mm) > Aganang (1559.1) > Polokwane (1551.8) > Musina (1534.2) > Lephalale (1516.5) > Thulamela (1501.2) > Mutale (1475.3) > Giyani (1371.7) > Tzaneen (1198.8) > Letaba (1175.6). The five municipalities with higher ET are from Limpopo WMA while those with lower ET are from Luvuvhu-Letaba WMA.

As a result, the Limpopo WMA has a higher average annual ET (1546.8) than the Luvuvhu-Letaba WMA (1344.5mm). The ET for the Limpopo Province is generally high having a negative influence on water resource availability; the question remains how much water is actually available for use in the study area.

(c) Water supply situation

Despite all the river catchments and the rainfall and ET patterns as described above, Limpopo is a water scarce province. As alluded to by Molden *et al.* (2002) the shortage of water in the province is a result of physical scarcity of the resource. The scarcity was affirmed by RSA (2003) statement that the province is one of those depending on other areas for water supplies and by OTP (2009) who revealed that the scarcity of the resource is a major constraint for development. The scarcity of water in the province has constrained supplies to different users and is a major problem.

The scarce supply of water in the Limpopo Province has necessitated this study. The rest of South Africa experiences a physical scarcity of the water resource to some extent, but little can be done to change this type of scarcity in the province. The water supply of the province may be improved through management interventions that promote resource storage and efficient use, and such interventions require water service organisations with relevant capacity. [f]It was therefore necessary for the study to identify water service organisations and to assess their capacity to address water sector challenges.

1.4 Purpose of the study

The above description of the Limpopo Province was based on 'real-life' issues that prevail in the area with some highlights of information gaps (a – f) that may be influencing the water sector negatively. These information gaps constitute 'real-life' problems of the water sector in the area and were used to inform the definition of the purpose of the study (Mouton, 2001).

As guided by Mouton (2001), reflection about the macro-environment of the study area and its 'real-life' problems was done in a non-scientific manner, and therefore a more rigorous and systematic reflection was necessary to formulate the research objectives. It was subsequent to this rigorous and systemic reflection that the research objectives were presented alongside the real-life problems identified when describing the macro-environment of the study area (Table 1.3).

Table 1.3 Real-life problems of the water sector in Limpopo Province and corresponding research objectives to address them

Level	Real-life problem	Research objective
Specific 1	[a] ...planners should know the quantity of water that can be stored in existing dams and the amount that could remain available for future storage...	To determine the prospects for developing water storage through analysis of runoff and storage capacity of river catchments and municipalities
Specific 2	[b] There is a lack of information about water managers knowledge of the water resources...	To conduct an inquiry on the perceptions of municipal water managers on water resources, uses and restrictions
Specific 3	[c] Need focussed investigation of the existing stakeholders and their level of participation in resource management decisions.	To investigate municipal water managers perceptions of stakeholder participation and influence on water management decisions
Specific 4	[d] It is not clear whether the Middle Letaba Dam will ever fill up to its capacity and allow for increased supply of water ...	To investigate the influence of rainfall on water gain and loss from the Middle Letaba Dam
Specific 5	[e] ...lack of information on water supply to rural households in the study area...	To investigate the water supply and requirements of rural households in the study area
Ultimate	[f] ...It was necessary to identify water service organisations and to assess their capacity to address water sector challenges.	To develop a water management decision model informed by the challenges and opportunities revealed by focussed investigations listed above.

1.5 Summary

This chapter presented the study foundation focusing on the overview of the national water resources, description of the study area (geographic, socio-economic and environmental), and the purpose of the study. The study posits that there are 'real-life' issues that prevail in the area with some highlight of information gaps that may be influencing the water sector rather negatively. These information gaps constitute 'real-life' problems of the water sector in the area and informed the definition of the purpose of the study. The research objectives were presented alongside the real-life problems identified when describing the macro-environment of the study area.

1.6 Outline of the thesis

The study objectives cover thematic issues of water resource, resource management, household water supply and requirement, and finally the development of a water management decision model (Table 1.3). The outline of the thesis inclusive of specific chapters based on the research objectives is as follows:

Chapter One (which is this chapter) is introductory and presents: (1) chapter introduction; (2) overview of national water resources; (3) description of the study area (geographic, socio-economic and environmental); (4) purpose of the study; and (5) summary and (6) outline of the thesis.

Chapter Two discusses the design and methods used in conducting the research. The discussion includes: (1) orientation and planning of the study; (2) the design of survey questionnaires; (3) sample frame and sampling procedure; (4) collection of data; (5) data analysis; (6) restrictions of the study; (7) time schedule; (8) description of the study area.

Chapter Three discusses the literature review with a focus on: (1) mathematical models; (2) social models; and (3) experiences of using the congruence model.

Chapter Four discusses runoff and storage capacity of catchment and municipalities in the study area. The discussion focuses on: (1) introduction of the concepts runoff and storage capacity; (2) study methods with special attention given to (a) description of the study area, (b) sample frame and sampling procedure and (c) data collection and analysis; and (3) results and their discussion with a focus on (a) runoff and storage capacity of river catchments and (b) runoff and storage capacity of municipalities; and (4) conclusions.

Chapter Five discusses rainfall influence on water gain and loss from Middle Letaba Dam with major topics discussed being: (1) introduction of concepts of water gain and loss by reservoirs; (2) research methods with a focus on (a) dam location and physical characteristics, (b) sampling procedure and (c) data collection and analysis; and (3) results and their discussion under major topics on (a) rainfall received over the surface area of the dam, (b) the influence of rainfall on inflow from source river, (c) rainfall influence on evaporation from the dam surface, (d) the influence of rainfall on outflow from the dam and (e) rainfall and dam water storage volume; and (4) conclusions.

Chapter Six discusses the perceptions of municipal water managers on water resources, uses and restrictions. The specific topics covered by the discussions were: (1) introductions of the concepts water resources, uses and restrictions; (2) study methods with a focus on: (a) area covered by the study, (b) sample frame and sampling procedure and (c) data collection and analysis; (3) results and discussion with particular attention on: (a) perceptions on municipal water resources, (b) perceptions on water uses, (c) perceptions on water restrictions; and (4) conclusions.

Chapter Seven discusses stakeholder participation and their influence in water management decisions as perceived by local municipal water managers. Specific issues discussed included: (1) introduction of the concepts stakeholders and stakeholder participation; (2) research methods with a focus on (a) description of the area covered by the study, (b) sample frame and sampling procedure and (c) data collection and analysis; (3) results and their discussion under the sub-headings: (a) stakeholder organisations and their roles, (b) stakeholder participation in water management decisions and (c) stakeholder influence on water management decisions; and (4) conclusions.

Chapter Eight discusses water supplies and uses by households in the study area. The topics covered by the discussions were: (1) introduction of household water supply and uses; (2) research methods focusing on (a) description of the area covered by the study (b) sample frame and sampling procedure and (c) data collection and analysis; (3) results and discussion with a focus on (a) characterization of the households, (b) household water supplies, (c) household water uses and (d) household rating of the water services; and (4) conclusions.

Chapter Nine analyses the water sector challenges and research conclusions of chapter three to eight and accordingly proposes a water management decision model to address these challenges. The discussions of this chapter focussed on: (1) introduction highlighting the water sector challenges; (2) study methods with special attention on (a) description of the Congruence Model as a framework of a proposed water management decision model, (b) sample frame and sampling procedure, (c) description of study area and (d) data collection and analysis; (3) results and their discussion with special attention on (a) input components and their influence on water sector, (b) major challenges faced by the water sector, (b) organisational strategies and their congruence with water sector challenges, (c) transformation components and their congruence with water sector challenges, (d) congruence flow analysis and proposed capacity improvement and (e) proposed water management decision model adapted from the Congruence Model.

Chapter Ten provides a highlight of the main findings and their implications for policy. These were followed by policy recommendations for (1) catchment runoff and storage capacity, (2) dam hydrology, (3) water managers' knowledge of the resource and its uses, (4) stakeholder participation in water decision making, (5) household water supply and requirement, and (6) water management decision model.

1.7 Publication of research work

It must be noted that several of the chapters of this study were written in the form of self-contained published scientific articles (chapters 4 to 9). The scientific publications that arise from this study are as follows:

Chapter 4: Runoff and storage capacity of municipalities and rivers of Limpopo and Luvuvhu-Letaba WMA of South Africa – **Abstract** was published in *Proceedings of the 10th WaterNet/WARFSA/GWP Symposium in Entebbe, Uganda, in 2009.*

Chapter 5: Rainfall influence on water gain and loss from Middle Letaba Dam in Luvuvhu-Letaba WMA – **Abstract** was published in *Proceedings of the 11th WaterNet/WARFSA/GWP Symposium in Victoria Falls, Zimbabwe, in 2010.* **Full text** was published in the *International Journal of Applied Science and Technology, 2(3): 24-33.*

Chapter 6: Perceptions of rural municipal water managers on water resources, uses and restrictions – **Abstract** was published in *Proceedings of the 10th WaterNet/WARFSA/GWP Symposium in Entebbe, Uganda in 2009.* **Full text** was published in the *International Journal of Business and Social Science, 3(5): 8-20.*

Chapter 7: Perceptions of rural municipal water managers on stakeholder participation in water issues in Limpopo and Luvuvhu-Letaba WMAs – **Abstract** was published in *Proceedings of the 10th WaterNet/WARFSA/GWP Symposium in Entebbe, Uganda in 2009.* **Full text** was published in the *American International Journal of Contemporary Research, **2(9):26-37***

Chapter 8: Household water supply and uses by rural households in the Limpopo Province of South Africa – **Abstract** was published in *Proceedings of the CTA Annual Seminar in Johannesburg, South Africa in 2010.* **Full text** was published in the *International Journal of Business and Social Science, 3(3): 37-49.*

Chapter 9: Challenge and capacity congruence analysis for development of a water management decision model – Accepted for **full text** publication in the *American International Journal of Contemporary Research, Vol. 2 No. 10 (scheduled to be published on 10 December 2012).*

CHAPTER 2

2 RESEARCH METHODOLOGY

2.1 Introduction

This chapter discusses the research methods followed in conducting the study to achieve the objectives outlined in Chapter 1. The choice of the methods was determined by the commitment to generate truthful knowledge as this is the overriding goal of science (Mouton, 1996). The quest for truth in this research has made choice of the correct methodology very important.

The study used available knowledge from various disciplines to produce relevant scientific knowledge to address water sector problems in the Limpopo Province. It was therefore regarded important to provide some description of 'knowledge' in general and 'scientific knowledge' in particular. The different types of knowledge obtainable in the study area define the context of the study and hence their proper description provides guidance for selection of the most suitable research methods.

2.2 Description of knowledge

The description of knowledge focused on the kinds of knowledge and some highlights of scientific knowledge.

2.2.1 Kinds of knowledge

There are three kinds of knowledge, namely: (1) folk or lay knowledge, (2) scientific knowledge and (3) meta-scientific knowledge (Mouton, 1996; Mouton, 2001). Lay knowledge is obtained from sources such as authority, opinions of peers, traditions, debating, and accidental observations (Welman *et al.,* 2005) and is acquired through learning, experience and self-reflection and enables us to live a human life (Mouton, 1996).

In order to generate scientific knowledge, scientists make phenomena (politics, economics, etc.) of folk knowledge objects of systematic and rigorous inquiry and investigation with the goal of searching for truth (Mouton, 1996; Leedy and Ormrod, 2010). The essence of research methodology in searching for truth was highlighted by Welman *et al.* (2005) who argued that the scientific approach is concerned with the way in which findings are acquired.

Meta-scientific knowledge on the other hand covers reflections on the nature and dynamics of scientific knowledge, and this has led to the development of disciplines such as philosophy of science and research methodology. Meta-science makes scientific knowledge an object of critical inquiry and reflection with the purpose of dissecting, deconstructing or analysing what scientists do toward the ultimate improvement of science (Mouton, 1996).

From the above discussion, folk knowledge serves as data (objects) for analysis and interpretation to generate scientific knowledge. At a different level, scientific knowledge also serves as data for higher level analysis and interpretation referred to as 'reflection' to generate updated scientific knowledge. Through their different levels of data analysis and interpretation, both the scientific and the meta-scientific processes generate scientific knowledge with the scientific process using folk knowledge as its data while the meta-scientific process uses scientific knowledge as its data.

This study used all the three kinds of knowledge. Folk knowledge included the secondary data mostly on climate and hydrological issues obtained from reports of the Department of Water Affairs (DWA) **(chapters 4 and 5)** and those of different water service organisations **(Chapter 9).** The folk knowledge was also in the form of perceptions of respondents to interview questions. The respondent perceptions were recorded in chapters where information was collected through interviews (**chapters 6 to 8**).

Also, folk knowledge was recorded from meetings with officers of different institutions involved in the water sector, and those included the Department of Water Affairs (DWA), Limpopo

Department of Agriculture (LDA) and different municipalities (**chapters 4 to 9**). Discussions were conducted with peer researchers at water conferences where some of the chapters were presented as research articles and some folk knowledge was recorded. Scientific knowledge was mainly collected through literature study where relevant scientific documents served as sources of the information.

The study subjected the collected folk knowledge to a systematic and rigorous inquiry (scientific process) to generate new scientific knowledge (Mouton, 1996; Leedy and Ormrod, 2010). In addition to folk knowledge, the research also collected existing scientific knowledge and this was mainly through literature. The existing scientific knowledge was subjected to critical inquiry and reflection (meta-scientific process) to generate updated (meta-) scientific knowledge. The updated scientific knowledge consisted of scientific statements that were upheld after the critical inquiry and reflection as well as those amended after rejection of the original statement. The use of all the three types of knowledge in this research project was necessary to have appropriate information for development of a water management decision model.

2.2.2 Scientific knowledge

The rationale for this study was to subject both folk knowledge and existing scientific knowledge to systematic and rigorous inquiry and reflection to generate new valid scientific knowledge relevant to address the water challenges in the study area. In-depth understanding of the nature of scientific knowledge was necessary for correct methodology to be used to generate the knowledge and for it to be properly used to solve problems.

Scientific knowledge was described as a 'house of science' with the foundation built of factual statements that are easily verifiable and seemingly irrefutable and the walls built of statements that are difficult to verify (Mouton, 1996). The easily verifiable statements are those that are objective and are often quantitative while those that are difficult to verify are subjective and are often qualitative. These different types of statements (quantitative and qualitative) informed the research approaches used and were discussed more under section 2.3.

In the same way that a house needs both the foundation and walls, scientific knowledge requires both the easily verifiable statements and those that are difficult to verify. As stated by Mouton (1996), the description of scientific knowledge as the house of science regards science as a phenomenon that progresses slowly but surely as additional bricks become more cemented. These additional bricks would be the new statements that are easily verifiable for the foundation and those that are difficult to verify for the walls of the house of science.

In addition to being described as a house (of science), scientific knowledge was also described as something that evolves, suggesting that it changes over time. In the cause of evolution, the scientific statements that withstand attempts at rejection emerge stronger and are accepted as part of the body of knowledge. The acceptance is always provisional until attempts at falsification succeed (Mouton, 1996; Terre Blanche *et al.,* 2009). The upholding and rejection of scientific statements occur as a result of the critical inquiry and reflection on existing scientific knowledge which in this study was mostly collected through literature survey.

The fact that scientific knowledge is only accepted provisionally results in the history of science being comprised of a period of normal science where a particular research paradigm (or tradition) dominates followed by a scientific revolution when the dominant paradigm is rejected, and this results in scientific knowledge consisting of sets of paradigms (Mouton, 1996). While this study made reference to knowledge from previous research work, it never regarded such knowledge to be the final truth (Walsham, 1995) as this would uphold the knowledge even when it should be rejected. Regarding existing scientific knowledge as the final truth limits the possibility of such knowledge being subjected to meta-scientific activities of analyses, dissection and deconstruction (Mouton, 1996) and the opportunity for ushering in new paradigms.

The two components of scientific knowledge (verifiable vs non-verifiable) are mutually inclusive and complementary and hence this study adopted both of them in its attempt to contribute to the generation of knowledge for addressing water sector challenges in the Limpopo Province. By subjecting existing folk and scientific knowledge to (meta-) scientific processes of systematic and rigorous inquiry and reflection, the study aimed to generate new scientific knowledge that will introduce new thinking in the water sector. The new knowledge should remain relevant not only spatially for the areas with similar socio-economic and hydrologic environment, but also temporally for the times when such hydrologic and socio-economic environment occurs. When such spatial or temporal relevance is lost, application of the knowledge and the subsequent water management decision model will inevitably also be lost to the historic sets of paradigms of scientific knowledge.

2.3 Research approach

The description of knowledge and the focussed description of scientific knowledge provided the context for selection of relevant research methods used in this study. Selection of relevant research methods was critical to produce credible knowledge to solve water sector problems in the Limpopo Province. Before considering specific research methods, it was considered necessary to select appropriate research approaches for the context described by the different kinds of available knowledge in order to generate truthful knowledge worthy to fulfil the epistemic interest of this scientific study.

2.3.1 Main approaches

There are two main approaches to research, the positivist and the anti-positivist approach (Welman *et al.,* 2005). The positivist is also known as the quantitative approach and underlies the natural-scientific method in human behavioural research. According to the positivist approach, research must be limited to what we can observe and measure objectively, i.e. that which exists independently of the feelings and opinions of individuals (Welman *et al.,* 2005). Anti-positivists are also known as qualitative researchers and share a resistance to upholding the natural-scientific method as the norm in human behavioural research (Welman *et al.,* 2005). For the purpose of simplicity, the two approaches were referred to in this study as the quantitative and qualitative approaches.

The quantitative approach emphasizes the measurement and analysis of causal relationships between variables (Denzin and Lincoln, 1994). This emphasis on measurement was upheld by Leedy and Ormrod (2010) who indicated that the approach quantifies behaviour in terms of such things as number of occurrence and ratings for accuracy or other dimensions.

The qualitative approach on the other hand emphasizes on processes and meanings that are not measured in terms of quantity, intensity or frequency (Denzin and Lincoln, 1994). This was supported by Leedy and Ormrod (2010) who described qualitative research as an approach that considers characteristics or qualities that cannot easily be reduced to numerical values.

The decision of whether this research study should adopt a quantitative or qualitative approach or both necessitated deep insight on these approaches. Important aspects for guiding the selection of an approach included the purpose and nature of research and data description, collection and analysis (Table 2.1).

Table 2.1 Comparison of quantitative and qualitative research approaches (Leedy and Ormrod, 2010)

Aspect of comparison	**Quantitative**	**Qualitative**
Purpose of research	• To test theory	• To build theory
Nature of research process	• Somewhat context-free • Detached view	• Context-bound • Personal view
Data description and collection	• Numerical data • Large representative sample • Standardized instruments	• Textual, image based data • Small informative samples • Loosely structured interviews
Data analysis	• Statistical analysis • Stress on objectivity	• Search for themes and categories • Subjective with potential bias

As shown in Table 2.1, the quantitative and qualitative research approaches contradict each other in all the aspects of comparison. Choice of the research approach for the current study had to consider these opposing views of the two approaches on the four aspects. The study included investigations using each of the two approaches and is therefore regarded as using a mixed approach.

2.3.2 Rationale for a mixed approach

Having gained more insight from the comparison of quantitative with qualitative research approaches by Leedy and Ormrod (2010), the attributes of the approaches were matched with the research objectives (Table 2.2) in order to select the correct approach for each objective. A research approach was decided for each research objective based on how well the attributes of the approach matched the statement of the objective.

As shown in Table 2.2, the selected approach for each objective was described as a dominant approach. This was necessary because the objectives would practically not entirely match one approach but would include a limited amount of the attributes of the unmatched approach. It was on the basis of the dominant matching attributes that the approach for each objective was selected.

Table 2.2 Research objectives and matching attributes of research approaches

Research objective	Major attributes	Dominant approach
1. To determine the prospects for developing water storage through analysis of amount of runoff and storage capacity of river catchments and municipalities	• To test theory • Numerical data • Statistical analysis • Stress on objectivity	Quantitative
2. To investigate the influence of rainfall on water gain and loss from the Middle Letaba Dam	• To test theory • Numerical data • Statistical analysis • Stress on objectivity	Quantitative
3. To conduct an inquiry on the perceptions of municipal water managers on water resources, uses and restrictions	• To build theory • Textual data • Loose structured interview	Qualitative
4. To investigate municipal water managers perceptions of stakeholder participation and influence on water management decisions	• To build theory • Textual data • Loose structured interview	Qualitative
5. To investigate the amount of water supply and requirements of rural households in the study area	• To test theory • Numerical data • Statistical analysis • Stress on objectivity	Quantitative
6. To develop a water management decision model informed by the challenges and opportunities revealed by focussed investigations listed above.	• To build theory • Textual data • Search for themes Subjective	Qualitative

As shown in Table 2.2, the quantitative and qualitative research approach was each selected for three of the study objectives. The study will therefore use both research approaches. According to Hurmerinta-Peltomaki and Nummela (2006), this study that uses both quantitative and qualitative approaches is referred to as a mixed study.

2.4 Research design

To develop a credible 'research design', it was important for the concept to be defined. A 'research design' is a set of guidelines and instructions to be followed in addressing the research problem (Welman *et al.,* 2005). The research design provides the overall structure for the procedures the researcher follows, the data collected and the data analysis conducted (Leedy and Ormrod, 2010). In simpler terms, the research design is like a route planner; it is a set of guidelines and instructions on how to reach the goal of the research (Mouton, 1996; Mouton, 2001). According to Mouton (1996) the rationale for a research design is to plan and structure a research project in such a way that the validity of the research findings is maximized through minimising or eliminating errors.

Development of an appropriate research design for this study necessitated a guiding framework. A comprehensive framework was developed by Mouton (2001) and includes factors such as design classification, type of sampling, data collection and data analysis and interpretation. The research designs for the different chapters of this thesis were developed based on these factors (Table 2.3). The development of chapter based research designs was necessitated by the fact that each chapter is based on a specific research objective with a dominant research approach (Table 2.2).

The design classification used for the current chapter **(Chapter 2)** was non-empirical and entailed the use of secondary textual data (Table 2.3). The decision to classify the design of this chapter as non-empirical was informed by the fact that the units of analysis were mainly objects in the world of science and not those in the world of everyday life (Mouton, 1996).

Table 2.3 Research designs for different chapters included in the study

Chapter	Design classification	Type of sampling	Data collection	Analysis & interpretation
2.Research methodology	Non-empirical, secondary, textual data	Non-probability, study documents and texts selected based on theoretical considerations	Existing literature and stakeholder consultation	Qualitative analysis with subjective interpretation
3.Literature review	Non-empirical, secondary textual or numerical data	Non-probability, documents and texts selected based on theoretical considerations	Existing literature collection based on main themes	Qualitative analysis with subjective interpretation
4.Building new dams through analysis of runoff & storage capacity	Empirical, secondary, numerical data	Random (probability) sampling	Existing data obtained mainly from DWA	Statistical analysis with objective interpretation
5.Rainfall *influence* on water gain and loss	Empirical, secondary, numerical data	Purposive (non-probability) sampling	Existing data obtained mainly from DWA	Statistical analysis with objective interpretation
6. Municipal manager perceptions on water resources	Empirical, primary, textual data	Random (probability) sampling	Respondent interviews using semi-structured questionnaire	Qualitative analysis with subjective interpretation
7. Municipal manager perceptions on stakeholder participation	Empirical, primary, textual data	Random (probability) sampling	Respondent interviews using semi-structured questionnaire	Qualitative analysis with subjective interpretation
8.Water supply & requirements of household	Empirical, primary, textual & numerical data	Random (probability) sampling	Respondent interviews using semi-structured questionnaire	Statistical analysis with objective interpretation
9.Water management decision model	Empirical, secondary, textual data	Purposive (non-probability) sampling	Existing strategic plans and annual reports of selected organisations	Qualitative analysis with subjective interpretation

As shown in Table 2.3, the chapter was based on secondary textual data. The chapter presented mainly non-probability sampling where the study methods were selected based on their attributes. In non-probability sampling the researcher has no way of guaranteeing that each element of the population will be represented in the sample (Leedy and Ormrod, 2010). The data used in the chapter is mainly from literature. Data analysis is qualitative and the interpretation highly subjective.

Qualitative analysis of data was described by Creswell (1998) who revealed that the process entails: (1) organizing the data where large bodies of text are broken into smaller units; (2) perusing the entire data set several times to have a sense of what it contains as a whole and to note major categories; (3) identifying general categories or themes and classifying them accordingly; and (4) integrating and summarising the data, a step that may include description of relationships among categories. These guidelines were followed in conducting the qualitative analysis of the data.

Chapter 3 is on literature review which used scientific knowledge in the form of literature as the object of analysis and therefore the design was also non-empirical with secondary data that was mainly textual. Non-probability sampling was again used where documents and texts were selected based on theoretical considerations. Data was in the form of existing literature and was analysed qualitatively with subjective interpretations.

As shown in Table 2.3, the research design used in **chapters 4 and 5** was empirical and used secondary data that was mainly numerical. The secondary data was composed of unpublished reports mainly from the Department of Water Affairs (DWA) that provided statistics of issues such as catchment runoffs, dam storage capacity and the hydrological factors of water gain and loss from the Middle Letaba Dam. While **Chapter 4** used random (probability) sampling to select the study units, **Chapter 5** used purposive (non-probability) sampling (Leedy and Ormrod, 2010). The data for both chapters were analysed statistically with objective interpretations. Statistical analysis involved the use of statistical calculations to analyse numerical data in order to establish the meaning beneath the numbers.

The designs used in **Chapters 6 to 8** were classified as empirical where primary mainly textual data was used for **Chapters 6 and 7** with both textual and numerical data used for **Chapter 8.**

Study units for these three chapters were selected using random (probability) sampling and data was collected using semi-structured questionnaires. The data was analysed using qualitative methods and interpreted subjectively for **chapters 6 and 7** while mixed (qualitative and statistical) analysis was used for **Chapter 8.** The research design for **Chapter 9** was also empirical with secondary textual data. Sampling was purposive (non-probabilistic) and the data was in the form of strategic plans and annual reports of selected water service organisations. Data analysis was through qualitative methods where interpretation was subjective.

2.5 Research methods

The concept of 'research method' refers to the techniques used to collect and analyse data. As a result, the method to be used for a particular research problem must always take into account the nature of the data that will be collected in the resolution of the problem (Leedy and Ormrod, 2010). With the adoption of a mixed research approach and multiple designs, the study also used multiple methods. The use of multiple methods was advocated for on literature on social science (Kock, 2002; Yoong and Pauleen, 2004; and Dick, 2006) and therefore the concept is not unusual. The different methods used in this study were literature review, secondary data analysis, survey method and content analysis.

2.5.1 Literature review methods

Literature reviews are studies that provide an overview of literature in a certain discipline through an analysis of trends and debates. The importance of literature review is that it provides lessons from other researchers on (1) how they have theorised and conceptualized on issues, (2) what they have found empirically and (3) what instrumentation they have used and to what effect (Mouton, 2001).

A review of literature is essentially an exercise where the researcher works from a 'sample' of texts that he / she reads in order to come to a proper understanding of a specific domain of knowledge. As a result, the sources of the literature must be representative to achieve good quality review (Mouton, 2001). A comprehensive and well-integrated literature review provides a good understanding of the issues and debates in the area of study, current theoretical thinking and definitions, as well as previous studies and their results.

A literature review can, at best, only summarise and organize the existing knowledge. Even a critical review of the literature cannot produce new, or validate existing empirical insights. Although literature reviews often lead to theoretical insights, we still need to undertake an empirical study to test our new insights.

In this study, Chapter 3 was dedicated to literature review and therefore discussion of the broad review of the literature was done in this chapter. Each of the subsequent chapters was presented as an independent research paper and hence chapter specific literature reviews were presented. In conducting the literature review, much attention was given to most recent sources. This was necessary to capture the latest research findings. Also, the literature review attempted to treat the authors fairly by providing each of them an opportunity to be assessed without pre-set interpretation. The review was organized according to themes so as to address the research objective to be achieved.

2.5.2 Secondary data analyses

Secondary data analyses aim at re-analysing existing data in order to test hypotheses or to validate models. The type of data used in this method is mostly quantitative and therefore quantitative analyses are mostly used. The strength of this method is that it saves on time and costs because of the use of existing data or the possibility of re-analysing previous findings. The limitation is that secondary data analysts are not able to control for data collection errors and are constrained in analysis by original objectives of the research (Mouton, 2001).

This study used secondary data analysis in Chapter 4 which focusses on runoff and storage capacity of catchment and municipalities in the study area and in Chapter 5 which discusses rainfall influence on water gain and loss from Middle Letaba Dam. In both chapters the secondary data was numerical and was obtained from the DWA.

2.5.3 Survey methods

The survey methods entail the researcher collecting data by posing a series of questions to willing participants after whom he/she summarises the responses with percentages, frequency counts, or more sophisticated statistical indexes. The researcher then draws inferences about a particular population from the responses of the sample (Leedy and Ormrod, 2010). This method allows respondents to tell the researcher what they believe to be true and sometimes what they think the researcher wants to hear and this may not have been thought until the researcher posed the question (Schwarz, 1999). As stated by Leedy and Ormrod (2010), the survey research typically uses a face-to-face interview, a telephone interview or a written questionnaire.

In this research project, a survey method was used to collect data for perceptions of municipal water managers on water resources, uses and restrictions (Chapter 6) and on stakeholder participation and their influence on water management decisions (Chapter 7) and to collect data for water supplies and uses by households in the study area (Chapter 8). Relevant questionnaires were developed for collecting data to address specific research objectives. The questionnaires included both closed-ended and open-ended questions and were piloted and accordingly amended to ensure correct and accurate data was collected.

The sample frames were defined and representative samples were drawn using relevant sampling procedures. The extent of trustworthiness of the results was informed by the degree of representativeness of the samples (Welman *et al.*, 2005). Where necessary, multistage sampling was conducted as described by Leedy and Ormrod (2010) and involved selection of such units as WMAs (primary units), municipalities (secondary units), villages (tertiary) and households (quaternary units). As highlighted in the focus chapters, combinations of purposive and random sampling were used.

The researcher personally collected the data for chapters 6 and 7 where smaller samples were used and trained enumerators to collect the data for chapter 8 which had a larger sample. The quantitative data was collected by the closed-ended questions while the open-ended questions recorded qualitative data (Leedy and Ormrod, 2010) making these investigations mixed studies (Hurmerinta-Peltomaki and Nummela, 2006). The data was analysed using the SAS Package (SAS Institute Inc, 2009). The Proc FREQ of SAS was used to generate simple frequency tables for each variable of interest. Selected data was summarized in Excel Spreadsheet.

2.5.4 Content analyses

Content analyses studies analyse the content of texts or documents. 'Content' refers to words, meanings, pictures, symbols, themes or any message that can be communicated. The analysis of the texts and documents is a non-reactive method and therefore errors associated with interaction between the researchers and subjects are avoided. Limitations in authenticity of data sources and representativeness of texts analysed may influence the validity of the findings negatively (Mouton, 2001).

Data collection in content analysis entails: (1) identification of the specific body of material to be studied; (2) definition of the characteristics or qualities to be examined; (3) breaking down of lengthy complex material into small, manageable segments that are analysed separately; and (4) scrutiny of the material for instances of each characteristic or quality defined in step 2 (Leedy and Ormrod, 2010). The analysis of the data entails tabulation of the frequency of each characteristic found in the material being studied making content analysis both qualitative and quantitative. In some cases, statistical analysis are performed on the frequencies or percentages obtained to determine whether significant differences exist.

In the current study, content analysis was used as the main research method in Chapter 9 which analysed the water sector challenges and planned solutions to inform development of a water management decision model. The focus for the content analysis was the service organisations of DWA and three WSAs, the Mopani District Municipality, Vhembe District Municipality and Polokwane Local Municipality. The body of material was the strategic plan of DWA and the integrated development plans of the WSAs. The characteristics focused by the investigation included the strategies for addressing identified problems and the allocation and utilisation of resources in addressing those problems. The analysis focussed on the assessment of the degree of congruence between the challenges and the strategies and between the strategies and the resources allocated and those utilized. With the degree of congruence presented as numerical ratings and some characteristics presented as text, the content analysis was both a quantitative and qualitative inquiry.

2.6 Elimination of error

This thesis was the culmination of a study in which phenomena from the disciplines of hydrological and of social sciences were selected and made objects of inquiry. These objects were subjected to systematic and rigorous inquiry, and hence the study was a scientific research. The over-riding goal of science is the search for 'truth' or 'truthful knowledge' that is valid and reliable (Mouton, 1996).

Although it is not possible to produce scientific results that are infallible and 'absolutely' true for all times and contexts, scientists are motivated to constantly strive for the most truthful and the most valid results (Mouton, 2001). It is this quest for producing truthful knowledge that necessitates that errors be minimized if not completely eliminated in research processes.

In order to eliminate errors from the research process, it was necessary to recognise their occurrence and to know their sources. Each research method has its sources of error and therefore the discussion of the sources of error and the strategies used to eliminate such errors was based on the research methods used. As shown in Table 2.4, necessary precautions were taken to minimize errors in this study. Multiple sources were used for collecting data for some of the research methods and this assisted in minimizing error.

Table 2.4 Main sources of errors for the five research methods used in the study (Mouton, 2001) and strategies used to eliminate the errors

Research method	Common sources of error	Strategies to eliminate the errors
Literature review	Selectivity in the sources; unfair treatment of authors; misunderstanding the source; selective interpretation to suit own view point; poor organisation and integration of review.	Selection of literature sources was done according to the main themes covered by the investigation. Each author was assessed fairly with minimum prejudices. The reviews were well organized according to themes.
Secondary data analysis	Contextual analysis; misunderstanding of original objects of the principal investigator.	The type of secondary data obtained is hydrological and numerical and is less affected by context and original object of principal investigator.
Survey method	Sampling error; questionnaire error; high refusal rates; high non-response; interviewer effects; respondent effects; data capturing error.	Both the sampling and questionnaire design was done with guidance of relevant literature and with consultation of experienced researchers. Interviews of municipal managers were done by researcher and those of households by trained enumerators with minimal non-response, interviewer and respondent effects. Data capturing and analysis was done by an experienced capturer.
Content analysis	Selection effects in sampling texts; lack of information on intentions or background; limited interpretation of texts by original authors.	Texts were cautiously sampled according to pre-determined themes. The texts were from strategic plans and annual reports for which the researcher is clearly aware of the intention and background. Additional literature was also studied to broaden the understanding and make up for limited interpretation by original authors.

The use of multiple methods of data collection was referred to as triangulation and was reported to increase the reliability of observations (Leedy and Ormrod, 2010). The precautions taken in this study are important for the epistemic interest of scientific research to be achieved. Although some errors may have remained, the precautions taken are reasonably sufficient for the results of the study to be considered credible.

2.7 Research process

The major steps of the research process as used in this study included (1) orientation and planning, (2) design of survey questionnaires, (3) definition of sample frames and sampling procedures, (4) data collection, analysis and interpretation, (5) report writing (scientific articles) and presentation in conferences, (6) publication of the scientific articles and (7) thesis writing.

2.7.1 Orientation and planning

The orientation and planning of the study began in 2006 with preliminary interactions with strategic offices of the Department of Water Affairs and Forestry (DWAF). The interactions were a result of experiences of frequent water shortages in Thohoyandou were the researcher stays, and complaints of similar situations in other areas, especially rural areas. The need for understanding the challenges regarding the supply and uses of water in the province became more evident when reports came of severe shortages of irrigation water in projects where the Limpopo Department of Agriculture (LDA) already made huge investments in irrigation infrastructure.

Interactions with DWAF introduced the researcher to some of the challenges faced by the department in its initiative to allocate and deliver water to the different use sectors and this served as a motivation for the researcher to decide to embark on a detailed study of the water supply and use systems in the Limpopo Province with the intention of developing a resource management decision model. A comprehensive literature review was conducted in search for more information about the challenges regarding water supply and uses.

Further discussions were made with a team of academics from the University of the Free State who visited the province during the same year (2006) to interact with officers of the LDA wishing to register with the University to further their studies. It was after the discussion with this team that work commenced to formulate the serious questions regarding the supply and uses of water into a research proposal. The proposal was thoroughly discussed with Professor Edward Nesamvuni who was responsible for research and training in the LDA for his inputs, and was subsequently sent to the University of the Free State for further advice. In 2007 the researcher registered with the University of the Free State for a Ph.D. Subsequent to this registration, the university appointed a team of study supervisors who assessed the proposal and guided on issues for improvement before finally approving it.

2.7.2 Design of survey questionnaires

Two survey questionnaires were developed, the first being for interviewing municipal water managers while the second was for interviewing members of rural households affected by the water scarcity in the study area. The questionnaire for interviewing municipal water managers was to collect information on two major areas, one on perceptions of the water managers on water resources, uses and restrictions (Chapter 6) and the other on stakeholder participation and influence on resource management decisions (Chapter 7). The questionnaire for the survey of households, on the other hand was designed to collect data on the socio-economic situation of the households, their livelihoods and their water supply and uses (Chapter 8).

2.7.3 Sample frame and sampling procedure

(a) The sample frame

Before researchers draw a sample of the population for analysis, they should obtain clarity about the population, or units of analysis to which their research hypotheses apply, and this involves compiling a sample frame. A sample frame is a complete list in which each unit of analysis is mentioned only once (Welman *et al.,* 2005). Unless such a sample frame is borne in mind, it is impossible to judge the representativeness of the obtained sample properly. The sample should be representative of the sample frame which ideally is the same as the population (Welman *et al.,* 2005).

In this study the sample frame was stratified into five different levels, namely: WMA with their river catchments, district, municipality, village and household. The sample frame increased in size from WMAs through districts, municipalities, villages to households. Four WMAs overlay the Limpopo Province, partially or in full. The WMA fully overlaying the province are the Limpopo and Luvuvhu-Letaba WMAs while those partially overlaying the province are the Crocodile West and Marico and the Olifants WMAs making a sample frame of four units of analysis.

The province has five districts, namely: Vhembe, Waterberg, Capricorn, Mopani and Sekhukhune (Figure 1.2, section 1.3.1(b)) making a sample frame of five units of analysis. As shown in Figure 1.2, the province has 25 municipalities of which 19 are fully or partially located in the Limpopo WMA and the Luvuvhu-Letaba WMA. The Limpopo WMA has seven municipalities fully overlaying it, namely: Musina, Aganang, Lephalale, Blouberg, Molemole, Mogalakwena, and Modimolle and five municipalities partially overlaying it, namely: Makhado, Polokwane, Mutale, Mokgopong and Thabazimbi, making a total of twelve municipalities overlaying this WMA. The Luvuvhu-Letaba WMA has three municipalities fully overlaying it, namely: Thulamela, Letaba and Giyani, and four municipalities partially overlaying it, namely: Mutale, Tzaneen, Makhado, and Baphalaborwa, making a total of seven municipalities overlaying this WMA. The two WMAs were selected for the study and therefore the sample frame at the level of municipalities was composed of the 19 municipalities fully or partially located in these WMAs.

A sample frame of villages was developed for three of the municipalities selected for the study from the Luvuvhu-Letaba WMA. As stated by Welman *et al.* (2005), this sample frame comprised of a list of villages in each municipality. The sizes of sample frames of villages for the study municipalities were 210 for Thulamela, 85 for Giyani, and 118 for Mutale making a total sample frame of 413 units of analysis.

As for households, the sample frames for the villages selected for the study were 476 for Muyexe, 521 for Siyandane, 524 for Makosha, 152 for Sigonde, 108 for Makwilidza, 324 for Lukau, 581 for Djilongo, 389 for Mavunde, 1025 for Dopeni, and 567 for Xigamani, making a total sample frame of 4667 units of analysis.

(b) Sampling procedure

Probability and non-probability sampling procedures can be distinguished. In probability sampling the probability that any element or member of the population will be included in the sample can be determined while in non-probability sampling such probability cannot be specified (Welman *et al.*, 2005).

As stated by Welman *et al.* (2005), the advantage of probability sampling is that it enables the researcher to indicate the probability with which sample results (e.g. means) deviate in differing degrees from the corresponding population values (e.g. population means). Probability sampling allows for estimation of sampling error which non-probability sampling cannot do, making non-probability sampling to be frequently used for reasons of convenience and economy. Examples of probability samples used in this study were simple random samples and stratified random samples while those of non-probability samples were purposive samples.

(i) Simple random sampling

Simple random sampling gives each member of the population the same chance of being included in the sample and each sample of a particular size has the same probability of being chosen (Welman *et al.*, 2005). As stated by Welman *et al.* (2005), this type of sampling involves two steps: (1) identification of all the units of analysis in the sampling frame and assigning them consecutive numbers and (2) sampling the units of analysis using mechanisms such as a table of random numbers or a computer program to ensure that each assigned number has an equal chance of being selected.

Simple random sampling was used in this study to select villages in targeted municipalities and also to sample households in each village selected for inclusion in the study (Chapter 6). The process used for sampling of both the villages and households started with the assigning of numbers to the units of analysis. The numbers were written in small equal pieces of paper. The papers were put in a basket and this was closed and thoroughly shaken to allow for a good mix of the pieces of paper. Some people outside the research team were invited to sample, and this was done by putting a hand in the basket and picking up one piece of paper at a time from the shaken basket without looking inside the container. The numbers written on each of the selected pieces of paper were recorded as they represented certain units of analysis.

(ii) Stratified random sampling

As stated by Welman *et al.* (2005), stratified random sampling is used where the population is composed of various clearly recognisable, non-overlapping sub-populations (referred to as strata). This study used stratified random sampling to select villages and households for inclusion in the household survey (Chapter 6). The strata here were the villages and the households with their various socio-economic conditions. The stratified random sampling entailed the definition of the strata after which simple random sampling was used within each stratum.

(iii) Purposive sampling

Welman *et al.* (2005) regarded purposive sampling as the most important type of non-probability sampling. According to Welman *et al.* (2005), researchers rely on their experience, ingenuity and / or previous research findings to deliberately obtain units of analysis in such a manner that the sample they obtain may be regarded as being representative of the relevant population. However, different researchers may proceed in different ways to obtain such sample and hence it is difficult to evaluate the extent to which such samples are representative of the relevant population.

Purposive sampling was used in this study to select the Limpopo and Luvuvhu-Letaba WMAs because of their being administered by the Limpopo Regional Office of DWA which is within the Province and can be quickly reached for information on these WMAs. The Middle Letaba Dam was purposively sampled for detailed hydrological study (case study) because of its unique challenge of not filling up even during rainy seasons (except for years of floods). The Luvuvhu-Letaba WMAs was purposively sampled for household survey because the researcher stays in this WMA and hence the municipalities (and villages) were in close proximity for monitoring the work of the enumerators.

2.7.4 Data collection and analysis

This research project used a mixed approach that included quantitative and qualitative research. Accordingly, multiple research designs were involved in the study. It is therefore comprehendible that the study also used multiple methods of collecting and analysing data as revealed under research methods.

2.8 Limitations of the study

The major limitation of this research project was that it covered two large WMAs and therefore it was difficult to cover both of them in adequate details. As a result more investigations were conducted in the Luvuvhu-Letaba WMA where the researcher stays and lesser work was done in the Limpopo WMA.

Limpopo Province is generally rural (OTP, 2009) and hence lacked the technologies at different levels of the study for recording information. Some municipalities, for instance did not have weather stations or the stations were too new for the climate data generated from them to be considered reliable. Actual records of water distributed from dams to different users were not always available and this presented itself as a limitation to the study. Water supplied to users was mostly not metered and hence the data in this regard was only limited to perceptions of respondents which could be very rough estimates.

2.9 Summary and conclusion

The chapter presented a broad discussion of the research methods used in the study. Discussion of the research methods included description of knowledge and was focused on research approaches, designs and methods. The issue of research error, process and limitations of the study are important for the research to accomplish its purpose and were also discussed.

The study used each of the two major research approaches in its various chapters, namely: the quantitative and the qualitative approach. The study therefore used a mixed research approach. Different research designs were used for the various chapters and these were influenced by the type of research approach used.

Also, different research methods were used for the different chapters. The type of research methods used for each chapter was influenced by the type of approach and design used. The research methods used included literature review, secondary data analysis, survey method and content analysis. The types of sampling used were simple random sampling, stratified random sampling and purposive sampling.

CHAPTER 3

3 LITERATURE REVIEW

3.1 Introduction

Water resources are scarce in semi-arid regions such as most of Southern Africa where the study area is located. Small changes in precipitation in these regions can cause significant changes in natural recharge of both surface and ground water (de Wit and Stankiewicz, 2006) The negative effects of water scarcity in semi-arid areas are increased by population growth and higher living standards that increase the demand for the resource for household and industrial uses. Also, population growths are associated with increased water requirement for environmental concerns such as aquatic life and recreation (Bouwer, 2003). According to Bouwer (2003), the world population is projected to almost double in this century, and this will increase the demand for water and exacerbate the scarcity of supply of the resource.

To protect water supplies against these changes in surface and ground water recharge, storage is needed to build water reserves during times of surplus for use in times of shortage (Keller *et al.*, 2000; Bouwer, 2003). The storage of water is mostly achieved with dams and unfortunately, catchment runoff is becoming limited to allow for construction of more dams. Also, sustainable supply of water under this situation of scarcity requires service organisations with good capacity to address the challenges that characterise the water sector. In order to be effective, the service organisations should promote participation by all stakeholders in water management decisions.

The focus of this study is to formulate the current status of water resources and the available capacity among water service organisations and finally to develop a model to help improve decision making by these water service organisations. In order to achieve this task, the researcher should have sound knowledge of the main themes defining the research objectives, namely: (1) water resources, (2) water resource management, and (3) household water supply and requirement, and (4) available models for addressing water sector challenges. These four themes provide the foundation for development of a water management decision model for Limpopo Province and are the focus of this literature review.

3.2 Water resources

In many areas of the world, growing human populations are rapidly depleting available fresh water supplies. The global human population increased fourfold to more than six billion during the 20th century, and water withdrawn from natural fresh water resources increased eightfold during the same period (Gleick, 1998). Water is therefore a scarce resource globally and increasing its productivity is a growing concern within the international research and development community (Twomlow *et al.*, 2008).

Natural freshwater resources are strongly influenced by issues such as seasonal high and low flows, and occasional floods and droughts (Sparks, 1995; Walker *et al.*, 1995; Stanford *et al.*, 1996; Poff *et al.*, 1997; Richter *et al.*, 1997). The occurrence of low flows and droughts result in reduced supply of water and this can have serious implications (World Bank, 2003).Further occurrence of low flows would be devastating as 1.8 billion people are already predicted to experience absolute water scarcity by 2025 with two-thirds of the world's population projected to be under water stressed conditions by this time (FAO, 2007). In fact water demand already exceeds supply in many parts of the world and indeed more areas are expected to experience this imbalance in the near future (Vairavamoorthy *et al.*, 2008). This statement was supported by Komnenic *et al.* (2009) who revealed that almost one quarter of the human population lack adequate access to water. Inocencio *et al.* (2003) predicted that all countries in Africa will be either physically or economically water scarce by 2025.

The scarce supply of water contributes to the limited access, both in the broader South Africa and in Limpopo Province. About 11.4% of South Africans (close to 6 million people) do not have access to a reliable source of water (Stats SA, 2009; Manase *et al.*, 2009) with 16.4% of residents of Limpopo Province (859 079 people) in this situation (Stats SA, 2009). Residents in the Limpopo and Luvuvhu-Letaba WMAs fully located within the province experience water scarcity which also affects those in the other river catchments and municipalities in Limpopo Province.

Excessive abstractions for human survival have negative effects on the river ecosystems. A comprehensive model for water management decision making should therefore be informed by human requirement while also making provision for ecological needs. The inclusion of information on water resources when developing a water management decision model is critical when considering that water is a scarce resource, be it globally (Twomlow *et al.*, 2008), country-wide in South Africa (DWAF, 2004a) or within the Limpopo Province (DWAF, 2003; DWAF, 2004a).

The scarcity of water has negative effects on the socio-economic conditions of rural communities. Women and children are responsible for the collection of water in rural areas and are hence most affected by the scarcity of this resource (Nankhuni and Findeis, 2004). For example, children aged 6-14 in Malawi are involved in domestic work and spend the most hours of their domestic work time taking care of other children followed by water collection (Nankhuni and Findeis, 2004) and this would reduce their success at school. The effect of water scarcity on the schooling of children has a negative influence on the future of a nation. Households with more women had increased likelihood of their children attending school, affirming the fact that it is female household members who are principally involved in household responsibilities (Nankhuni and Findeis, 2004). The effects of number of women increasing their children's school attendance and reducing their work burdens were also reported for Peru (Levison and Moe, 1998) and Egypt (Assaad *et al.*, 2001).

In order to quantify the components of the hydrological balance, important information about the water resources of an area including (a) rainfall and runoff generation and (b) resource storage and distribution systems need to be considered.

3.2.1 Rainfall and runoff generation

The supply of water for human survival is much dependent on the quantity of runoff and this is in turn influenced by the amount of rainfall. Runoff is defined as the water yield from a given catchment that consists of mainly stormflow and baseflow (Schulze, 1995; DWAF, 2004a). Runoff is the water that is seen on the land surface and can potentially be stored for abstraction for use (DWAF, 2004a). Stormflow is defined as the water that is generated on or near the surface of a catchment from a rainfall event and it contributes to flow in the streams within that catchment (Schulze, 1995). On the other hand, baseflow is regarded as water from previous rainfall events that has percolated through the soil horizons into the intermediate and groundwater zones and then contributes to the streams within a catchment as a delayed flow (Schulze, 1995; Fargo, 2002; Webb, 2005).

Analysis of African river systems identifies three climatic regimes, namely: (a) low rainfall areas, (b) intermediate rainfall range, and (c) high rainfall areas. The low rainfall areas have virtually no perennial runoff (drainage) generation. The intermediate range regimes have a perennial runoff with a drainage density that increases with increasing rainfall. The intermediate range regime is referred to as unstable and a change in climate would directly result in a change in surface water supply. In high rainfall areas other factors, such as vegetation, play a role, and a slight decrease in drainage density with increasing rainfall is observed (de Wit and Stankiewicz, 2006).

As a result of climate change, it is estimated that by 2050 rainfall in much of sub-Saharan Africa could drop by 10% leading to major water shortages. A 10% decrease in rainfall in regions on the intermediate regime's upper boundary (1000 mm year^{-1}) would reduce runoff by 17%, whereas in regions receiving 500 to 600 mm year^{-1} such a drop would cut 50 to 30%, respectively of surface runoff (de Wit and Stankiewicz, 2006). South Africa falls mostly into the region receiving about 500 mm year^{-1} with Limpopo Province receiving approximately 450mm year^{-1} (DWAF, 2004a) and could therefore experience in excess of 50% reduction in runoff.

3.2.2 Water supply system

In addition to the amount of runoff, the amount of water supply can be increased by increasing the availability of storage infrastructure such as dams (Mostert, 2008). Man can therefore enhance water storage by constructing reservoirs such as dams to impound the water (Keller *et al.*, 2000; Muller, 2000). Water storage infrastructure plays a key role in water management (Mostert, 2008), and the ability of a nation to invest in it usually determines its ability to develop its water resources. According to Inocencio *et al.* (2003), developing storage infrastructure is an obvious response to the problem of water scarcity. Dams are the common infrastructure for water storage in the study area and were therefore the focus of this investigation.

Dams are classified as small or large. Small dams are those with an embankment volume generally less than 0.75 million m^3 (BOR, 1987; ICOLD, 1998). These small dams have the advantage of being operationally efficient and being flexible and often closer to the point of use. However, the high surface area to volume ratio of most small dams leads to high evaporative losses. Small dams lose, on average, 50 % of their impoundment to evaporation in arid and semi-arid areas, and this becomes a great disadvantage (Gleick, 1993; Sakthivadivel *et al.*, 1997). Large dams are the most costly to build to impound huge quantities of water. However, large dams provide larger quantities of water for allocations for different uses and hence play a more important role in promoting national water security.

In addition to investment in storage infrastructure, improved access to water requires construction of sufficient reticulation infrastructure. The storage dams and reticulation infrastructure constitute important water supply systems, where necessary, it is advisable to invest in new supply systems (Rietveld *et al.*, 2009). The water supply system should (a) have sufficient capacity, be in good condition and durable, and (b) should ensure availability of water (Ashley *et al.*, 2004; Lundie *et al.*, 2005) at all times.

(a) System capacity, condition and durability

System capacity pertains to the adequacy of the storage and distribution facilities to supply water to the community. Problems related to capacity will typically arise when a village grows in size, per capita demand and population to the point where a previously good system will begin to be inadequate (Rietveld *et al.*, 2009). The main indicators of capacity are (1) pumping capacity from the source, (2) storage volume to overcome differences between demand and pumping capacity calamities, (3) distance of water points from consumers and (4) the number of points with inadequate flow rates (Rietveld *et al.*, 2009). The condition of a water supply system refers to the status of the system in terms of its serviceability. To determine the condition of a water supply system, components such as reservoir, pumps and stand pipes must be assessed. A detailed examination of all the elements of the water supply system is often time consuming and impractical and therefore the condition of the water outlet points (tap at a communal standpipe) is often selected as an indicator of the condition of the system (Rietveld *et al.*, 2009).

As stated by Ashley *et al.* (2004), durability refers to the expected lifetime of a system. Despite the robustness of the system, the expected lifetime of a system is heavily dependent on the level of service and maintenance. Generally speaking, a system may not live up to its expected lifetime because of lack of service and poor maintenance, and in some cases because of a number of other external factors such as vandalism (Rietveld *et al.*, 2009). Durability assessments evaluate the readiness of the components of a system to perform their required function (Grigg, 2006).

(b) Water availability and supply continuity.

Availability pertains to the adequacy of the source in terms of quantity of the water that can be obtained from a supply system. Also, availability pertains to the quality of water the system supplies which should be according to the standard for drinking water (Rietveld *et al.*, 2009). Assessment of availability based on quantity includes storage and distribution network, taking into account the adequacy of both pressure at individual nodes and the subsequent flow (Fujiwara and Ganesharajah, 1993).

Supply continuity refers to the consistency of water supply from the source to the water point. Water supply can be interrupted when: (a) a pump is broken, (b) there is a shortage of diesel / electrical or other energy, (c) pipes are damaged or (d) taps cannot be opened (Rietveld *et al.*, 2009). Lack of continuity may lead to total or partial system failure. System failure can result in a prolonged period without water supply. According to Rietveld *et al.* (2009), households may have sufficient water stored for use during short time periods without water, while for prolonged periods without the resource; the households may have to search for alternative sources. The main indicators for continuity are: (a) number of hours per day without interruption of water supply and (b) number of days per month without interruption of water supply to the households.

Schreiner *et al.* (2002) revealed that millions of South Africans are still dependent on water from open streams and stagnant sources. This is a result of inadequate development and poor maintenance of the water supply systems faced by the country. In particular, water delivery to the rural areas is very poor and hence need for development of water supply system is more serious in these areas.

3.3 Water resource management

Apart from the situation regarding the status of water resources, the way in which the resource is managed is important for development of an appropriate water management decision model. The status regarding water resource knowledge and the degree of stakeholder participation are important aspects of water resource management.

3.3.1 Resource knowledge and its implementation

Important aspects about resource knowledge include the availability of credible knowledge and the issue of whether it is used or not. The use of water resource knowledge is influenced by the extent to which it is accessed by relevant stakeholders, and this is in turn influenced by the success of knowledge transfer.

(a) Knowledge availability and extent of use

Economic growth, rapid technological change, and the expansion of scientific knowledge have made societies more confident in their abilities to manage water resources. In order to address the challenge of water scarcity, it is very important for the resource to be managed efficiently based on expert knowledge. Environmental experts often express their concern over the fact that their knowledge is not adequately used by decision makers (Hermans, 2008) and the same may be said by water experts. The experts spend time and effort to develop and give advice on policies that should ensure sustainable management of natural resources, and their advice is not implemented by decision makers. Important decision makers for water management in the study area include municipal water managers and relevant government departments. In order to make appropriate resource management decisions, the water managers need expert knowledge about the resource and its uses.

Other than expert knowledge which is produced scientifically, traditional (local) knowledge is also important for water resource management and should also be considered in policy decision-making. The importance of traditional response to inadequate water supply is relevant to the concept of social adaptive capacity referred to by Ashton and Haasbroek (2002) as the ability of a society to adapt its patterns of (water) resource use to increasingly scarce supplies and achieve a sustainable measure of social stability.

Relevant strategies should therefore be developed to improve the connection between experts, policy decision makers and relevant traditional authorities. Such strategies should include the process of learning where knowledge is adopted and used by relevant actors. It is envisaged that a participatory process of social learning (ICS, 2002; Gunderson and Light, 2006) would be a most appropriate approach and hence a focused discussion of the concept 'social learning' is necessary.

(b) Social learning

Social learning refers to the learning that individuals obtain by observing others and their own social interactions within a group (Bandura, 1977) and hence assumes an interactive feedback between learners and their environment. The term has been used extensively in the field of public policy to refer to policy change and the role of ideas in this process (Hall, 1993; Greener, 2001). Social learning is also linked to concepts such as public participation, polycentric governance, collaborative governance, and co-management of natural resources (Webler *et al.*, 1995; Pretty and Ward, 2001; Olsson *et al.,* 2004), all of which are relevant for effective water resource management.

The process of social learning in natural resources such as water resources is informed by two important ideas, namely: (1) all stakeholders should be involved in water resource management as no single stakeholder has all necessary information (legal, financial, technical etc.); and (2) water resource management requires a form of organisation based on which stakeholders could enter into long-term working relationships (Meinzen-Dick, 1997), multi-stakeholder platforms (Leach and Pelky, 2001; Warner, 2006) , or informal policy networks (Klijn and Koppenjan, 2006).

In order to initiate social learning, stakeholders should first realize their interdependence and agree that participation in the process can yield better results. Success of the process requires the development of trust, joint problem definition, joint fact finding and verification, the development and assessment of different alternatives, joint decision making, and joint planning for implementation (Gray, 1989). To be effective, social learning should allow experts to find out the main concerns of decision makers and should focus on analytical activities that fit the demands of policy making process (de Bruijn and ten Heuvelhof, 2002). The experts should use participatory research methods where stakeholder platforms are implemented (Pahl-Wostl and Hare, 2004), i.e. representatives from different stakeholder groups are assembled. The participatory research should include activities such as stakeholder analysis to study the characteristics of actors and policy networks (Grimble and Wellard, 1997) and to map actor perceptions and values (Stone, 2002; Mouratiadou and Moran, 2007).

Social learning would enable water service organisations to improve their methods used to pursue their objectives over time and tackle new objectives as the context changes (Adger *et al,* 2005; Brooks *et al.,* 2005). The ability to tackle new objectives will be influenced by the capacity to build and maintain social and ecological diversity as this serves as a source of renewal and reorganisation (Peterson, 2000). According to Gunderson (2000), the success of building knowledge about water issues into organisations should improve the fit between policies and environmental realities.

3.3.2 Stakeholder participation

Apart from the issue of resource knowledge, the level of stakeholder participation is important for effective management of water resources. Effective stakeholder participation requires involvement of relevant stakeholders at all levels in decision making.

(a) Stakeholder selection

It is sometimes difficult to select relevant stakeholders for inclusion in a participatory process. The complexity in the selection of stakeholders is from cases where, for instance, (1) certain categories of stakeholders may be historically marginalized from management decisions and may therefore be reluctant to actively participate; (2) conflicts exist between different groups making them reluctant to join a deliberation process; or (3) participatory processes tend to focus on small groups for in-depth deliberation and mutual learning, which excludes some stakeholders and results in lack of representativeness (Daniels and Walker, 2001; Grimble and Wellard, 1997).

Informed selection of stakeholders for a participatory process therefore requires an appropriate process of stakeholder analysis. Stakeholder analysis has become popular in the management of natural resources such as water and land, and this shows an increasing recognition of the extent to which stakeholders should influence water decision making- processes (Burroughs, 1999; Duram and Brown, 1999; Selin *et al.,* 2000). A properly conducted stakeholder analysis should define important aspects of the system under study, identify the actors who have a stake in those aspects of the system, and prioritize stakeholders for involvement in decisions about those aspects of the system (Grimble and Wellard, 1997; Mushove and Vogel, 2005). Without a proper definition of the aspects of the system under study, it would be difficult to know which stakeholders should be involved (Dougill, 2006).

Innovative methods for assessing and analysing conflicts between stakeholders should be used (Hjortso *et al.,* 2005; Kilgour and Hipel, 2005). With proper assessment of conflicts among prospective stakeholders, their concerns, objectives, and priorities can be identified (Grimble and Wellard, 1997; Borsuk *et al.,* 2001). Information from stakeholder analysis provides useful insight into the feasibility of policy measures based on interests, potential conflicts, and influences of various role-players (Brugha and Varvasovszky, 2000).

A well planned process of stakeholder selection in a study area should also include those historically marginalized from management decisions. Mitchell *et al.* (1997) mentions common approaches where stakeholders are selected based on assessment of the urgency, legitimacy and power of potential stakeholders in relation the aspects under study. These approaches tend to prioritize economically high-ranked, more powerful stakeholders resulting in under-representation of those economically low-ranked, less powerful groups (Grimble and Chan, 1995; MacArthur, 1997).

(b) Extent of stakeholder participation

Water stakeholders are people or groups of people with a legitimate interest in water resource issues (Van Hofwegen, 2001). The necessity of stakeholder participation in water management decisions was well stated by Mashau (2001) who indicated that greater participation by stakeholders is important for sound management of the water resource. Participation by all stakeholders in the management of the water resources is important to ensure its fair allocation (Shah *et al.,* 2001) and increased productivity. Schreiner and Van Koppen (2000) argued that water scarcity is more severe among the poor and this makes it important for them to be represented among stakeholders responsible for water management decisions.

The amount of participation by non-governmental stakeholders in decision-exploring processes through to implementation, monitoring, and sanctioning varies from the provision of information by authorities to various levels of consultation, collaboration, and empowerment (IAP2, 2004). During stakeholder participation, the ways in which stakeholders frame the issues can explain collaborative success or failure (Gray, 2004) depending on their degree of convergence or divergence. According to Gray (2004), the frames of stakeholders may refer to issues such as risk and attitudes. Rayner (2003), for instance, regards expert knowledge as incomplete and biased and with such a view meaningful participation may not occur.

Effective participation entails deliberation, a process of open communication, discussion, and reflection among stakeholders who have different viewpoints and understandings (Leeuwis, 2000). Deliberation allows for stakeholders to learn from the views and motivations of others (Schusler *et al.,* 2003) and can take place in many settings, both formal and informal, including through networks when actors are more dispersed (Dryzek, 1999). Deliberative processes can help policy decision makers and experts better understand each other's point of view or approach (Backstrand, 2003).

A noteworthy example of successful stakeholder participation in a natural resource programme is that of the Australian Landcare Programme launched in 1989. This program was reported to have been voluntary and participatory, and was based on education (Curtis and Lockwood, 2000). According to Curtis and Lockwood (2000), the three attributes (voluntary, participatory, and education based) contributed to the creation of stewardship. Central to the landcare programme were the ideas of empowerment and participation (Pannell, 2002) and issues such as skill and level of facilitation that made it a success. Craps and Prins (2004) reported a participatory project in which a riverine floodplain in a densely populated area in Belgium was successfully restored.

In order to be effective in managing water resources over large areas, the water service organisations should have multiple centres with each having sufficient capacity. Availability of multiple centres is thought to create opportunities for understanding and for servicing needs in large often spatially heterogeneous contexts (Imperial, 1999; Cash, 2000). The capacity of the organisations to persist enables them to maintain and recreate their identity without having to be continually invested in, subsidized or replenished from outside (Carpenter *et al.,* 2001; Holling, 2001). Also, the water service organisations should have a sense of accountability and should therefore be obliged to provide information and explain decisions and actions or inactions (Agrawal and Ribot, 1999).

3.4 Water supply and requirement

Water is indispensable for human daily life and survival (Aiga and Umenai, 2002) and therefore access to an adequate supply of this resource is a universal indicator of human well-being and development (Potter and Darmame, 2010). Lack of access to safe water supplies in developing countries is a major concern since water is a basic need for sustenance (Mazvimavi and Mmopelwa, 2006).

The focus on water as a necessity for life obscures the fact that in most present societies, only a very small fraction of water consumption is used for drinking and for sustaining human life. A large proportion of water usage is for convenience, comfort and aesthetics (Inocencio *et al.*, 1999). Although it is only a small fraction of water consumption that is used for sustaining human life, a large number of people lacks adequate supply of the resource. Some 900 million people in the world do not have access to safe drinking water (Manase *et al.*, 2009), and almost one sixth of the world population of 6.1 billion remains without access to improved water supplies (Potter and Darmame, 2010). According to Manase *et al.* (2009), close to 6 million people do not have access to a reliable source of safe drinking water in South Africa.

Relevant decisions on water resource management require reliable information about the basic requirement and supplies for different uses. The UN, as part of its Millenium Development Goals (MDGs), has set a target of halving the proportion of people without access to safe drinking water by 2015 (Sachs, 2005; Dungumaro, 2007). The World Health Organisation (WHO) has therefore declared 2005-15 the decade of water, with the goal of establishing the framework of eventually providing full access to water supply and sanitation for all people (Rietveld *et al.*, 2009).

In accordance with the declaration by WHO, the South African government has listed water supply as one of its priority service delivery programmes (RSA, 2011), and the main focus is basic household use. Despite the inclusion of water supply among the RSA government priority service delivery programmes, drinking water supply remains a problem in South Africa, especially in rural areas. According to Rietveld (2009), it is important to deliver sufficient quantities of water to all South Africans. In order to develop an appropriate water management decision model, accurate information about household supply and consumption of water is required and hence focussed discussions on these issues are necessary.

3.4.1 Household water supply

Literature with information on how much water is supplied to a household is very limited (Merrett, 2002; Whittington, 2002) and supplies would vary for different countries. Estimates of water use in the Manila Metro show that daily per capita consumption ranges from a low of 20 litres up to a high of 400 litres (Inocencio *et al.,* 1999). The lower end of this range exhibits a limited supply possibly due to non-availability or excessively high prices while the upper bound illustrates supply beyond the basic water requirement. The volume of water collected by a household in informal settlements in Botswana also varied from 20 to 400 litres with an average of 100 litres per day (Mazvimavi and Mmopelwa, 2006) and is similar to the range of use per capita in the Manila Metro. According to Mazvimavi and Mmopelwa (2006), the supply of water to some households in Botswana made provision for less than 20 litres *per capita* per day, and with this provision, basic personal and food hygiene requirements for water could not be satisfied.

The amounts of water supplied for household consumption are dependent on availability of water sources and distance of the water sources from residential sites. The quantity supplied usually increases with an increase in the availability of water sources. The quality of water supplied is influenced by the safety of the sources used and is dependent on the economic status of the household. Poor households in South Africa obtained water from less safe sources of wells, vendors or kiosks while wealthier residents had safer piped connections (Goldblatt, 1999, Aiga and Umenai, 2002, Manase *et al.,* 2009).

The distance of water sources from residential sites was influenced by the level of social and economic development of a community. The distance generally shortened with more development (Makoni *et al.,* 2004) and therefore water was more accessible in economically developed areas. According to Mazvimavi and Mmopelwa (2006), the water sources located more than a kilometre from residential sites might be considered inaccessible and would adversely affect the amount of water used to satisfy basic personal needs. In order to gain knowledge of the quantity of water needed to satisfy personal needs, a focussed discussion of household resource requirement is necessary.

3.4.2 Household requirement of water

The concern for determining the basic or minimum household water requirement comes about in the light of the current state of water resources and the growing scarcity against a rapidly growing population (Inocencio *et al.,* 1999; Gleick, 1998). There is a lack of reliable information on quantity of water required by households for different purposes (Merrett, 2002). Household water demand forecasts are difficult to make partly because of the general lack of empirical data on domestic water consumption. As stated by Young (1996), simplistic extrapolation of trends in per capita requirements in water system planning often gives misleading results. A range of socio-economic and demographic variables such as occupancy and subtle ones such as occupant age determine the demand for water by households (Fox *et al.,* 2009) and these vary across countries. For example, in Mvunyane Village in KwaZulu-Natal Province of South Africa, 43% of households used less than 50 litres and a further 49% used between 50 and 100 litres of water per day. With the average household size of five people in Mvunyane Village, the average quantity of 15 litres of water used per capita per day was far less than the design standard of 25 litres per capita per day (DWAF, 1994 and Goldblatt, 1999).

Households in the study area of Limpopo Province had no metered connections and that made it difficult to have accurate figures of the quantities of water they used. Whittington *et al.* (2002) revealed that even villages with household connections could lack or have broken meters making it difficult to estimate precisely how much of the water supplied actually reaches the customers. As stated by Whittington *et al.* (2002), households with connections could also use alternative sources of water such as wells and public taps which would complicate calculation of the amount of water consumed. The household water consumption as reported for Mvunyane Village (DWAF, 1994 and Goldblatt, 1999) could probably provide a fair estimate of the requirement in the study area.

Water use in rural areas may be classified into basic household use or productive use. Basic household uses refer to water used for drinking, preparing food and personal hygiene (Merrett, 2002; Keshavarzi *et al.,* 2006; Katsi *et al.,* 2007). Productive consumption on the other hand highlights economic activities that are highly dependent on availability of water supplies, namely vegetable gardens, animal drinking, traditional beer making and brick making (Makoni *et al.,* 2004; Mazvimavi and Mmopelwa, 2006) and car washing (Arbues *et al.,* 2003; Keshavarzi *et al.,* 2006).

3.5 Models for water resource management

Development of a water management decision model requires understanding of the concept 'model'. In order to ensure a comprehensive coverage, discussion of water resource models will include (1) description of the modelled world, (2) characterization of models, (3) types of models, (4) organisational diagnostic models and (5) rationale for selecting the Congruence Model to provide a framework for a water management decision model for Limpopo Province.

3.5.1 Description of the modelled world

Comprehensive treatment of the topic of models necessitates sound description of the world that is modelled. Such description is important because the modelled world determines the nature and character of models. Various authors describe the modelled world differently. The following aspects present but some of the descriptions of the modelled world and are by no means exhaustive:

(a) Object, event or process

The modelled world may be described as an object, event or process indicating how the world works (Oh & Oh, 2011). Understanding of the modelled world as described by these three words necessitates examination of the meanings of the words. As stated by Hornby (2005), an object is a thing that can be seen and touched; an event is a thing that happens, especially something important; while a process is a series of things that are done in order to achieve a certain result. The modelled world therefore includes things that are tangible as well as those that are not.

(b) Phenomenon

The modelled world may be referred to as a phenomenon (Cartwright, 1983; McMullin, 1985; Bailer-Jones, 2003; Shen and Confrey, 2007; Giere *et al.,* 2006). A phenomenon is an observable event (Massimi, 2009) The description of the modelled world using the concept of phenomenon is therefore focused on things that may not be tangible.

(c) Base, target or referent

The modelled world may also be described as a base, a target or a referent (Maki, 1992; Grune-Yanoff, 2011). As was stated by Maki (1992), a base may be any description of the actual world. The target is an aspect focussed at (Hornby, 2005) and in this case would be an aspect of the world selected to be modelled. A referent is something that is referred to (Hornby, 2005) and is therefore an aspect of the world referred to by a model. The concept 'base' therefore allows a modelled world to be either tangible or intangible while 'target' and 'referent' emphasize referral relationship of a model to the modelled world.

(d) System

The world that is modelled is also described as a system (Ingham and Gilbert, 1991; Giere, 1999a; Gilbert and Ireton, 2003; Krohs, 2008; Maki, 2009). The concept of 'system' was defined by Hornby (2005) as an organized set of ideas or theories or a particular way of doing something, and this suggests a modelled world to be intangible. As stated by Hornby (2005), a system may also be defined as a group of things or pieces of equipment that are connected or work together, and this accommodates a fact that a modelled world may be something tangible.

These different concepts describing a modelled world will be used throughout this chapter. Having provided this description of the modelled world, it will be possible to present a comprehensive characterization of models. The characterization of models is mostly in relation to the modelled world and is discussed in detail as the next topic.

3.5.2 Characterization of models

Models were initially neglected and were only intensively studied from the 1960s as the focus before then were on theory (Bailer-Jones, 1999; Cartwright, 1999). New positions have developed and models are no longer regarded inferior to theory (Bailer-Jones, 2002). The thought of proposing solutions to challenges experienced by the water sector through a model is therefore in line with the importance currently attached to models. The characterization of models in this study will focus on their definition, main characteristics and on their relations with theory.

(a) Definition of models

Although there is wide agreement that models are important elements in scientific practice, no unique definition of models has been established. Even scientists who consider models to be central to their research have different meanings of these models (Van der Valk *et al.,* 2007). With this wide variation of the perceptions on models, it is not the intention of this study to provide exhaustive definition of models. The definition of models will focus on the aspects that are important for guiding the development of a water management decision model.

(i) Model as an interpretive description

A model is an interpretative description of a phenomenon (Bailer-Jones, 2003). As stated by Bailer-Jones (2003), the word 'description' in this definition includes various forms of representation. The ability of a model to describe a specific phenomenon depends on the interpretation that goes beyond pure phenomenological reality (Bulle, 2009). The phrase 'interpretive description' is therefore key in this definition.

(ii) Model as a representation

A model is a representation of how some aspect of the world works (Windschitl and Thompson, 2006). There is a great variance in what can be represented by a model, and this includes the different descriptors of the modelled world, e.g. targets and systems (Oh & Oh, 2011). A model is a representation of some target in the sense that it stands for that target as its substitute. Instead of obtaining information about the target by examining it directly, one may therefore examine the properties of the model and indirectly acquire information about the target (Grune-Yanoff, 2011).

A model is a simplified representation of a system and focusses attention on specific aspects of the system (Ingham and Gilbert, 1991). A model is therefore an abstract structure which represents systems in the world (Giere, 1999a), and this may be via a relationship of similarity. A model enables aspects of the system (objects, events or ideas) to be rendered visible (Gilbert, 1995).

(iii) Model as a mediator

A model is a mediator between the abstract and the concrete or between theory and a phenomenon in the world (Cartwright, 1983). A model stands in an intermediate position between theory and the features of the world it is meant to model (Glennan, 2005). Although models are defined as interpretive descriptions, representations and mediators, discussions in the rest of this chapter will use one concept at a time.

(b) Main characteristics of models

The definition of models provides a good indication of what models are and hence present some understanding of these important scientific entities. An increased understanding of models may however be obtained by providing detailed descriptions of their characteristics. The main characteristics of models will be discussed in this study in terms of concepts such as isolation, selection, representation and propositions.

(i) Isolation as a characteristic of models

Isolation is a process that leads from a base to an isolated product (Grune-Yanoff, 2011) and is an important characteristic of models. The isolation occurs in modelling when some feature of the base is excluded and has no impact in the isolated product. The word 'base' describes the environment the isolation seeks to manipulate and control and is the actual world (Maki, 1992). In addition to being a model, the product yielded by isolation may be a concept or theory (Grune-Yanoff, 2011) and represents the base in some sense.

(ii) Selection as a characteristic of models

The focus of selection as a characteristic of models is on features of the phenomenon that are chosen for the purpose of modelling. The assumption is that the features of a phenomenon that are not currently subject to modelling can be disregarded. Other models may later be developed to complement the first model by addressing those features that were ignored in the first model (Bailer-Jones, 1999).

Similar to the rationale for use of isolation, the use of selection is based on the fact that models practically never aim to describe a phenomenon in its entirety. The models set themselves smaller, manageable tasks and focus only on selected aspects of phenomena or of the system. The task of modelling only an aspect of a phenomenon is easier and less complex than trying to model the entire phenomenon with all its features and properties (Bailer-Jones, 2003). It is therefore possible to have different models of one and the same phenomenon that do not necessarily relate to each other as they may each address a different aspect of the phenomenon (Bailer-Jones, 2003).

(iii) Representation as a characteristic of models

As reflected in some of the definitions, one of the major characteristics of models is that they represent something. In fact representation is a key term in the current debate about models The issue of representation as a characteristic of models was affirmed by Grune-Yanoff (2011) who mentioned that a model is representative of a target in the sense that it stands for that target as its surrogate.

The word 'representation' as used in models does not mean 'resemblance' and therefore a model does not need to resemble the target. According to Suarez (1999) a resemblance is not necessary for representation and a model is typically representational. This was supported by Maki (2006) who revealed that models are simpler representations of the target system and are devoid of most properties of the system. Also, Giere *et al.* (2006) revealed that a model is similar to the target only in the intended respect and to the intended degree of accuracy. This was further affirmed by Weisberg (2007) who revealed that models represent only those factors that make a difference to the occurrence and essential character of the target.

The fact that models only represent the target in certain respects has allowed for multiple modelling of each target. The reasons for such multiple modelling as highlighted by Oh & Oh (2011) are: (1) different models can be built to represent different aspects of the same system or target; (2) models only represent selected features of targets and have limitations and therefore various models are needed to provide a full-fledged explanation of the real world system; (3) two or more rival models may coexist because there are multiple ways of explaining or conceptualizing the same thing; and (4) models may be created in multiple forms of representation.

The representational relationship may be described as a fit between a model and the world represented (Giere, 1999b). The fit between the model and the real word can be explained in terms of that between a map and the world where a map aspires to represent only some and not all aspects of the world. Targets such as space shuttle and volcanic mountain may be represented by scale models that are perceptually similar but are enlarged or reduced at different rates (Harrison and Treagust, 2000). Again it should be mentioned that models only focus on certain aspects of a phenomenon and allow some other aspects of the same phenomenon to be excluded.

(iv) Models entail propositions

Among the important characteristics of models is that they can be expressed as propositions about the empirical world (Bulle, 2009). Even if large parts of a model are described by means of images, there is often a commentary on these images that relates the images to the empirical world in the way intended in the model, and such a commentary would be propositional (Bailer-Jones, 2003).

It is not easy to determine the number of propositions made through models about the empirical world. Where the number of propositions could be determined, the ratio of the number of true and false propositions made by the model is an indicator of weather the model should be regarded true or false (Bailer-Jones, 2003). As revealed by Bailer-Jones (2003): (1) model users assess propositions made by a model and determine the balance between true and false propositions; and (2) the propositions that are crucial for meeting the intended function of the model are not allowed to be false while those less central to the function can be false without doing much damage.

(c) Relations between model and theory

Among the definitions of models is that they are mediators between the real world and theory (Glennan, 2005). The relations between a model and the real world were discussed in detail as part of a definition and main characteristics of models (Section 3.5.2 (a) and (b)). A comprehensive discussion of the relations between a model and a theory is however necessary.

The concept 'model' was already defined and to present a meaningful description of the relationship between a model and theory, it is necessary to also define the concept of 'theory'. Theory is an abstract, coherent and causal representation of features of described objects (Gopnik and Meltzoff, 1997). The theory is coherent and causal in the sense that it presents systematic and causal relationships with the described objects (Glennan, 2005).

According to Gopnik and Meltzoff (1997), the function of a theory is to predict, interpret and explain data. It is through the predictive and interpretive function that theory helps scientists understand a mass of unreconstructed data. A theory is explanatory because its abstract, coherent and causal structure promotes an understanding of the data connected with the theory (Glennan, 2005).

The definitions of theory reveal lots of similarity with model. This view was affirmed by Cartwright (1983) who regarded a theory to be a resemblance of a model. The distinction between model and theory is hard to determine, and this is especially because philosophers and scientists use the two terms in a variety of ways with scientists sometimes using the words interchangeably (Glennan, 2005).

However, some distinctions do occur between model and theory, and those include:

(i) A model is applied to concrete empirical phenomena whereas a theory is not. A theory, in turn, has the capacity for being applied to empirical phenomena when specific conditions belonging to a concrete case are satisfied and corresponding variables are inserted (into the theory). Subsequent to insertion of specific conditions of the concrete phenomenon, a theory can be moulded and adjusted to address the real and concrete empirically observed situation (Bailer-Jones, 2003).

(ii) A model aims to match specific empirical situation while a theory aims to be general. As stated by Bailer-Jones (2003), a model is more specific and is locally valid while a theory aims at addressing the empirical world through general principles and is globally valid. According to Bulle (2009), a model is a subset of a theory and is a more comprehensive system of explanation while a theory is in fact represented as sets of models.

(iii) A theory is reported to develop from a model, implying that a theory is a good model. The theory is regarded as a model that has been tried and tested and has indeed proved to be a good model (Bailer-Jones, 2002). It is assumed from this description that the theory is the best we can do, the state of the art. A theory may contain approximations, but usually only well controlled approximations while a model may include rough approximations. As a result, Bailer-

Jones (2002) concluded that there is a more definite truth claim associated with a theory than with a model.

3.5.3 Types of models

Description of different types of models is necessary to make an appropriate choice of the type to be adopted. Various authors classify models differently and therefore there is no single method for model classification. While models may be classified into many different types, this study will only highlight a few to introduce the reader to the Congruence Model that will be used to develop a water management decision model.

(a) Models as semiotic resources

The classification of models as semiotic resources emphasizes their presentation of features of the world through the use of signs. This categorization of models was alluded to by Bailer-Jones (2002) who mentioned that the content of a model is expressed through a range of different means that include diagrams, mathematical equations and language sentences written on a piece of paper. These different means reflect various forms of semiotic resources.

Affirmation of the classification of models as semiotic resources was provided by Gilbert and Ireton (2003) and Ramadas (2009) who described them as linguistic entities, pictures, diagrammes, graphs, concrete materials, animations, actions and their combinations. The classification was further supported by Oh & Oh (2011) who indicated that models are often characterized as the use of visual resources such as pictures, diagrammes, animations, or material objects which simplify and highlight certain aspects of the targeted system. As revealed by Oh & Oh (2011), there are four different types of models under semiotic resources, namely: scale model, analogue model, mathematical model and theoretical model.

(i) Scale model

A scale model may be regarded a representation or copy of the object that is larger or smaller than the actual size of the object, which seeks to maintain the relative proportions of the physical size of the original object. It is the relation between the actual size of something and its size on a map, diagramme or model that represents it (Hornby, 2005). Material objects and pictures are larger or smaller and seek to maintain the relative proportions of the physical size of the original object and are perhaps the common examples of scale models.

(ii) Analogue model

The concept of 'analogue' refers to a thing that is similar to another thing (Hornby, 2005). An analogue model as used by Koons and Henderson (1995) is for modelling the mechanics of a large scale problem at a scale that is applicable to a laboratory setting. Diagrammes and animations are possible examples of analogue models.

(iii) Mathematical model

A mathematical model may be considered an abstract model that uses mathematical language to describe the behaviour of a system. As alluded to by Hornby (2005), a mathematical language involves the use of numbers and shapes, so mathematical models therefore entail the use of mathematical equations and graphs to represent the real world.

(iv) Theoretical model

A theoretical model is based on the use of theory to explain something. The theoretical model explains an entire situation or behaviour to the level of eventually being able to predict the behaviour. A theoretical model entails the use of various semiotic resources such as linguistic entities and diagrammes.

Among the examples of a theoretical model would be a conceptual model. This category of model is important for attainment of conceptual understanding in science at a level that goes beyond memorized facts, equations or procedures (Clement, 2000). The conceptual model provides simplified description and explanation of concepts thereby promoting better understanding of the concepts.

(b) Diagnostic models

Other than classification as semiotic resources, models may also be categorized as diagnostic tools. Diagnostic models can be probabilistic, confirmatory and multidimensional (Rupp and Templin, 2008). The models are suitable for modelling observable categorical response variables. As revealed by Rupp and Templin (2008), diagnostic models enable multiple interpretations and associated feedback for diagnostic purposes. The diagnostic models can be used to make sense of some data (Leighton, 2008).

This study is to use an organisational diagnostic model to develop a water management decision model specifically being the Congruence Model of Nadler and Tushman (1980). As a result, a dedicated section is necessary to provide a detailed discussion of organisational diagnostic models.

3.5.4 Organisational diagnostic models

With the concept 'model' already defined, a comprehensive discussion of organisational diagnosis should first describe the concept 'organisation'.

(a) Organisation

An organisation is the planned coordination of the collective activities of two or more people who, functioning on a relatively continuous basis and through the division of labour and a hierarchy of authority, seek to achieve a common goal or a set of goals (Robbins, 1983). From this definition, the achievement of a common goal is the ultimate purpose of the existence of organisations. It could have been a result of this emphasis on goal that March and Sutton (1997) regarded organisations simply as instruments that are coordinated by intentions and goals. The ability of organisations to achieve their goals is influenced by a number of factors, and those include organisational environment and leadership.

Literature on organisational decision making shows that organisations must continually monitor their environment and make strategic decisions to keep the firm strengths aligned with new opportunities and threats in the environment (Barr and Huff, 1997). The continual monitoring makes it possible for the organisations to update their strategies to remain competitive in a changing environment.

(b) Organisational diagnosis

The main purpose of organisation development strategies is to improve the effectiveness (Cummings and Worley, 1993) and sustainability (Kiron *et al.*, 2012) and hence organisations commit a lot of resources to achieve this purpose (Haanaes *et al.*, 2011; Kruschwitz and Haanaes, 2011). Among the factors determining the sustainability of an organisation is its impact on the environment, and this is also influenced by the political situation (Schendler and Toffel, 2011).

Organisational diagnosis is one of the organisational development strategies and involves 'diagnosing', or assessing an organisation's current level of functioning in order to design appropriate change interventions. The organisational diagnostician uses specialized procedures to collect vital information about the organisation, to analyze this information, and to design appropriate organisational interventions (Salvatore and Falletta, 2005).

Diagnosis identifies organisational factors that necessitate change of strategy to create competitive advantage (Kiron and Shockley, 2011; Simchi-Levi *et al.*, 2012). These organisational factors may include information technology (Brynjolfsson and McAfee, 2012) and factors related to building and sustaining a strong talent pipeline (Stahl *et al.*, 2012). Organisational factors associated with building talent are important for generating more value from employees (Schweer *et al.*, 2012). The advance of information technology makes it necessary for managers to cope with innovations in this technology (Swanson, 2012) often acquired from external sources (Lichtenthaler *et al.*, 2011). The change of strategies should aim at influencing markets (Von Hippel *et al.*, 2012; Murray and Haubl, 2012) locally and internationally (Baaij *et al.*, 2012). Correct diagnosis is important for relevant strategies to be adopted to 'treat organisational wounds' (Kahn, 2011).

Within an organisation, the diagnostic process often facilitates an admission by top management that the organisation does indeed have problems or needs that should be addressed (Harrison, 1987; Manzini, 1988). In order to develop the most appropriate interventions, organisational diagnosis continues at a detailed level to search for the underlying problems (Fordyce and Weil, 1983). The results of the diagnosis are fed back to the members of the organisation in order to begin the process of organisational change (French and Bell, 1995; Harrison, 1987).

3.5.5 Suitability of organisational diagnostic models to guide water decisions

(a) Selected examples of organisational diagnostic models

Five examples of organisational diagnostic models were selected based on the variability of the aspects they cover. These models are (a) the McKinsey 7S Framework, (b) Tichy's Technical Political Cultural Framework, (c) High Performance Programming, (d) Diagnosing Individual and Group Behaviour, and (e) the Congruence Model. Selection of a model to guide water management decision making in the study area is based on the model that allows for responsiveness to the situation in this area.

(i) McKinsey 7S Framework

The M7SF was developed by McKinsey Consulting (Salvatore and Falletta, 2005) and provides a useful framework for reviewing the impact of change (Noolan, 2004). The M7SF was created as a recognisable model in business and is composed of seven variables (also called levers). The variables all begin with the letter 'S' and were described by Noolan (2004) as follows:

- Strategy: States how an organisation will attain its vision and respond to the threats and opportunities of the new mediums.
- Shared Values and Beliefs: This imparts to the organisation (and externally) what the organisation stands for and what it believes in.
- Systems, including Processes: Capabilities are required in information technology, sales and service, legal and actuarial science.
- Staff: Human resource management for developing the skills and aptitude for building lifetime customer relationships.
- Style: This refers to the management style best suited for the organisation. The challenge for management is to use appropriate styles for the situation without confusing staff.

- Structure: Changes to processes and style inevitably require changes to organisational structure (e.g. centralised vs decentralised, structure).
- Skills: The degree to which necessary skills exist is the core of workforce planning. Staff acquisition of necessary skills requires appropriate learning environment.

As revealed by the description of the variables, the M7SF focuses on the internal aspects of an organisation with little focus on external input and output aspects and this suggests lack of responsiveness to the situation outside the organisation.

(ii) Tichy's Technical Political Cultural Framework

The Tichy's Technical Political Cultural Framework (TTPCF identifies key variables that are important to the change management process. The variables of the TTPCF were defined by Salvatore and Falletta (2005) as follows:

- The environment and history are two major categories of input to the organisation whereas resources are a third category of input.
- The mission/strategy variable is the organisation's approach to carrying out its mission and strategy and criteria for effectiveness.
- The tasks variable refers to the technology by which the organisation's work is accomplished.
- The prescribed networks refer to designed structure of the organisation, such as the organisation of departments and the communication and authority networks.
- The people variable refers to the characteristics of organisational members, including their background, motivation, and managerial style.
- The organisational processes are the mechanisms which enable the formal organisation to carry out the work and these include organisational communication, decision-making, conflict management, control, and reward systems.
- The final throughput variable, emergent networks, refers to the structures and processes in the organisation which emerges informally.

The issues emphasized in TTPCF include the externally located aspects of input and the internal organisational aspects with no attention provided to the external outputs of organisations.

(iii) High Performance Programming

The High Performance Programming (HPP) framework focuses on organisation performance.

Table 3.1 Conceptualisation of four HPP framework systems (Nelson and Burns, 1984)

Organisational system	**Characterisation**
High performing organisation *Level 4*	Leaders focus on empowering members to achieve organisational excellence. Communication throughout the organisation is relatively unrestrictive. Organisational evolution is guided by a common vision. Members prise their identity with the organisation highly. Opportunities for self-actualisation are substantial.
Proactive organisation *Level 3*	The organisation focusses on the future. Leadership focusses on developing purpose for the organisation. Members focus on quality of contribution to organisational successes. The organisation is actively involved in planning and developing strategies.
Responsive organisation *Level 2*	The organisation is more functional, achieves clarity of purpose and goal and has capability to adapt to changing environment. Leaders actively coach members to achieve organisational goals, and there is cohesion among work teams.
Reactive Organisation *Level 1*	The organisation is badly in need of renewal. There is lack of shared focus, and management is preoccupied with assigning blame for poor outcomes. Members spend time avoiding aversive consequences, and leaders spend time enforcing policies that often lack relevance to any common purpose.

The HPP framework assesses the current level of performance of an organisation in order to plan interventions to transform the organisation into a high performing system (Nelson and Burns, 1984). As stated by Salvatore and Falletta (2005), the HPP framework is described in terms of four systems that are more or less effective, namely: high-performing organisation (level 4), proactive organisation (level 3), responsive organisation (level 2), and reactive organisation (level 1) as shown in Table 3.1. As revealed by the conceptualisation of the systems of the HPP framework, this model is more focussed on internal aspects influencing organisational performance with no illustration of linkage with the external environment and may be little responsive.

(iv) Diagnosing Individual and Group Behaviour

The Diagnosing Individual and Group Behaviour (DIGB) model represents an open systems perspective with minimal boundaries between the organisation and external environment. The external environment in the model is represented by resources and feedback loops (Salvatore and Falletta, 2005). The variables accounted for in the model are conceptualised at individual and group levels (Harrison, 1987) as shown in Table 3.2.

Table 3.2 Conceptualisation of Individual and Group Levels in DIGB model (Harrison, 1987)

Factors affecting performance	**Description**
	Individual Level
Individual characteristics	Physical and mental state, social background and traits, training and education, individual needs
Individual attitudes, beliefs & motivation	Motivation, rewards experienced, job felt to be intrinsically rewarding, expectations, equity, trust, specific attitudes (e.g., satisfaction with current procedures, attitudes toward proposed changes)
	Group Level
Group composition, structure, and technology	Social and occupational composition, structure (e.g. nature and extent of rules and work procedures, flexibility, clarity of tasks and assignments, responsibilities), technology (e.g. impact of work procedures and physical arrangements, types of workflow interdependencies)
Group behaviour, processes, and culture	Relationships among group members (e.g. cohesiveness, feelings of attachment to group, similarity of views), processes (e.g. communication, cooperation and conflict, decision making, problem solving), supervisory behaviour, culture

The emphasis of this model is on the internal organisational transformation component with particular focus on the behaviour of people that work in an organisation. Broad organisational issues and the external components of input and output are not provided for in this model.

(v) The Congruence Model

The Nadler-Tushman Congruence Model is a comprehensive model, specifying inputs, throughputs, and outputs, which is consistent with open systems theory (Katz & Kahn, 1978). The inputs within the Nadler-Tushman Congruence model include such factors as the environment, resources, history (i.e. patterns of past behaviour), and organisational strategies. Nadler and Tushman (1980) are explicit in their conceptualisation of each of the factors. For example, they describe the resources available to the organisation as human resources, technology, capital, information, and other less tangible resources. Strategy is an input in the model as it is the single most important input to the organisation (Salvatore and Falletta, 2005).

The internal transformational components are informal organisational arrangements, task, formal organisational arrangements, and human resources (Nadler and Tushman, 1980). Similarly, the outputs of the model include individual, group, and organisational outputs. The Congruence Model emphasizes a degree of congruence or fit between each pair of components of the model. The congruence between two components is defined as the degree to which the needs, demands, goals, objectives, and structures of one component are consistent with those of the other (Nadler and Tushman, 1980). The greater the degree of congruence between the various components, the more effective will be the organisation. Effectiveness was defined as the degree to which actual organisational outputs are similar to expected outputs (Nadler and Tushman, 1980; Wyman, 2003; Bezboruah, 2008). Different aspects are used to describe congruence between different pairs of internal transformational components of the model (Table 3.3).

Table 3.3 Issues for describing congruence between different pairs of internal transformational components of the Congruence Model (Nadler and Tushman, 1980)

Component pair	Issues for describing congruence
Individual - Formal Organisational Arrangements	How are individual needs met by the organisational arrangements? Do individuals hold clear or distorted perceptions of organisational structures? Is there a convergence of individual and organisational goals?
Individual - Task	How are individual needs met by the tasks? Do individuals have skills and abilities to meet task demands?
Individual - Informal Organisation	How are individual needs met by the informal organisation? How does the informal organisation make use of individual resources consistent with informal goals?
Task - Formal Organisational Arrangements	Are organisational arrangements adequate to meet the demands of the task? Do organisational arrangements motivate behaviour that is consistent with demands?
Task - Informal Organisation	Does the informal organisation structure facilitate task performance or not? Does it hinder or help meet the demands of the task?
Formal Organisational Arrangements - Informal Organisation	Are the goals, rewards, and structures of the informal organisation consistent with those of the formal organisation?

The Nadler-Tushman Congruence Model is indeed a comprehensive model specifying inputs, transformation and outputs. The model provides a fair emphasis of both internal transformational issues and external input and output issues and would likely result in responsive water service organisations.

(b) Selection of model for water management decision making

A decision on which of the described diagnostic models should be selected for adaptation into a water management decision model necessitates that the described models be evaluated. The evaluation will be guided by the extent to which the models provide attention to the aspects of inputs and outputs that are external to the organisation and to transformational issues that are internal. The evaluation is based on these components because they define a well-functioning organisation (Gill, 2000; Mertikas, 2008) that is responsive to the challenges presented by the external environment (Table 3.4).

Table 3.4 Evaluation of described diagnostic models based on their inclusion of aspects defining a well-functioning and responsive organisation (Gill, 2000; Mertikas, 2008)

Model	Input	Transformation	Output	Total rating
McKinsey 7S Framework	1	2	0	3
Tichy's Technical Political Cultural	2	2	0	4
High Performance Programmign	0	2	0	2
Diagnostic Individual & Group	0	2	0	2
Congruence Model	2	2	2	6

Key: 0=Not included; 1=Uncertain, little inclusion; 2=Included

As shown in Table 3.4, the Congruence Model is the only one that includes all the aspects (external input, organisational transformation, and output) that define a well-functioning organisation and hence attained the maximum rating (of 6). All the models included transformational issues which suggests more focus on internal organisational as opposed to a balance of external input and output issues. After the Congruence Model, the TTPCF is the second best model well-functional organisation (rating=4) followed by the M7SF (rating=3).

As the Congruence Model is the only model surveyed that included all aspects defining a well-functional organisation, it was selected for adaptation into a water management decision model for Limpopo Province. In addition to inclusion of all necessary aspects, the model also puts emphasis on the necessity of congruence between pairs of aspects which is important to ensure the effectiveness of the organisation.

3.6 Summary and conclusion

This chapter presented the literature survey which enabled the researcher acquire new ideas and perspectives about the research topic and helped with the interpretation of the findings of this study. Interpretation of the findings of this study was improved by comparing the results of the study with those of other researchers.

The literature survey discussed the water resources, water resource management, household water supply and requirement, and the use of models in water resource management. Discussion of water resources included on rainfall and its influence on runoff generation and it was shown that an increase in rainfall results in increase in the generation of runoff. Water supply system is an important aspect of the water resource and the literature survey indicated that adequate system capacity, maintenance to ensure good condition and durability of the system are important for improved water supply, and this depends on water availability.

The discussion of water resource management focussed on the issue of resource knowledge and stakeholder participation. Experts claimed to have valuable knowledge which is not used by policy decision makers, and non-government stakeholders where shown to be excluded from water decision making, and participatory social learning was highlighted as a strategy to bring the stakeholders together to learn from each other. The household water supply was shown to be inadequate to meet the demand.

Discussion of models was to indicate the prospects of using them to make relevant water management decisions to address the challenges faced by the sector. Focussed discussion was made of organisational diagnostic models, and these were assessed for suitability to guide water management decision making with the Congruence Model proving to be the most suitable. The issues covered in the literature survey were all necessary to inform the development of a water management decision model for the Limpopo Province.

CHAPTER 4

4 RUNOFF AND STORAGE CAPACITY OF RIVER CATCHMENTS AND MUNICIPALITIES

4.1 Introduction

The supply of water in an area is dependent on the quantity of runoff and this is in turn influenced by rainfall. The importance of rainfall was stated by Schulze (1995) who described it as the fundamental driving force and important input behind most hydrological processes. Occurrence of low rainfall and subsequent runoff in an area results in water shortage described in terms of resource stress or scarcity. An area is water stressed when annual supplies per capita drop below 1 700 m^3, is water scarce when the supplies decrease below 1 000 m^3 and has absolute scarcity when the supplies are below 500 m^3 (FAO, 2007).

The rainfall of an area is influenced by the climatic region in which it is located. Three climatic regimes were identified in Africa, namely: the low rainfall areas, those of intermediate range and the high rainfall areas (de Wit and Stankiewicz, 2006). South Africa is located in a predominantly low rainfall area. The climate is relatively arid in the west and humid in the east. The average annual rainfall is 450mm, and is well below the world average of about 860mm (DWAF, 2004a). Accordingly, the Limpopo Province is also situated in a low rainfall area with lesser rainfall recorded in the western located Limpopo WMA compared to that received by the eastern located Luvuvhu-Letaba WMA (DWAF, 2003; DWAF, 2004b). The river catchments and the municipalities located in these WMAs are therefore affected by the water scarcity.

To mitigate against the challenge of scarcity, water resources should be more efficiently managed, and this should begin with an assessment of the amount of runoff in a specific area. Runoff was described as the water yield from a given area and consists of mainly stormflow and baseflow, and is in fact the water that can be seen on land surfaces and can potentially be stored for use (Schulze, 1995; DWAF, 2004a). Stormflow is the water that is generated on or near the surface of a catchment from the occurrence of rainfall and contributes to flow in the streams within that catchment (Schulze, 1995). On the other hand, baseflow is regarded as water from previous rainfall events that has percolated through the soil horizons into the intermediate and groundwater zones and then contributes to the streams within a catchment as a delayed flow (Schulze, 1995; Fargo, 2002; Webb, 2005).

In addition to the amount of runoff, the amount of water supply depends on the availability of storage infrastructure such as dams (Mostert, 2008). Water is stored in dams during high rainfall seasons when and where the economic value of the resource is low and is reallocated to times and places when and where its economic value is high. The concept of 'economic value' includes both the social and environmental value of water (Keller *et al.,* 2000). The dam storage capacity of a river catchment refers to the quantity of water that can be stored in man-made dams in that catchment and availed for different uses.

The objective of this study was to investigate the amount of available water by assessing the runoff and storage capacity relationships of river catchments and municipalities in the Limpopo and Luvuvhu-Letaba WMAs. The water storage capacity within the area is compared to the runoff to assess the possibility of constructing new dams in some catchments and of implementing new strategic water projects such as rain water harvesting in municipalities (Section 1.4, Table 1.3, specific objective 1).

4.2 Methodology

4.2.1 Study area

The study was based in two WMAs located in the Limpopo Province and administered by the Limpopo Regional Office of Department of Water Affairs and Forestry (DWAF), the Limpopo and Luvuvhu-Letaba WMAs (Figure 4.1).

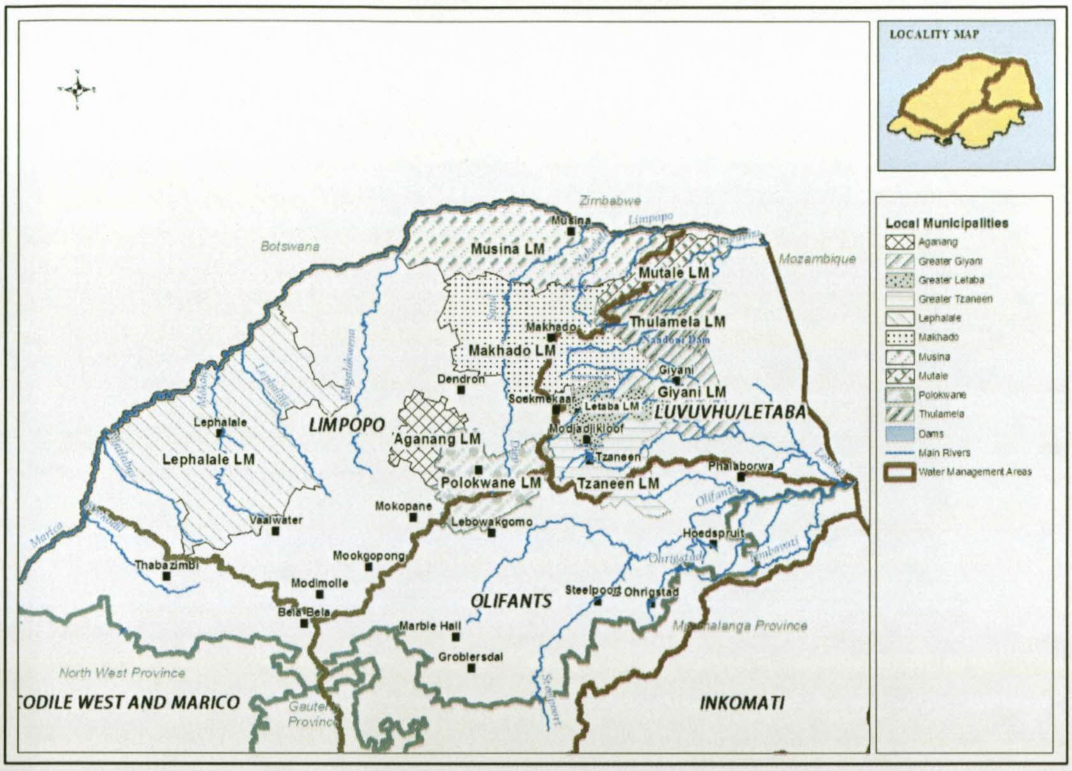


Figure 4.1 Map of the Limpopo Province showing the Limpopo and Luvuvhu-Letaba Water Management Areas (red border line) and the ten municipalities (hatchings) sampled for the study (DWAF, 2004a)

Ten municipalities under the two WMAs were sampled for the study, five from each WMA. The five municipalities sampled from the Limpopo WMA include three which are fully contained in the WMA, namely: Musina, Aganang, and Lephalale and two which have a large part of their land area located in the WMA, namely: Makhado and Polokwane. As for the Luvuvhu-Letaba WMA, the five municipalities sampled were the Letaba and Giyani which are fully contained and Mutale, Thulamela and Tzaneen with larger part of their land areas located in the WMA.

4.2.2 Sampling procedure

The study units were selected from the sample frame (Section 2.7.3(a), Chapter 2). Sampling was done using the multistage approach for WMAs and municipalities (Leedy and Ormrod, 2010). Purposive sampling was used to select the Limpopo and Luvuvhu-Letaba WMAs as they are managed by the nearby Limpopo Regional Office of DWAF that is more accessible for information (Welman *et al.*, 2005; Leedy and Ormrod, 2010). All main river catchments for each WMA were included in the study, seven for Limpopo and six for Luvuvhu-Letaba WMA. Informed by the ease of availability of information, 10 municipalities were also purposively chosen, five in each of the WMAs (Figure 4.1).

4.2.3 Data collection and analysis

Data for runoff and storage capacities of river catchments (1960-1996) was obtained from DWAF (2003) for the Limpopo and from DWAF (2004b) for the Luvuvhu-Letaba WMA. The data for municipal runoff was calculated from that of representative quaternary catchments as presented by Midgley *et al.* (1994). As guided by Leedy and Ormrod (2010), the data was properly organized for ease of analysis by classifying them into main themes covered by the investigation, namely: runoff and storage capacity of the study area. As mentioned earlier, the study area was categorized into WMAs, river catchments and municipalities.

Interpretations were objective and precise to specific situations and generalizations were made only in strict accordance with the data. The data was related to the purpose of the study and pre-existing literature while also determining the practical significance of relationships among variables (Leedy and Ormrod, 2010).

4.3 Results and discussion

4.3.1 Runoff and storage capacity of river catchments in the study area

The occurrence of runoff determines the extent to which man will access water for various uses, including domestic, industrial and agricultural uses. Several authors highlighted the benefits of practices such as conservation tillage in improving the agricultural productivity of water (Kongo and Jewitt, 2006; Mutiro *et al.,* 2006; Ngigi *et al.,* 2006; Mupangwa *et al.,* 2008; Munodawafa and Zhou, 2008; and Sturm *et al.,* 2009). With conservation tillage, dryland farming is therefore possible without runoff impoundments in reservoirs that tend to be more necessary for irrigated agriculture.

Other than conservation tillage, man can enhance water storage by constructing reservoirs such as dams to impound the water (Keller *et al.,* 2000; Muller, 2000). Water storage infrastructure plays a key role in water management (Mostert, 2008), and the ability of a nation to invest in it determines its ability to develop its water resources. According to Inocencio *et al.* (2003), developing storage infrastructure is an obvious response to the problem of water scarcity. Dams are the common infrastructure for water storage in the study area and were therefore the focus of investigation.

Dams are classified as small or large with small dams characterised by a storage volume generally less than 0.75 million m^3 (BOR, 1987; ICOLD, 1998). Although small dams have an advantage of being operationally efficient and being flexible and often closer to the point of use, the high surface area to volume ratio of these small dams leads to high evaporation loss. Small dams lose, on average, 50% of their impoundment to evaporation in arid and semi-arid areas, and this becomes a disadvantage (Gleick, 1993; Sakthivadivel *et al.,* 1997). On the other hand, large dams are costly to build for huge quantities of water to be impounded. Large dams provide larger quantities of water for allocations for different uses and hence play a bigger role in promoting national water security.

(a) Runoffs of catchments in the study area

The amount of runoff from a catchment influences the stream flows and hence the sizes of rivers flowing through that catchment. In fact the size of a river at a catchment is determined by runoff from the catchment under consideration plus the runoff contribution from all upstream catchments (Schulze, 1995). Many of the rivers flowing through the study area are permanently flowing at their headwaters and then pass through drier regions and become seasonal rivers due to natural losses as well as abstractions (Gorgens and Boroto, 2003). The mean annual runoff of river catchments of the Limpopo and Luvuvhu-Letaba WMA is presented in Fig. 4.2 (DWAF, 2003; DWAF, 2004b).

As shown in Fig. 4.2, the total MAR of river catchments in the Limpopo WMA was 985.9 million m^3 while that of the catchments in the Luvuvhu-Letaba WMA was 1 183.9 million m^3. Considering MAR, this result indicated that the Luvuvhu-Letaba WMA had more available water than the Limpopo WMA. It would therefore be expected for the Luvuvhu-Letaba to have more potential for development of dam storage than the Limpopo WMA.

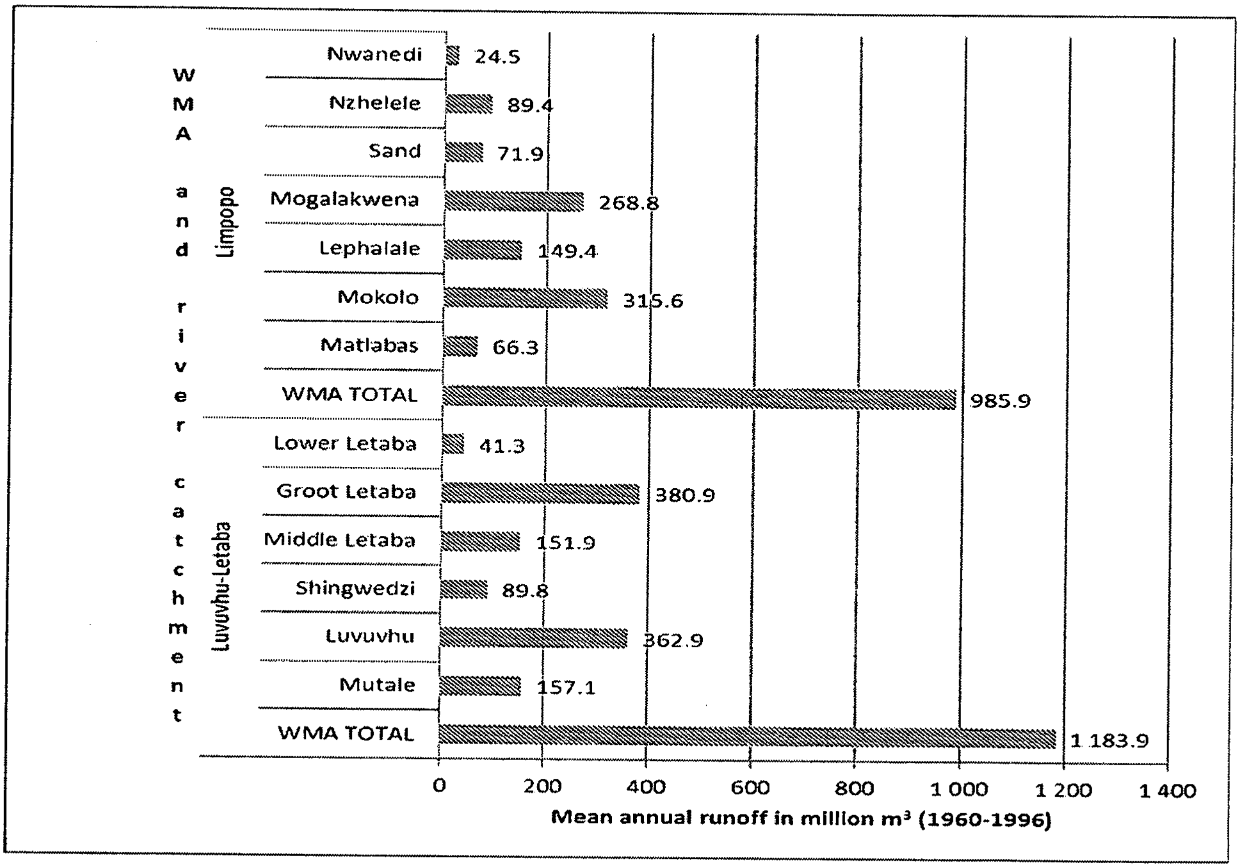


Figure 4.2 Mean annual runoff (MAR) of river catchments of the Limpopo and Luvuvhu-Letaba WMA (DWAF, 2003; DWAF, 2004b)

Assuming a MAR requirement of at least 100 million m^3 for a river catchment to accommodate major dams, seven catchments had enough water to accommodate such dams. The seven river catchments are Mogalakwena with MAR of 268.8 million m^3, Lephalale (149.4 million m^3) and Mokolo (315.6 million m^3) in the Limpopo WMA and the Groot Letaba (380.9 million m^3), Middle Letaba (151.9 million m^3), Luvuvhu (362.9 million m^3) and Mutale (157.1 million m^3) in the Luvuvhu-Letaba WMA. Of the seven catchments, three are in the Limpopo WMA and four are in the Luvuvhu-Letaba WMA and this affirms the point that the latter WMA had more available water.

The range of MAR is from 24.5 million m^3 for Nwanedi River to 315.6 million m^3 for the Mokolo River in the Limpopo WMA and 41.3 million m^3 for the Lower Letaba to 380.9 million m^3 for the Groot Letaba in the Luvuvhu-Letaba WMA. These wide ranges show a large variation of MAR from one river catchment to the other, thereby revealing large differences in potential for development of dam storage across the catchments.

(b) Water storage capacity of major catchments under study

Keller *et al.* (2000) alluded to the fact that dam storage captures water when and where its marginal value is low and can then reallocate it to times and places when and where its marginal value is high. For the area under study, the MAR of river catchments varies from one season to the other, and also differs from one catchment to the other (Figure 4.2) and this necessitates the development of dam storage.

The river catchments for the two WMAs under study were semi-closed with larger outflows to the oceans during rainy seasons and less during dry seasons. As a result, dam storage allowed for this scarce resource to be captured during the rainy season when the MAR was high, thereby reducing the amount of water lost to the oceans, and availing it to be stored for the dry season when the MAR is low, thereby increasing the supply during this time of scarcity. The storage capacity for all the dams in each river catchment was added up to obtain the total storage capacity of the catchment, referred to as catchment storage capacity (Table 4.1).

Table 4.1 Storage capacity and available MAR for possible development of new dams in river catchments of the Limpopo and Luvuvhu-Letaba WMAs (DWAF, 2003; DWAF, 2004b)

Water Management Area	Catchment	MAR (million m^3)	Storage capacity (million m^3)	Storage capacity + 5% MAR for ecological reserve (million m^3)	Available MAR for possible development of new dams (million m^3)
Limpopo	Nwanedi	24.5	20.6	21.8	2.7
	Nzhelele	89.4	57.8	62.3	27.1
	Sand	71.9	22.1	25.7	46.2
	Mogalakwena	268.8	73.6	87.0	181.8
	Lephalale	149.4	5.2	12.7	136.7
	Mokolo	315.6	145.9	161.7	153.9
	Matlabas	66.3	0	3.3	63.0
	WMA total	**985.9**	**325.2**	**374.5**	**611.4**
Luvuvhu-Letaba	Lower Letaba	41.3	0.0	2.1	39.2
	Groot Letaba	380.9	265.7	284.7	96.2
	Middle Letaba	151.9	250.0	257.6	-105.7
	Shingwedzi	89.9	0.0	4.5	85.4
	Luvuvhu	362.9	240.0	258.1	104.8
	Mutale	157.1	3.9	11.8	145.3
	WMA total	**1184**	**759.6**	**818.8**	**365.2**

In order to establish accurate estimates of available catchment MAR for possible development of additional storage, provision was made for the requirements of the ecological reserve. In accordance with the findings by Hughes (2005), this was calculated at 5% of existing catchment MAR.

The total storage capacity of river catchments in the Limpopo WMA was 325.2 million m^3 (33% of MAR) while that of the catchments in the Luvuvhu-Letaba WMA was 759.6 million m^3 (64.2% of MAR). Four river catchments had a storage capacity > 100 million m^3 and had major dams. The four rivers are the Mokolo in the Limpopo WMA with a storage capacity of 145.9 million m^3 and the Groot Letaba (265.7 million m^3), Middle Letaba (250 million m^3) and Luvuvhu (240 million m^3) in the Luvuvhu-Letaba WMA. The results reveal that more runoff is stored in the Luvuvhu-Letaba than that in the Limpopo WMA (Table 4.1) suggesting that the latter WMA was less developed in terms of water storage infrastructure.

Accordingly, the Limpopo WMA had 611.4 million m^3 of available MAR for possible development of new dams compared to only 365.2 million m^3 for the Luvuvhu-Letaba WMA. These results show that opportunities for development of additional storage infrastructure are more in the Limpopo than in the Luvuvhu-Letaba WMA, and this is contradictory to the view of DWAF (2004a). Based on these results, the Limpopo WMA should be given more priority for development of new dams than the Luvuvhu-Letaba WMA.

Five river catchments in the study area had available MAR > 100 million m^3 for possible development of the new dams and should be targeted for this purpose. The five rivers are the Mogalakwena (181.8 million m3), Lephalale (136.7 million m^3) and Mokolo (153.9 million m^3) in the Limpopo WMA and the Luvuvhu (104.8 million m3) and Mutale (145.3 million m^3) in the Luvuvhu-Letaba WMA.

For the Luvuvhu-Letaba WMA, it was revealed that the Middle Letaba catchment had available MAR of -105.7 million m^3 for possible development of additional storage. This negative figure occurred as the present storage capacity is larger than the catchment MAR. As revealed by DWAF (2004b), the major contributor to the storage capacity that exceeded the catchment MAR was the 184.2 million m^3 Middle Letaba Dam built in a catchment with MAR of 151.9 million m^3, with smaller dams in the catchment exacerbating the situation. The situation was reported to have been caused by the misplacement of the dam due to the political situation of the time.

On the contrary, the Mutale catchment had the highest available MAR (145.3 million m^3) in the WMA for possible development of new dams as only a small storage capacity of 3.9 million m^3 had been developed. It is therefore recommended that priority for development of new dams be given to the Mogalakwena, Lephalale and Mokolo river catchments in the Limpopo WMA and to the Luvuvhu and Mutale catchments in the Luvuvhu-Letaba WMA.

(c) Influence of catchment runoff on storage capacity

As stated by Mostert (2008), the degree of water availability depends on the magnitude of storage capacity in addition to the amount of runoff. For water stressed countries, it would be expected that the development of storage infrastructure should be influenced by the amount of runoff, and this would be the situation in the study area (Figure 4.3).

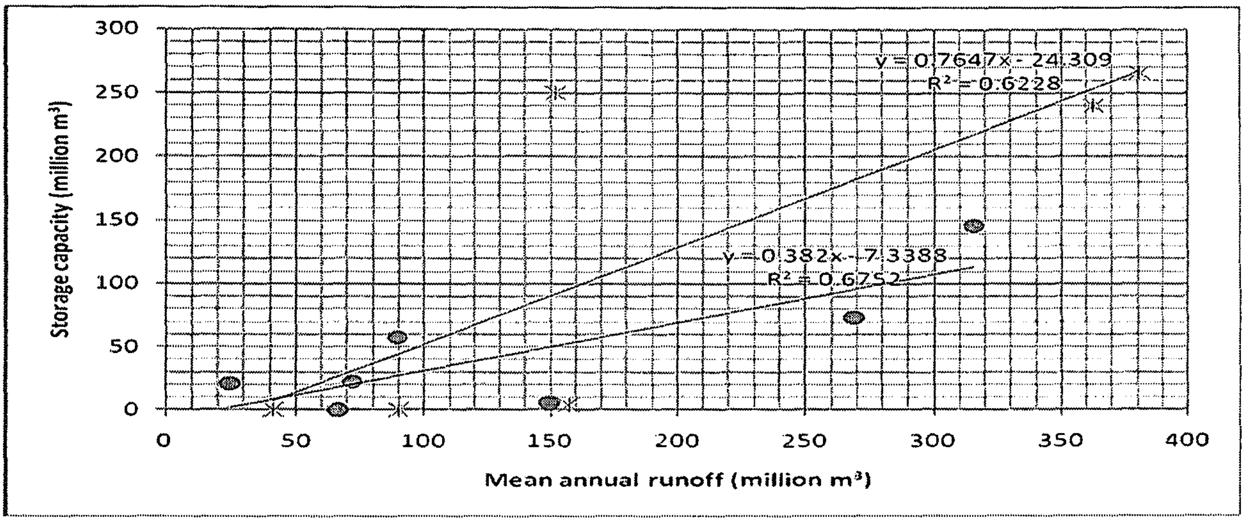


Figure 4.3 Influence of runoff on storage capacity of river catchments of Limpopo and Luvuvhu-Letaba WMAs

There was a moderate to strong correlation (R^2=0.6752) between runoff and storage capacity of the river catchments in the Limpopo WMA (Figure 4.3). As revealed by the graph (Y=0.382x – 7.3388), an increase in MAR was accompanied by an increase in water storage capacity. The results indicate that more storage infrastructure was developed in catchments with more runoff. Storage infrastructure was therefore properly planned taking catchment runoff into consideration.

A moderate to strong correlation (R^2=0.6228) was also recorded between runoff and storage capacity of catchments in the Luvuvhu-Letaba WMA. The graph (Y=0.7647x – 24.309) also shows an increase of storage capacity with an increase in catchment runoff. The steeper gradient of the graph for the Luvuvhu-Letaba WMA suggests a larger increase of storage capacity per increase of catchment runoff and is in accordance with the fact that 64.2% of runoff was stored in this WMA compared to only 33% in the Limpopo WMA. Contrary to the picture presented by the Middle Letaba Dam, the rest of the dams in the Luvuvhu-Letaba WMA were well designed with due consideration made of available runoff.

4.3.2 Runoff and storage capacity of municipalities in the study area

The runoff and storage capacity of municipalities are important determinants of their water availability.

(a) Runoffs of municipalities in the study area

Although water in South Africa is a national resource (RSA, 1998a; DWAF, 2004a), analysis of the amount of runoff across the area of a municipality is important. Knowledge of runoff of municipalities assists in identifying those in which strategic water projects could be initiated for developmental activities. The projects would be of economic benefit to municipalities that would otherwise have to be supplied from storage infrastructure that is a long distant away, and this could be costly.

Adoption of rainwater harvesting practices improves water supply for domestic and productive purposes. For instance, on-farm storage ponds and *in situ* rainwater conservation systems such as conservation tillage are possible strategies for upgrading rainfed agriculture in semi-arid environments (Ngigi *et al.,* 2006). The runoffs of study municipalities was calculated from those of quaternary catchments located in the municipalities (Figure 4.4).

The total MAR of the study municipalities in the Limpopo WMA was 602.7 million m^3 while that of the Luvuvhu-Letaba WMA was 898.3 million m^3 The MAR of Luvuvhu-Letaba WMA is larger than that of Limpopo WMA by almost 50%, suggesting that the former had a larger quantity of available water.

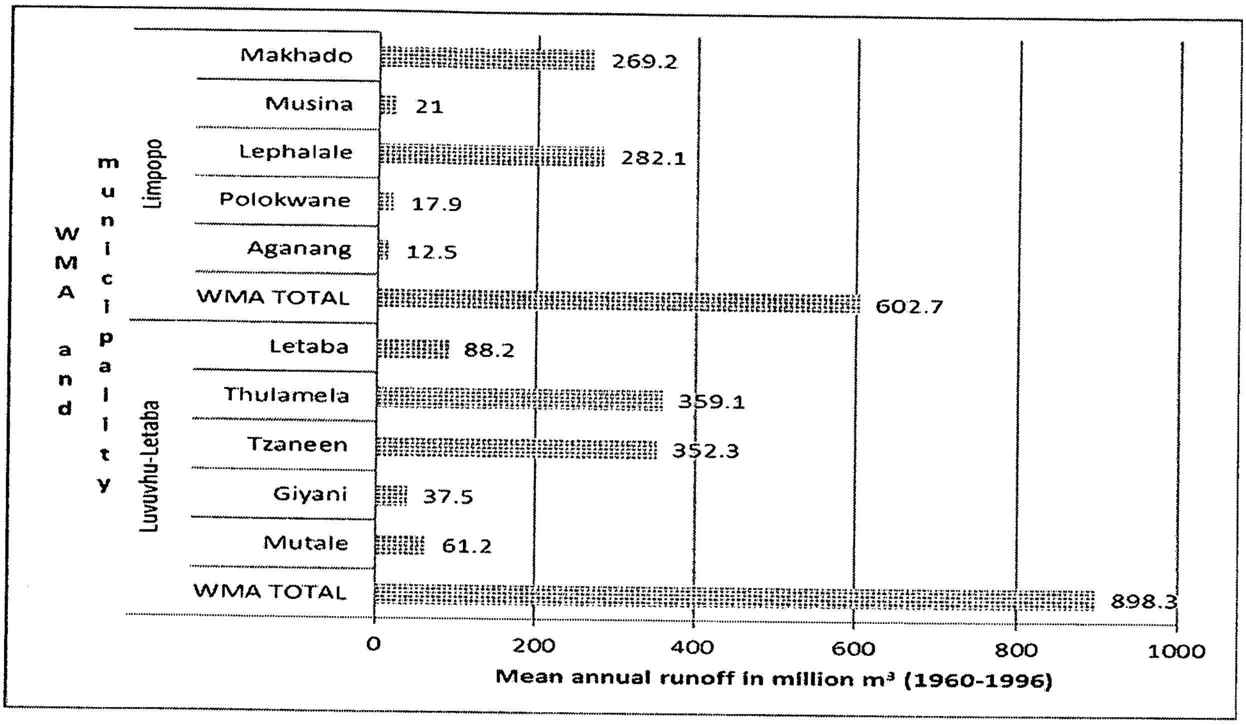


Figure 4.4 Mean annual runoff (MAR) of municipalities of the Limpopo and Luvuvhu-Letaba WMA (Midgley *et al.*, 1994)

Four municipalities had MAR > 100 million m^3 and were the locations of the larger quantities of available water. The four municipalities are Makhado (269.2 million m^3) and Lephalale (282 million m^3) in the Limpopo WMA and Thulamela (359.1 million m^3) and Tzaneen (352.3 million m^3) in the Luvuvhu-Letaba WMA. Of the four municipalities, the two in the Luvuvhu-Letaba WMA had larger amounts of available water than their counterparts in the Limpopo WMA.

(b) Water storage capacity of municipalities under study

The water storage capacity of a municipality determines the available MAR for possible development of new strategic water related projects not fed from major impoundments. These strategic water projects would include on-farm ponds and conservation tillage for upgrading rainfed agriculture in semi-arid environments (Ngigi *et al.*, 2006). When more storage capacity is available in a municipality, less MAR remains to justify development of such strategic water projects.

Dam storage capacity refers to the full supply capacity of a dam and therefore represents the maximum capacity that the dam has to store water. Municipal storage capacity was calculated as the total of the storage capacity of dams in a municipality and therefore represents the maximum capacity that a municipality has to store water (Table 4.2).

Table 4.2 Storage capacity and available MAR for possible strategic water related projects in selected municipalities of the Limpopo and Luvuvhu-Letaba WMAs (DWAF, 2003; DWAF, 2004b)

Water Management Area	**Municipality**	**MAR (million m^3)**	**Storage capacity (million m^3)**	**Storage capacity with ecological reserve at 5% of MAR (million m^3)**	**Available MAR for possible development of new strategic water projects (million m^3)**
Limpopo	Makhado	269.2	32.9	46.4	222.8
	Musina	21.0	0.0	1.1	20.0
	Lephalale	282.1	145.9	160.0	122.1
	Polokwane	17.9	13.2	14.1	3.8
	Aganang	12.5	0.0	0.6	11.9
	WMA total	**602.7**	**192.0**	**222.1**	**380.6**
Luvuvhu-Letaba	Letaba	88.2	2.0	6.4	81.8
	Thulamela	359.1	218.8	236.8	122.3
	Tzaneen	352.3	243.3	260.9	91.4
	Giyani	37.5	213.5	215.4	-177.9
	Mutale	61.2	20.6	23.7	37.5
	WMA total	**898.3**	**698.2**	**743.1**	**155.2**

The total storage capacity was 192 million m^3 (31.9% of municipal MAR) for Limpopo WMA and 698.2 million m^3 (78.2% of MAR) for Luvuvhu-Letaba WMA (Table 4.2) implying that the latter WMA is more developed in terms of storage capacity. Four municipalities had storage capacity > 100 million m^3, and those were Lephalale (145.9 million m^3) in the Limpopo WMA and Thulamela (218.8 million m^3), Tzaneen (243.3 million m^3) and Giyani (213.5 million m^3) in the Luvuvhu-Letaba WMA. The results reveal that municipalities in Luvuvhu-Letaba WMA were more developed in terms of water storage infrastructure than those in Limpopo WMA.

The available MAR for possible development of new strategic water related projects was 380.6 million m^3 (63.1% of total MAR) for Limpopo WMA and 155.2 million m^3 (17.3% of total MAR) for Luvuvhu-Letaba WMA. These results imply that the Limpopo WMA offers a larger opportunity than the Luvuvhu-Letaba WMA for development of new strategic water related projects. Such water related projects should be prioritized for municipalities with larger available MAR (> 100 milliom m^3), namely: Makhado (222.8 million m^3) and Lephalale (122.1 million m^3) in the Limpopo WMA and Thulamela (122.3 million m^3) in the Luvuvhu-Letaba WMA.

The reduction of the available MAR for the Luvuvhu-Letaba WMA was worsened by the anomaly at the Giyani Municipality were storage capacity exceeded MAR, resulting in available MAR for possible development of additional storage being -177.9 million m^3. This anomaly was a result of the large Middle Letaba Dam with storage capacity of 184.2 million m^3 built in a catchment with a lesser MAR of only 151.9 million m^3. In terms of the plan, the dam was to have been built downstream from its current position, and this had to be changed because of lack of political consensus on the original site.

4.4. Summary and conclusion

The results of the investigation in this chapter revealed that there is more available water in the Luvuvhu-Letaba (total MAR=1 183.9 million m^3) than in the Limpopo (985.9 million m^3) WMA. There was a wide range of MAR from one catchment within a WMA to the other and this indicated large differences in potential for development of dam storage across the catchments.

The total storage capacity of river catchments in the Limpopo WMA was 33% of MAR while that of the catchments in the Luvuvhu-Letaba WMA was 64.2% of MAR, revealing that the latter WMA had more storage capacity. Accordingly, the Limpopo WMA had a larger available MAR of 611.4 million m^3 for possible development of new dams compared to only 365.2 million m^3 for the Luvuvhu-Letaba WMA. Also, the municipalities in the Limpopo WMA had a larger available MAR of 380.6 million m^3 for implementation of strategic water related projects compared to 155.2 million m3 of those in the Luvuvhu-Letaba WMA.

The results suggest that the Limpopo WMA should be prioritized for development of new dams and strategic water related projects. The development of new dams should prioritize the Mogalakwena, Lephalale and Mokolo river catchments in the Limpopo WMA and the Luvuvhu and Mutale catchments in the Luvuvhu-Letaba WMA. As for strategic water related projects, priority should be given to Makhado and Lephalale municipalities in the Limpopo WMA and Thulamela municipality in the Luvuvhu-Letaba WMA. Although the Limpopo Province is water scarce, adequate runoff still occurs in some catchments to warrant the construction of new dams for increased water storage.

CHAPTER 5

5 RAINFALL INFLUENCE ON WATER GAIN AND LOSS FROM MIDDLE LETABA DAM

5.1 Introduction

The demand for water exceeds supply in many parts of the world, and more areas are expected to experience this imbalance in the near future. Increased scarcity of water is predicted to occur as a result of increasing population and resource demand per capita. The increased scarcity of water will continue to affect life negatively as the resource is required for domestic, industrial, agricultural, recreational and environmental uses (Vairavamoorthy *et al.,* 2008).

Water storage has become important, and man enhances the storage by constructing dams to impound water (Keller *et al.,* 2000; Muller, 2000). According to Keller *et al.* (2000), storage of water in dams allows for the resource to be captured in periods and places of abundance and availed for use in periods and places of scarcity. Dams support economic, social and cultural activities and the functioning of ecosystems (Saiko and Zonn, 2000; Mostert, 2008) through their water supplies for household, industrial, irrigation and ecological requirements (Katambara and Ndiritu, 2009). As revealed by Inocencio *et al.* (2003), construction of dams is an obvious response to the problem of water scarcity.

Dams are often characterised on the basis of their storage volume as small or large. According to BOR (1987) and ICOLD (1998), small dams are those with storage volumes generally less than 0.75 million m^3 while large dams have storage volumes of 1 million m^3 or more. Some dams are excessively large, for example, the total annual withdrawal of the world's largest dam is 3 800 km^3 (Gleick, 1998) while the design storage capacity of the largest dam was recorded to be about 6 000 km^3 (LeCornu, 1998).

The ability of a dam to supply water for different uses is dependent on its water gain and loss and these are influenced by the amount of rainfall it receives. The water gains are inputs (rainfall and inflows) while the losses are outputs (evaporation, abstractions, and outflows), and these result in changes in storage (ORMCP, undated).

The purpose of this study was to investigate the influence of rainfall received over the surface area of the dam on water gain and loss and on water storage volume of the Middle Letaba Dam in the Luvuvhu-Letaba WMA. The gain components investigated were the rainfall itself and inflow from the source river while the loss components were potential evaporation from the dam and outflow (inclusive of domestic and industry supplies, irrigation and normal flows). The study was necessary to assess whether the dam would ever fill up to its capacity and allow for increased supply of water (Section 1.4, Table 1.3, specific objective 4).

5.2 Methodology

5.2.1 Dam location and physical characteristics

The Middle Letaba Dam is on the Middle Letaba River which is part of the Letaba catchment of the Luvuvhu-Letaba WMA. The catchment is located in a semi-arid region in the north-eastern part of South Africa. The western part of the catchment is mountainous with an altitude higher than 2 000m above mean sea level, and that decreases gradually towards the eastern part to slightly below 450m above mean sea level. The Middle Letaba River originates from the mountainous region and flows towards the lower eastern part of the catchment (Katambara and Ndiritu, 2009).

The dam is located within the South African Quaternary Catchment (QC) number B82D with an area of 632km^2 while its total catchment area is 1 806km^2 (Midgley *et al.,* 1994). Specifically, the dam is located at 30°24′4.68′′E and 23°16′16.967′′S. Smaller dams such as Lorna Dawn and Altenzur Dam occur in the same catchment upstream of the Middle Letaba Dam (Figure 5.1).

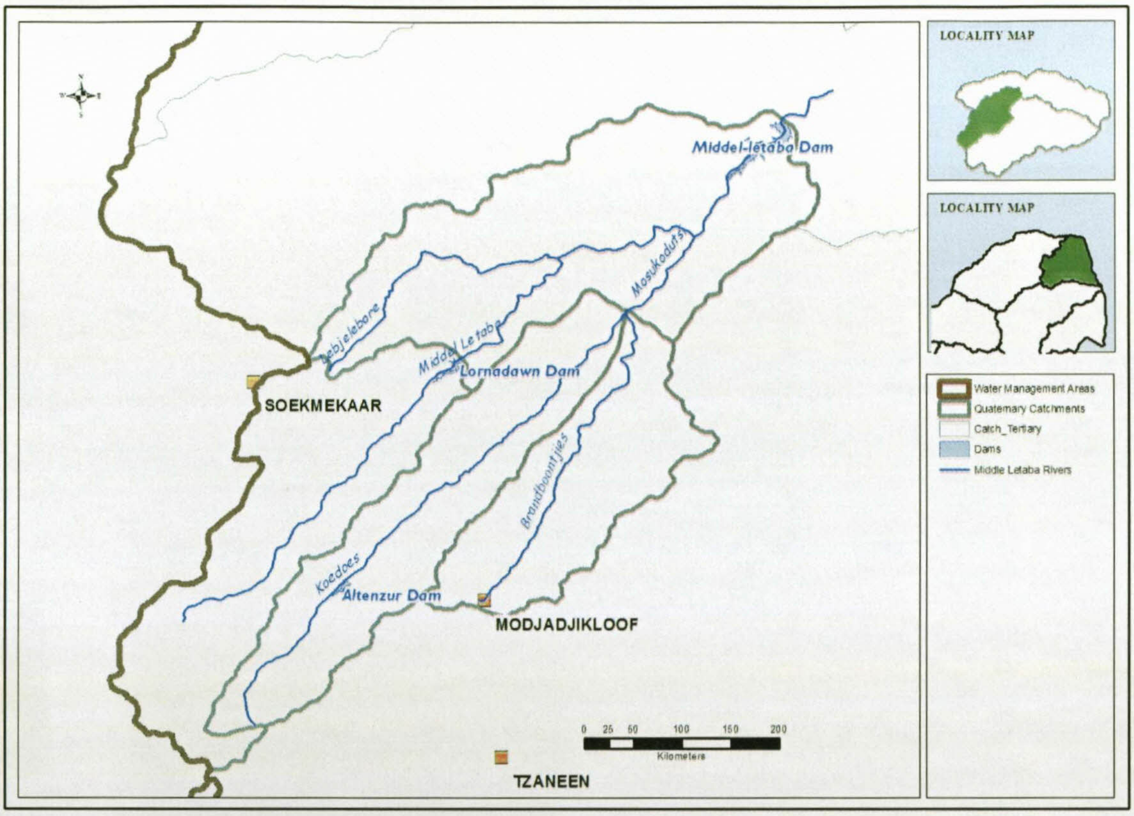


Figure 5.1 Location of the Middle Letaba Dam (blue water body) in the Middle Letaba Catchment (grey line) within the Luvuvhu-Letaba WMA (red line)

At full supply, the dam has a surface area of 1 926ha and a head of 18m with the lowest outlet at -0.520m. The gross full supply capacity is 184 210 000m^3 while the net supply capacity is 171 930 000m^3 (DWAF, 2004a), making the Middle Letaba the largest dam in the WMA when full supply capacity is considered.

5.2.2 Sampling procedure

The Middle Letaba Dam was purposively sampled for the study because of its water storage volume that was persistently low making water use communities to experience continued shortage of the resource. Leedy and Ormrod (2010) described purposive sampling as the selection of study units for a particular purpose. The purpose of selecting the Middle Letaba Dam was to investigate the influence of the rainfall received over the surface area of the dam on its water gain and loss components and to subsequently identify the causes of persistent low storage volume.

As a result of the low water storage volume, the dam completely failed to supply water during July 1994 to February 1995 (DWAF, 2004b). Domestic demand in this period was met by pumping water from dead storage into the outlet tower. The dam continues to fail to supply water to the targeted communities of Giyani Municipality, making it arguably the most water stressed municipality in the Limpopo Province.

5.2.3 Data collection and analysis

The data for rainfall and related water gain and loss components of the Middle Letaba Dam was obtained from the Department of Water Affairs. The department collected the data at the dam site over a period of 20 years from 1990 to 2009 (DWAF, undated).

The data was organized using spread sheet to perform relevant calculations and to draw graphs to illustrate relationships between rainfall and the water gain and loss components. This method of data analysis was in accordance with Leedy and Ormrod (2010) who indicated that electronic spreadsheets can quickly and easily organize the data and make simple calculations once the data is entered into the sheets.

5.3 Results and discussion

5.3.1 Rainfall received over the surface area of the dam

Rainfall is the fundamental driving force and pulsar input behind most hydrological processes (Schulze, 1995) and is in fact a major source of water for a dam (Nath and Bolte, 1998). According to Kongo and Jewitt (2006), the hydrological response of a dam can generally be defined as its reaction to rainfall. The mean monthly rainfall received over the surface area of the Middle Letaba Dam varies across different seasons of the year (Figure 5.2).

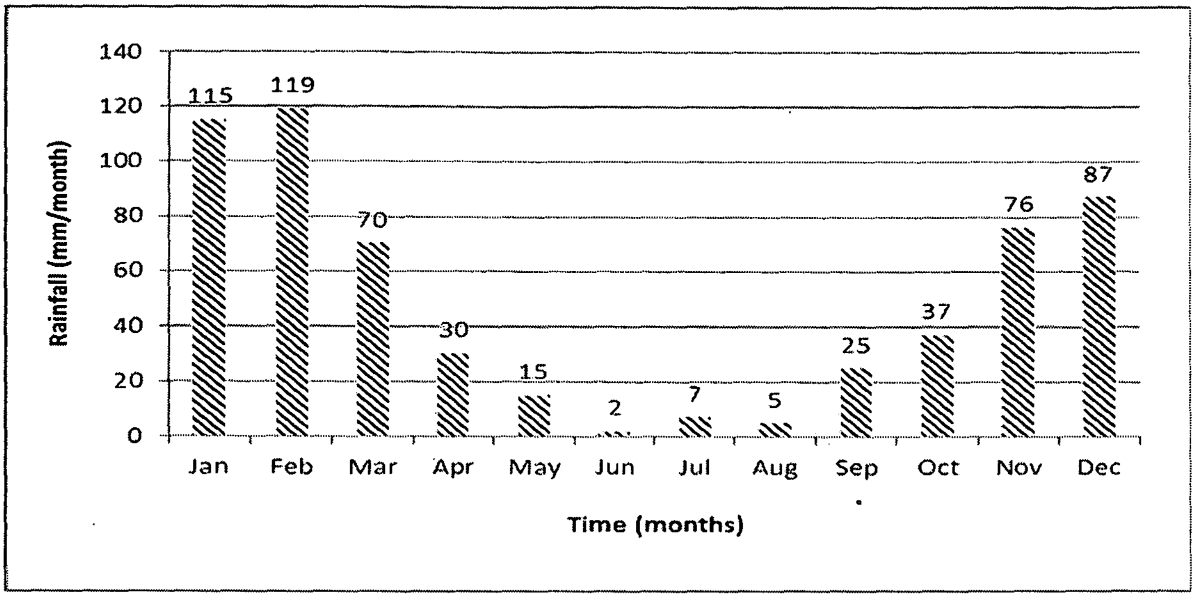


Figure 5.2 Mean monthly rainfall received over the surface area of the Middle Letaba Dam during 1990- 2009 (DWAF, undated)

According to Figure 5.2, the rainfall received over the surface area of the dam was high for summer months with 76mm recorded for November, 87mm for December, and 115mm for January. High rainfalls were also received during February (119mm) and March (70mm) with lesser amounts received in the rest of the months. The least rainfalls occurred in June (2mm).

The rainfall increased through spring from September (25mm) to October (37mm), and continued to increase in the summer months. The dam received high rainfall in summer with higher falls coming later during the early to mid-autumn. This pattern of rainfall is similar to the general trend in the WMA. It would be expected for the dam to gain more water from direct rainfall during the higher rainfall months.

5.3.2 The influence of rainfall on inflow from source river

The rainfall received over the surface area of the dam would likely also occur in some parts of the catchment and this would be expected to influence inflow from the source river. This inflow, often referred to as streamflow, consists of the above-dam runoff from the catchment where the dam is located and the runoffs from all upstream catchments. Runoff was defined as the water yield from a given catchment and consists of stormflow, baseflow and seepage (Schulze, 1995; Fargo, 2002; Webb, 2005).

The magnitudes of stormflow and baseflow after a rainfall event are influenced by the condition of the land surface. Land with more vegetative cover promotes baseflow while that with lesser vegetative cover promotes stormflow (Chandler, 2006; Heck *et al.,* 2006) and this could have some effect on the amount of inflow at a given time. Land use in the catchment upstream of the Middle Letaba Dam is characterized by irrigated crop farming where tomato is the major crop. The irrigated area varies during the cropping season from 2 100ha to 3 700ha with irrigation water pumped directly from the river (DWAF, 2004b). This type of land use results in lesser vegetative cover which promotes storm flow. The monthly inflows from the source river were calculated based on dam surface area to determine the extent to which the inflows would affect the level of the dam (Figure 5.3).

Although rainfall started to increase in September (25mm), inflow remained low at 114mm. It was only when rainfall continued to increase in October (37mm) that the inflow from the source river increased from to 271mm, showing a time lag of inflow response to rainfall increase. As rainfall continued to increase through November to February, inflow increased up to March. While the peak of rainfall was recorded in February (119mm), that of inflow only occurred in March (8 764mm), presenting a time lag of one month from the highest rainfall received over the surface area of the dam to maximum inflow from the source river.

As revealed in Figure 5.3, occurrence (or increase) of rainfall received over the surface area of the Middle Letaba Dam was accompanied by an increase of inflow from the source river with a time lag of one month. With the catchment area upstream of the dam often under irrigated cropping with sparse cover, land use patterns may not adequately explain the one month time lag from peak rainfall to peak inflow. The time lag could have resulted from a number of factors, and these include spatial distribution of rain gauges and the occurrence of small dams in the catchment upstream of the Middle Letaba Dam (Figure 5.1).

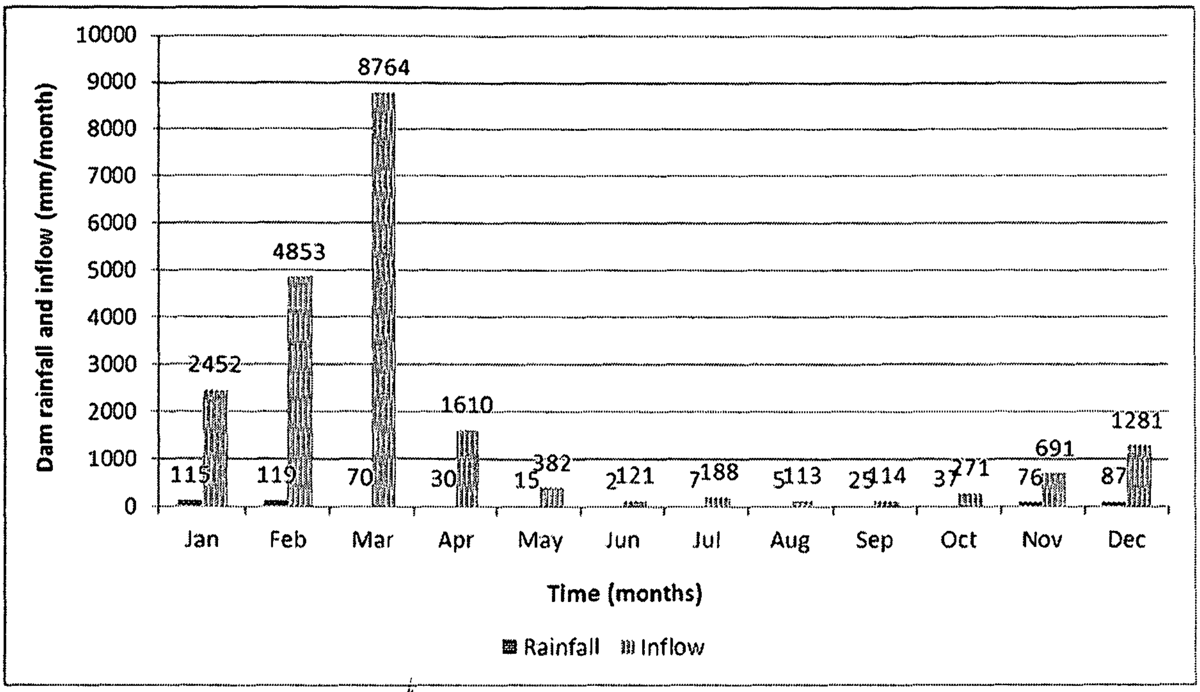


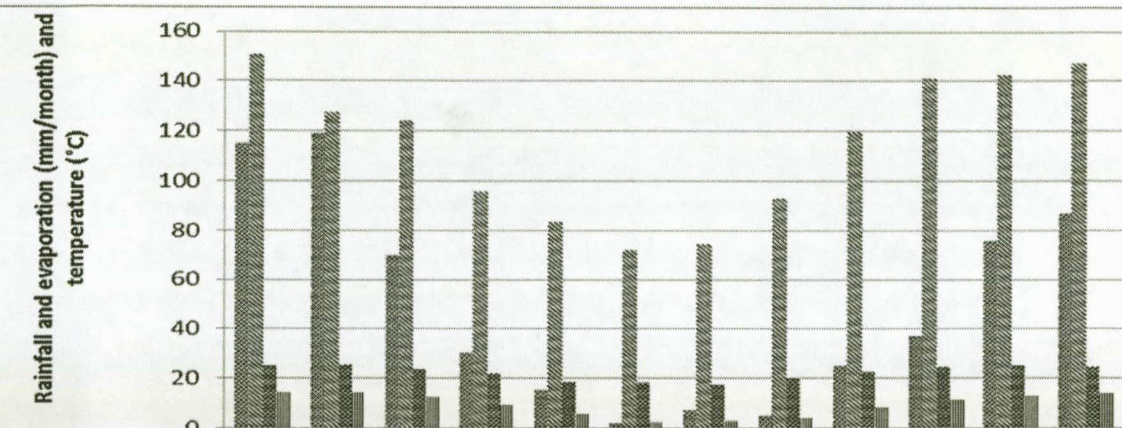
Figure 5.3 Mean monthly rainfall and inflow to the Middle Letaba Dam during 1990 – 2009 (DWAF, undated)

The occurrence of other dams in the catchment upstream of the Middle Letaba Dam supports Katambara and Ndiritu (2009) who revealed that there are many farm dams in the Letaba River system. The time lag from peak rainfall to peak inflow is probably a result of the need for filling time for these upstream dams before the runoff may flow over to the downstream Middle Letaba Dam. The time lag may also be a result of spatial variation of rainfall upstream of the dam.

5.3.3 Rainfall influence on evaporation from the dam surface

The term evaporation includes potential and actual evaporation where the former is defined as the evaporative demand of the atmosphere and occurs when there is unlimited supply of water while the latter reflects the actual amount of water evaporated from the soil and includes situations of limited supply of the resource (de Silva, 1999). The evaporation from dam surface reflects a situation of unlimited supply and is therefore regarded as potential evaporation.

The estimates of the amount and rate of potential evaporation are required in water resource management for a variety of purposes such as the design of dams, catchment water balance studies and municipal and industrial water supply (Mengistu and Savage, 2010). An investigation of the influence of rainfall on potential evaporation from the Middle Letaba Dam is important for better understanding the hydrology of the dam. The influence of temperatures on potential evaporation is important and hence temperature in included in the investigation (Figure 5.4).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	115	119	70	30	15	2	7	5	25	37	76	87
Evaporation	150.4	127.4	124.0	96.0	83.7	72.0	74.4	93.0	120.0	141.1	142.5	147.3
Mean max temp	25.0	25.5	23.6	21.8	18.7	18.0	17.3	19.7	22.6	24.6	25.2	24.7
Mean min temp	14.3	14.2	12.4	9.2	5.9	2.5	2.6	4.2	8.2	11.3	13.0	13.7

Figure 5.4 Mean monthly rainfall and evaporation from the Middle Letaba Dam during 1990 – 2009 (DWAF, undated)

Figure 5.4 reveals that potential evaporation from the surface area of the Middle Letaba Dam was higher than rainfall for the twelve months of the year and this could be reason for levels of the dam to be often low and for its failure to supply water during July 1994 to February 1995 (DWAF, 2004b). Actual evaporation from the dam surface increased with rainfall and was accordingly higher during summer compared to winter months. The potential evaporation (in mm/month) could not have been influenced by changes in the surface area of the dam due to changes in rainfall as the evaporation was based on the existing dam surface area. The results reveal that rainfall had no influence on the potential evaporation from the Middle Letaba Dam.

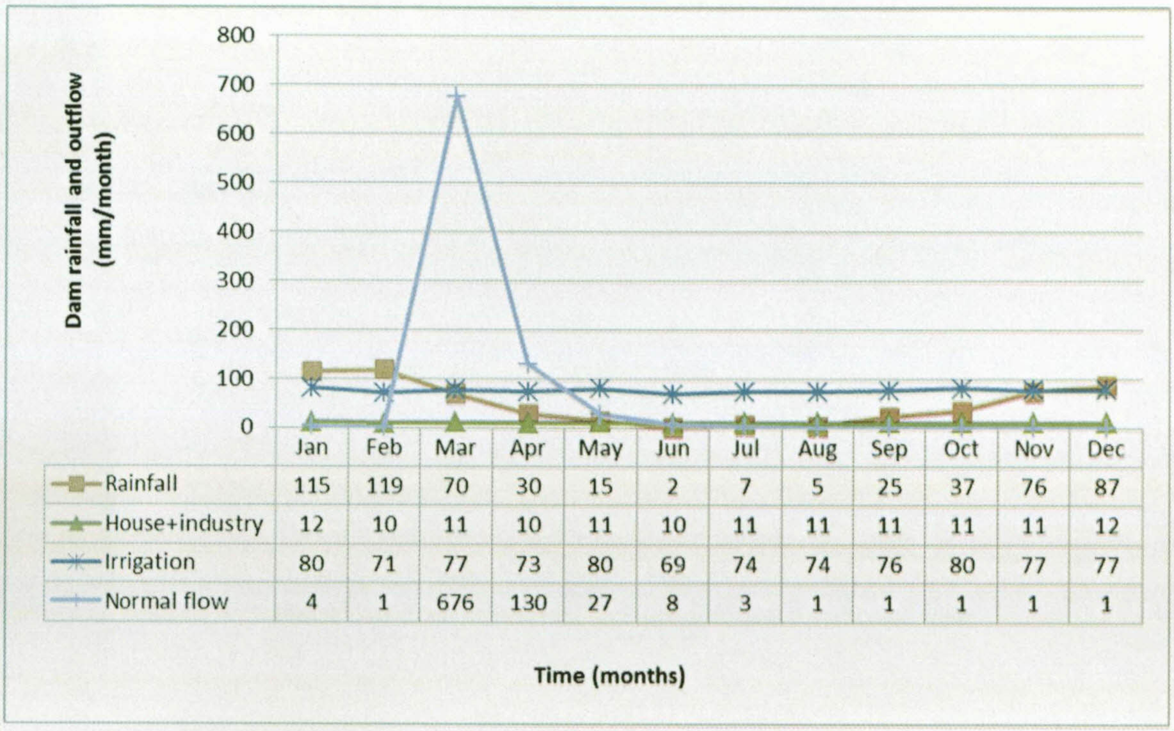
As shown in Figure 5.4, the temperatures (both maximum and minimum) at the dam changed with months of the year with higher temperature recorded in the summer compared to winter months. Higher temperatures were associated with higher potential evaporation. The higher temperatures resulted in more energy being available to evaporate the water and hence the changes in potential evaporation across the months were caused by temperature changes.

5.3.4 The influence of rainfall on outflow from the dam

Outflow from the Middle Letaba Dam includes supplies to households and industry, irrigation and normal flow. The water supplied to households and industry is for primary consumption and is regarded as a priority. The water supplied for household is used for domestic and productive activities while that for industry is used for processing activities. In order to understand the uses of household and industrial water supplies, it is important to consider the population and economic activities (Johnson, 2001; Kojiri, 2008).

A total of 2 400ha has been developed for irrigation from the Middle Letaba Dam. The irrigation water demand to serve this area is estimated at 21 million m^3/a. As a result of water shortages and the increased use of the resource for household purposes, the area irrigated is estimated at 1 300ha with a mean annual field edge requirement of 10.3 million m3/a (DWAF, 2004b). With the continued increase of water demanded for household use, the amount of the resource available for irrigation and hence the area covered could currently be much lesser.

Normal flow also comprises an important part of outflow. Most streams contain, in legal terms, 'public' water, and therefore downstream riparian and other users have a right to a certain amount of water that would likely have been available as streamflow, had the dam not been constructed. As a result, a compulsory release of water from the dam called 'normal flow' has to be discharged downstream (Schulze, 1995). A portion of the normal flow is used to satisfy the requirements for the ecology. The relationship between monthly rainfall and outflow from the Middle Letaba Dam should be assessed for one to understand the hydrology of the dam (Figure 5.5).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	115	119	70	30	15	2	7	5	25	37	76	87
House+industry	12	10	11	10	11	10	11	11	11	11	11	12
Irrigation	80	71	77	73	80	69	74	74	76	80	77	77
Normal flow	4	1	676	130	27	8	3	1	1	1	1	1

Figure 5.5 Mean monthly rainfall and outflows from the Middle Letaba Dam during 1990-2009 (DWAF, undated)

Abstractions for household and industry and for irrigation were almost constant throughout the year (Figure 5.5). According to Nyabeze *et al.* (2007), the operating rules of the Middle Letaba Dam indicate that 100% of the water demand for household and industry and for irrigation would be supplied when the dam is full. When the reservoir is 30-50% full, 70% of the water requirements for household and industry would be supplied while 35% of water demand for irrigation would be supplied. The fact that the abstractions for the use sectors were constant throughout the year suggests that rainfall did not result in adequate rise in dam level to allow for increase in water supply as guided by the operating rules.

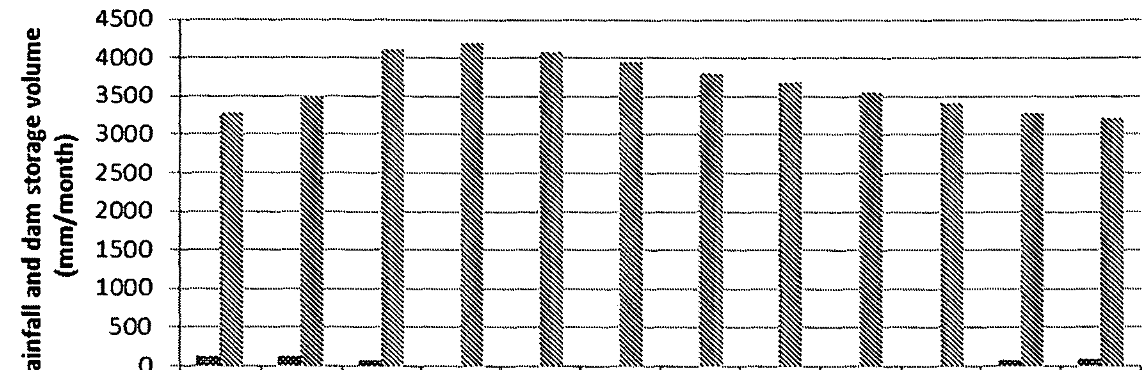
Contrary to the other components of outflow, normal flow seemed to have been influenced by rainfall. While the rainfall increased from September to December, normal flow remained constant at 1 mm/month. With continued increase in rainfall in January, normal flow picked up to 4 mm, but this was followed by a drop back to 1 mm in February, a month in which the highest rainfall was recorded. The highest amount of normal flow occurred in March with a mean of 676 mm recorded. This flow was exceptionally high and resulted from the floods in the years 2000 and 2001.

5.3.5 Rainfall and dam water storage volume

The dam water storage volume reflects the quantity of water stored in a dam at a particular time. The dam storage volume is a product of the interactions of water gain with water loss components. If water gain components bring more water to the dam with water loss components remaining constant, the dam storage volume will increase and *vice versa.*

Rainfall is an important water gain component which has a positive influence on the other gain component of inflow and different influences on loss components. An investigation of the relationship between the rainfall and dam storage volume is therefore necessary for proper planning of water supply and use issues (Figure 5.6). The dam storage volume was presented as dam level (in mm/month) based on the dam surface area of 1926 ha.

Figure 5.6 seems to be showing an inverse relationship between rainfall and dam storage volume. As the rainfall increased from September to December, dam storage volume decreased. This trend discontinued in January to February in which case a positive relationship occurred, i.e. dam storage volume increased with an increase in rainfall. The inverse relationship generally recurred from March through to the winter months.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	115	119	70	30	15	2	7	5	25	37	76	87
Dam level	3 280	3 494	4 104	4 184	4 081	3 937	3 803	3 680	3 548	3 409	3 274	3 216

Time (months)

Figure 5.6 Mean monthly rainfall and dam storage volume of Middle Letaba Dam during 1990-2009 (DWAF, undated)

Increases in rainfall during September to December were accompanied by decreases in dam storage volume. As rainfall continued to increase in January (115mm), dam storage volume also increased (3 280mm). As rainfall increased to its peak in February (119 mm), further increased dam storage volume was recorded (3 494mm), with larger storage volume registered in March (4 104mm) when rainfall actually started to drop. As the rainfall dropped sharply in April (30mm), dam storage volume increased slightly to a peak of 4 184mm. With the rainfall remaining low through winter months, dam storage volume gradually decreased. The peak storage volume of 4 184 mm represents 80.6 million m^3 which is far less than the 184,210,000m^3 design storage capacity of the dam, an assertion of the view that the dam levels are persistently low.

The peak of rainfall was recorded in February, that of inflow was in March and the highest dam storage volume was in April (Figure 5.6). The results reveal a time lag of two months from the peak of rainfall to that of dam storage volume. Again the time lag could have resulted from factors such as the spatial distribution of rain gauges, spatial variation of rainfall and the occurrence of small dams in the catchment upstream of the Middle Letaba Dam.

The apparent inverse relationship between rainfall and dam storage volume should be a result of the two months time lag between the two factors of the hydrology of the dam. Detailed analysis is necessary to clearly show the effect of the two months time lag between peak rainfall and storage volume (Figure 5.7).

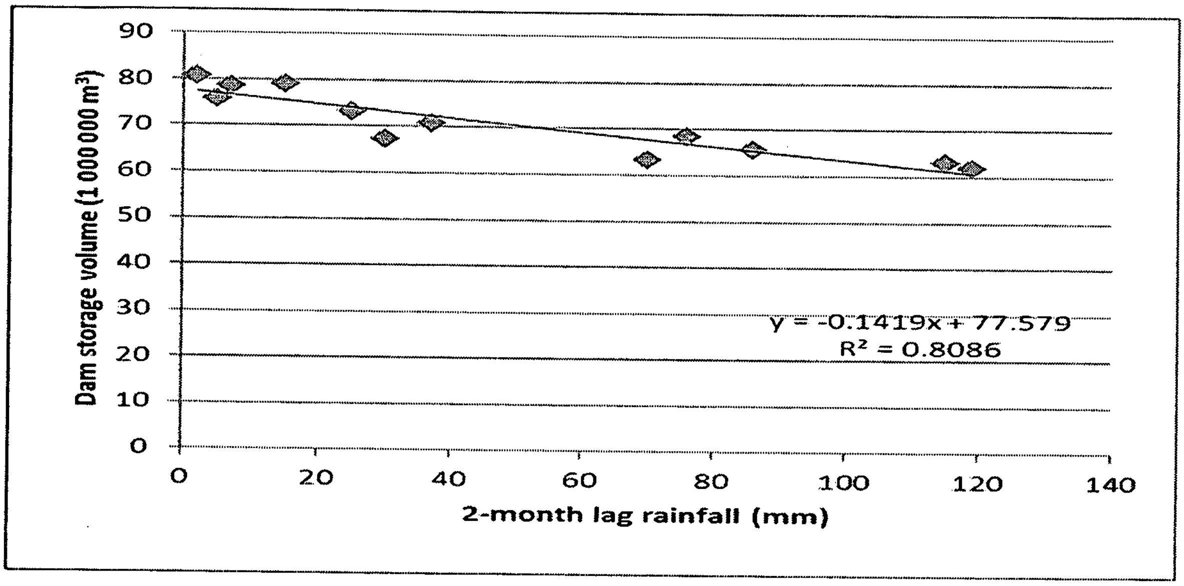


Figure 5.7 Correlation between mean monthly rainfall with a 2-month lag and dam storage volume of Middle Letaba Dam during 1990-2009 (DWAF, undated)

A strong correlation (R^2=0.8086) occurred between rainfall lagged by two months and dam storage volume. This result shows that occurrence of rainfall had a strong influence on dam storage volume although this influence would usually be evident after two months from the rainfall event when the rainfall itself had stopped (or decreased). Consequently, the slope of the graph is negative, suggesting an inverse relationship in which occurrence of rainfall would lead to a decrease in dam storage volume and *vice versa.*

The peak water storage volume of 80.6 million m^3 compared to dam design storage capacity of 184,210,000m^3 suggest that the dam can never be filled from rainfall, but will require transfer of water from other catchments to fill up. It is recommended that a detailed study of the water balance of the dam be carried out to obtain more information about the water status of the reservoir.

5.4. Summary and conclusion

The rainfall received over the surface area of the Middle Letaba Dam was high in summer and low in winter months with the peak in February (119mm) and the least in June (2mm). The rainfall had a positive influence on inflow from the source river with a time lag of one month from the peak of rainfall to that of inflow.

Although there seemed to be a positive relationship between rainfall received over the dam surface area and the potential evaporation from the dam, the two hydrological factors had no influence over each other. The potential evaporation was rather influenced by the temperatures at the dam site. The rainfall influenced normal flow as a component of outflow and such influences were only evident during years of large rainfalls (floods). Abstractions for household and industry and for irrigation were not influenced by rainfall and this was because these components of outflow are controlled under strict operation rules of the dam.

Dam storage volume also increased with increasing rainfall with a time lag of two months from peak rainfall to maximum storage volume. There was a strong correlation (R^2=0.8086) between rainfall lagged by two months and dam storage volume. The time lag between rainfall and inflow from the source river and that between rainfall and storage volume were probably a result of the spatial distribution of rain gauges, spatial variation of rainfall and the occurrence of small dams within the catchment upstream of the dam.

The dam storage volumes were very low compared to dam design capacity suggesting that the dam cannot be maintained at a desirable full level from only the rainfall (including inflow), but will need to be filled through transfers from other catchments.

CHAPTER 6

6 PERCEPTIONS OF MUNICIPAL WATER MANAGERS ON WATER RESOURCES, USES AND RESTRICTIONS

6.1 Introduction

The perceptions of municipal water managers on water resources and their uses reflect the amount of knowledge they have on the resources and have a strong influence on their decisions regarding the management of the resource. To make appropriate water management decisions, the water managers must be exposed to relevant knowledge usually scientifically generated by experts. According to Hermans, (2008) water experts expressed concern that their knowledge is insufficiently used (Section 3.3.1(a)). The lack of use of knowledge makes the task of overcoming the world water scarcity one of the most formidable challenges on the road to sustainable development (Alexander, 2002).

In addition to expert knowledge produced scientifically, municipal water managers should also have local based traditional knowledge in order to respond appropriately to community needs. Traditional response to inadequate water supply is associated with social adaptive capacity described by Ashton and Haasbroek (2002) as the ability of a society to adapt its patterns of water resource use to increasingly scarce supplies and achieve a sustainable measure of stability.

In situations where water policy decision makers such as water managers lack knowledge on water resource or its uses, it is necessary that they be helped to acquire the knowledge. The participatory process of social learning is one of the relevant approaches for knowledge acquisition (ICS, 2002; Gunderson and Light, 2006). The concept of 'social learning' refers to learning by observing others and their social interactions within a group (Bandura, 1977) (Section 3.3.1(b)).

The objective of the study was to investigate the perceptions of municipal water managers of Limpopo Province on water supply, uses and restrictions (Section 1.4, Table 1.3, specific objective 2) as the perceptions will, upon translation into municipal programs, influence the management of the water resource and hence the prospects for its availability for socio-economic development.

6.2 Research methods

6.2.1 Description of study area

The study focused on ten municipalities from two WMAs, the Limpopo and the Luvuvhu-Letaba WMAs. The municipalities covered by the study were Makhado, Musina, Lephalale, Polokwane and Aganang for the Limpopo WMA and Letaba, Thulamela, Tzaneen, Giyani, and Mutale for Luvuvhu-Letaba WMA (Figure 6.1).

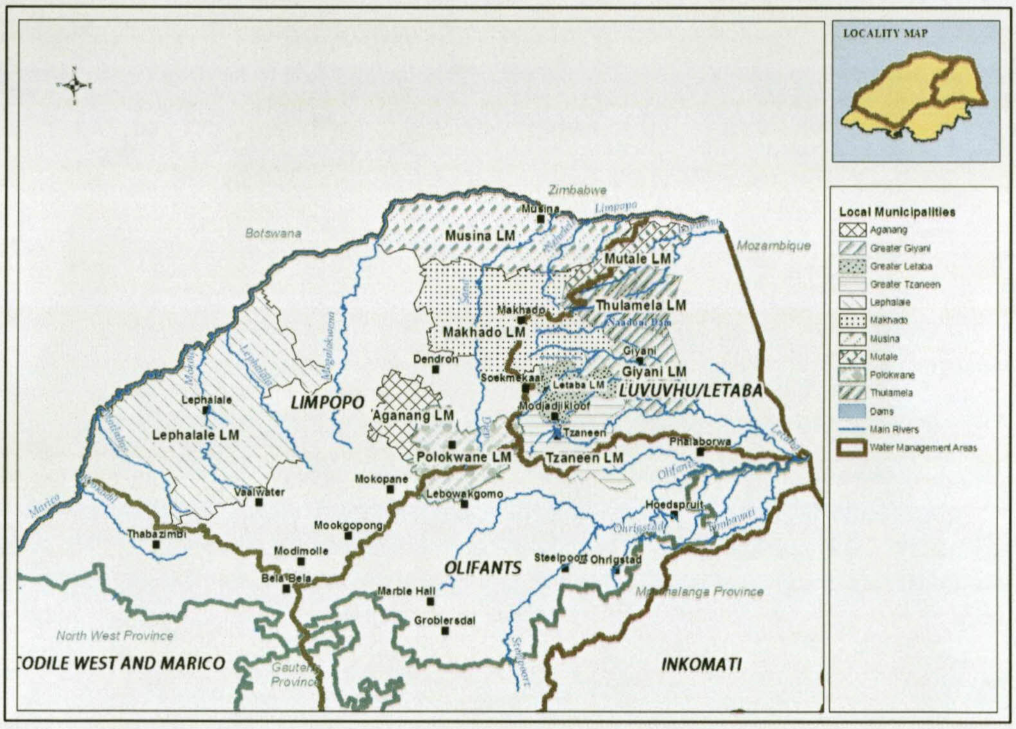


Figure 6.1 Map of the Limpopo Province showing the Limpopo and the Luvuvhu-Leataba WMAs (red line) and the study municipalities (hatchings)

6.2.2 Sampling procedure

Purposive sampling was used to select both the WMAs and the municipalities. The Limpopo and Luvuvhu-Letaba WMAs were chosen because they are managed under the nearby Limpopo Regional Office of the Department of Water Affairs (DWA) that would be easily accessible for information. The five municipalities in each of the WMAs were selected for their readily available information on runoff and water storage capacity (Section 4.3.2). The municipal information on runoff and storage capacity was necessary to assess the level of knowledge managers had on water resources.

6.2.3 Data collection and analysis

A questionnaire was developed for interviewing the water managers of the municipalities sampled for the study. The questionnaire had two major types of questions, the closed-ended questions that collected quantitative data and the open-ended questions collecting qualitative data (Leedy and Ormrod, 2010). The interviews were more structured when dealing with closed-ended questions and provided limited opportunities for respondents to give more insight on the aspects covered by the questions. As for open-ended questions, the interviews were less structured and probed respondents to give more insight on the aspects covered. The study therefore fit into Hurmerinta-Peltomaki and Nummela (2006)'s description of a mixed research.

The focus of the questionnaire was on a range of water supply and use issues, and these included perceptions on sizes of rivers in the municipalities, water uses for domestic, industrial and agricultural purposes and issues of resource supply restrictions. The researcher conducted the interviews himself and this allowed for clarification of the questions that were not immediately understood by the respondents, ensuring good quality of the data.

Quantitative data was captured and analysed using the SAS package (SAS Institute Inc, 2009). The Proc FREQ procedure of SAS was used to generate simple frequency tables of occurrence in each class utilizing one-way tables. The procedure is appropriate to give descriptive statistics about categorical data such as the demographic datasets. The syntax is provided to the SAS software, which automatically calculates the percentage of observations falling within each category of response. The output contains both the actual and the cumulative frequencies. Qualitative data was summarised and analysed using subjective interpretations (Leedy and Ormrod, 2010).

6.3 Results and discussion

6.3.1 Perceptions on municipal water resources

The perceptions of municipal water managers on water resources have strong influence on how they will manage the resources and as alluded to by Vairavamoorthy *et al.* (2008), determines the extent of availability of water for social and economic uses such as agricultural, industrial, household, recreational and environmental uses. Surface resources such as rivers are major sources of water in the study area and their availability and sizes are easier to assess and were therefore the focus of discussion of the perceptions of water managers.

The number and sizes of rivers are influenced by the direction of flow and amount of catchment runoffs described by Schulze (1995) as the water yield from a given catchment that consists of stormflow, baseflow, seepage, normal flow and overflow from any reservoirs within the catchment. The perceptions of municipal water managers on the number and sizes of rivers in their municipal areas indicate the managers' knowledge of the water resources (Table 6.1).

Considering the municipalities in the Limpopo WMA, three rivers were reported by the water manager of Makhado to be flowing through the municipality, namely: Luvuvhu, Mutshedzi and Nzhelele while two were omitted, the Sand and the Klein Letaba River (Table 6.1). The omitted rivers are major and were accordingly included among the rivers of the study WMAs (Chapter 4).

The Luvuvhu River was perceived to be the largest, followed by Mutshedzi and last Nzhelele. The rating of Mutshedzi River as larger than Nzhelele is incredible because the Mutshedzi River is in fact a tributary of the Nzhelele River and as opposed to the Nzhelele River, is not even included among major rivers in the study WMAs

Table 6.1 Perceptions of municipal water managers on number and sizes of rivers flowing through their municipal areas

Water Management Area	Municipality	Catchment rating
Limpopo	Makhado	Luvuvhu > Mutshedzi ک Nzhelele – (Klein Letaba, Sand)
	Musina	Limpopo > Nzhelele > Nwanedi ک Sand
	Lephalale	Mokolo > Lephalale ک Mogalakwena – (Matlabas)
	Polokwane	Sand
	Aganang	-
Luvuvhu-Letaba	Letaba	Molototsi
	Thulamela	Luvuvhu > Mutshindudi > Mbwedi ? Nzhelele – (Shingwedzi)
	Tzaneen	Groot Letaba > Letsitele
	Giyani	Klein Letaba > Msami
	Mutale	Nwanedi ک Mutale

Key: > means correctly rated larger than; ک means incorrectly rated larger than;
? means no data to assess rating of larger than; () means not enlisted

The incorrect rating of the Mutshedzi River as being larger than the Nzhelele River could have resulted from the former having a well-known dam, the Mutshedzi Dam which supplies water for domestic use. The Nzhelele Dam on the Nzhelele River only supplies water for irrigation and is therefore lesser known.

For Musina Municipality, four rivers were mentioned, namely: the Limpopo River perceived the largest followed by Nzhelele which was rated the second largest. The Nwanedi was rated the third largest while the Sand was regarded the smallest river flowing through the municipality. According to DWAF (2003), the mean annual runoff (MAR) of the Nwanedi River is 24.5 million m^3 while that of the Sand River is 71.9 million m^3, implying that the Sand is larger than the Nwanedi River, and this is contrary to the perception of the municipal water manager. The rating of the Nwanedi River as larger than Sand could have resulted from the former having a large Nwanedi Dam built on it while there was no major dam on the Sand River.

Three rivers were mentioned for Lephalale Municipality, and those were Mokolo rated the largest, Lephalale regarded the second largest and lastly Mogalakwena. Although it is one of the major rivers in the Limpopo WMA (Chapter 4, Section 4.3.1.1), the Matlabas was not mentioned. The MAR of Lephalale River is 149.4 million m^3 while that of Mogalakwena is 268.8 million m^3 (DWAF, 2003), revealing Mogalakwena as larger than Lephalale and is contrary to the perception of the municipal water manager. Polokwane Municipality only has Sand River flowing through it while Aganang Municipality has no major river flowing through it, and these were correctly reported by the water managers.

As for municipalities in the Luvuvhu-Letaba WMA, the water manager for Thulamela mentioned four rivers, the Luvuvhu River rated the largest, Mutshindudi regarded the second largest, Mbwedi perceived the third largest and Nzhelele viewed the smallest, with the Shingwedzi River omitted from the list. The Luvuvhu River has MAR of 362.9 million m^3 (DWAF, 2004b) and is confirmed the largest. The Mutshindudi and Mbwedi (catchment MAR of 138.1 million m^3) were presented as a combined river system forming a tributary of the Luvuvhu River. When the two rivers are considered as a combined river system, they are larger than the Nzhelele River (catchment MAR of 89.4 million m^3). If the Mutshindudi and Mbwedi were to be rated as separate rivers however, a different result would likely be reported. The rating of the Mutshindudi River as the second largest was likely influenced by its having a well-known Vondo Dam which supplies water for domestic use to the municipality. The rating of Mbwedi River as larger than Nzhelele is rather inexplicable.

The Tzaneen and Giyani municipalities had two rivers mentioned for each, and those seemed to be correctly rated. The water manager for Mutale Municipality rated the Nwanedi larger than Mutale River. The MAR of the Nwanedi River is 24.5 million m^3 while that of the Mutale River is 157.1 million m^3 (DWAF, 2004b), implying that the Nwanedi is in fact much smaller than Mutale River as opposed to the perception of the water manager.

The omission of major rivers by municipal water managers and the incorrect ratings of the sizes of the rivers imply that the water managers had limited knowledge of the water resources of their areas. Based on these inaccurate perceptions, the water managers are likely to make water management decisions that are not appropriate. Inappropriate water management decisions will negatively influence the availability of the resource for socio-economic development in the study area. It is therefore necessary for the water managers to be equipped with relevant knowledge of water resources for them to make appropriate decisions that will promote resource availability for socio-economic development.

6.3.2 Perceptions on municipal water uses

Water is required for agricultural, industrial, household, recreational and environmental uses (Vairavamoorthy *et al.*, 2008). Growing national, regional and seasonal water scarcities in much of the world pose severe challenges for national governments and international development and environmental communities (Rosegrant *et al.,* 2002). According to Winstanley and Wendland (2007), adequate supplies of clean water are fundamental requirements for human welfare and economic development. Conversely, water shortages and polluted waters limit human and economic growth.

Water is consumed by multiple uses, often referred to as domestic and productive uses. Domestic uses of water refer to water used in the homes for drinking, cooking, personal hygiene and household cleaning, while productive uses highlight the fact that in rural areas people engage in economic activities that are highly dependent on the availability of secure and reliable water supplies (Moriarty *et al.,* 2004). Perez de Mendiguren Castresana (2003) mentioned that specific multiple uses of water in Bushbuckridge in the Mpumalanga province of South Africa include drinking, washing, cooking, irrigation, manufacturing, brick making and beer making.

For municipal water managers to manage this scarce resource well, they should have some knowledge of the major uses of the resource in their areas of jurisdiction. Schreiner and van Koppen (2000) state that poor people's water needs for multiple uses should be the starting point for meaningful management of the resource, confirming the importance of water managers' knowledge of the multiple water uses by the poor.

Seven out of ten (70%) of the water managers claimed they have knowledge of the relative quantities of the water consumed by each of the major uses in their municipalities. Knowledge of the perceptions of municipal managers on major uses of water is necessary as it influences the managers' decisions on the management of the resource (Table 6.2).

Table 6.2 Perceptions of municipal water managers on major uses of the resource according to quantities consumed

Water Management Area	Municipality	Perceived quantity of water consumed				
		Ecological	Household	Industrial	Agricultural	Recreational
Limpopo	Makhado	2	5	3	4	1
	Musina	0	5	3	4	0
	Lephalale	2	5	1	4	3
	Polokwane	0	5	4	3	0
	Aganang	0	5	0	4	0
Luvuvhu-Letaba	Letaba	3	5	2	4	1
	Thulamela	3	4	1	5	2
	Tzaneen	3	4	2	5	1
	Giyani	3	5	2	4	0
	Mutale	4	5	2	3	1
	Average	**2.0**	**4.8**	**2.0**	**4.0**	**0.9**

Key: 0=None consumed, 1=Very small, 2=Small, 3=Medium, 4=Large, 5=Very large quantity consumed

According to Table 6.2, domestic use was perceived to have consumed a very large quantity of water (rating=4.8), followed by agriculture that consumed a large quantity (rating=4.0). The quantities of water consumed for ecological and for industrial purposes was regarded small (rating=2.0) while that used for recreational purposes was reportedly very small (rating=0.9).
The ratings of the major water uses by the respondents differ to some extent from that reported by DWAF (2004a) who presented agriculture as the largest consumer of the resource in the study area at 62%. The respondents reported agriculture to be a large consumer of water and to be

second after domestic use, and the sector is still highly rated considering the quantity of water consumed.

The perception of the managers that agriculture was the second and not the largest consumer of water could have resulted from the fact that they were not involved in supplying the major agricultural sector which received allocations directly from DWA. Municipalities were mainly rural with less industrial and recreational facilities and this could be reason for these sectors being perceived to be small consumers of water.

Three municipalities in the Limpopo WMA (Musina, Polokwane and Aganang) and one in the Luvuvhu-Letaba WMA (Giyani) reported lack of water consumption by some use sectors. The report of non-consumption could be an indication of the water managers' lack of knowledge of the consumed amounts. Each of the five major water use sectors was further discussed to better understand their perceived water consumption.

(a) Perceptions on household uses of water

Household use of water is essential for human health and indeed for survival. Water for household use is supplied for domestic and for productive purposes. Domestic water was described as the supply which caters for health and hygiene, covering specific issues such as water for drinking, cooking, sanitation and washing (Soussan *et al.*, 2002; Pollard *et al.*, 2002). Productive water caters for household economic activities.

The 2003 Johannesburg Symposium on Poverty and Water resolved that the quantity of water sufficient for domestic use would typically be between 50 and 150 litres per person per day. Moriarty *et al.* (2004) stated that the benchmark target for South Africa was 25 litres per person per day and this was clearly insufficient, especially if needs for productive activities were considered. The recommended minimum supply of water should be 50 litres per person per day if we were to cater for both domestic and productive uses (Gleick, 1993).

The inclusion of productive uses in household water budgeting is important as it provides opportunities to turn water into cash needed to buy spare parts and to pay for routine maintenance of the water supply infrastructure (Lovell, 2000). As a result, water supply systems that are designed to provide only domestic norms with exclusion of productive uses would most likely fail. The failure would be a result of the water supply system not being able to meet the demand of the water users and this may bring about economic and political instability (Schouten and Moriarity, 2003).

Perez de Mendiguren Castresana (2003) revealed the kind of benefits in monetary values for the various productive uses of water. Ice-block making provided the highest return (R1,70 per liter), followed by beer brewing (R1,05 per liter) and hair saloons (R0,84 per liter). Brick laying was next (R0,30 per liter), followed by livestock rearing (R0,025 per liter) and fruit production (R0,02 per liter). Vegetable production provided the lowest return (R0,013 per liter). Knowledge of household uses of water would therefore be necessary for water managers to make appropriate decisions in investing in the development of the resource and in allocating the resource to different major use sectors.

All the water managers in the study area mentioned drinking, cooking, washing and processing food for sale as important household uses of water. Nine out of ten (90%) of them mentioned processing drinks for sale as an important household use of water. On the basis of their knowledge of household water use, the respondents rated the uses of the resource according to the quantity consumed (Table 6.3).

Washing was perceived to have consumed a large quantity of water (rating=3.9), followed by agricultural activities (rating=3.4), drinking (rating=3.1) and cooking (rating=2.8) with perceived medium consumptions (Table 6.3). Very small quantities of water were reportedly consumed by processing of food (rating=1.2) and drinks (rating=0.9) for sale.

The rating of water uses according to the quantity of water consumed suggests that more water was used for domestic activities such as washing, drinking and cooking than the amount of water used for productive activities such as processing food and drinks for sale. Although agricultural activities are productive, they were reportedly medium consumers of water. This perceived distribution of water where basic domestic activities use more water than their productive counterparts are indicative of short supplies forcing households to allocate more water to basic life activities.

Table 6.3 Perceptions of municipal water managers on household uses of water according to quantities consumed by activity

Water Management Area	**Municipality**	**Perceived quantity of water consumed by household activity**					
		Drinking	**Cooking**	**Washing**	**Agricultural**	**Process drink**	**Process food**
Limpopo	Makhado	3	4	5	2	1	1
	Musina	5	3	2	4	1	1
	Lephalale	5	3	4	2	1	1
	Polokwane	4	3	5	2	0	0
	Aganang	1	1	2	4	0	3
Luvuvhu-Letaba	Letaba	2	3	4	5	1	1
	Thulamela	3	1	5	4	2	1
	Tzaneen	5	4	3	2	1	1
	Giyani	1	3	4	5	1	2
	Mutale	2	3	5	4	1	1
	Average	**3.1**	**2.8**	**3.9**	**3.4**	**0.9**	**1.2**

Key: 0=None consumed, 1=Very small, 2=Small, 3=Medium, 4=Large, 5=Very large quantity consumed

The fact that agriculture was perceived to consume the second largest amount of water implied that communities had realized the critical role played by the agricultural sector, both in promoting food security and in earning incomes for the rural households. This result supports Schreiner and Van Koppen (2000) who mentioned that water is vital to increase incomes above one US dollar per day. The reason for agriculture not being regarded the largest consumer of water could be the small scale of practice and the fact that it is not all families that practice agriculture at household level.

Two municipalities in the Limpopo WMA reported that there was no water consumption by some use sectors. These were the Polokwane Municipality who reported non-consumption for drink and for food processing and the Aganang Municipality indicating non-consumption for drink processing. The report of non-consumption suggests that the water managers did not have knowledge of the quantities consumed by the sectors.

(b) Perceptions on industrial uses of water

Vairavamoorthy *et al.* (2008) indicated that national water policies of many countries place industrial alongside household water needs. The use of water for industrial purposes in a municipality is dependent on the extent to which the municipality has developed industrially. The number and sizes of industries in a municipality determine the quantity of water that is consumed for these industrial purposes.

Nine of ten (90%) water managers reported that some water in their municipalities was used by industries. Different types of industries which consumed water were identified. Food processing at industrial level was identified by seven of the ten (70%) municipalities as a user of water. Drink processing and manufacturing was each regarded by half of the municipalities as a user of water. Sound management of the water resource requires the municipal water managers to have knowledge of the quantities consumed by different industrial activities (Table 6.4).

Food processing was perceived to have consumed a large quantity of water (rating=3.6) and was followed by drink processing whose water use was rated medium (rating=2.6). The water uses for manufacturing (rating=1.3) and mining (rating=0.9) were perceived to be very small while that for power generation (rating=0.4) by the Electricity Supply Commission (Eskom) was regarded almost non-existent (Table 6.4).

Table 6.4 Perceptions of municipal water managers on industrial uses of water according to quantity consumed by activity

Water Management Area	Municipality	Perceived quantity of water consumed by industrial activity				
		Process food	Process drinks	Manufacturing	Mining	Eskom
Limpopo	Makhado	5	3	4	0	0
	Musina	5	0	0	0	0
	Lephalale	0	0	0	5	4
	Polokwane	3	5	0	4	0
	Aganang	0	0	0	0	0
Luvuvhu-Letaba	Letaba	5	4	3	0	0
	Thulamela	5	4	3	0	0
	Tzaneen	4	5	3	0	0
	Giyani	5	0	0	0	0
	Mutale	4	5	0	0	0
	Average	**3.6**	**2.6**	**1.3**	**0.9**	**0.4**

Key: 0=None consumed, 1=Very small, 2=Small, 3=Medium, 4=Large, 5=Very large quantity consumed

The results suggest that more water in the study area was consumed by the processing of food and drinks, often for sale. Food and beverage industries were more common in the study area and this could have been reason for more water being consumed by these industrial activities. Mining and Eskom power generation only occurred in some municipalities and hence the perception of less amount of water being consumed by these activities was not surprising.

All municipalities had some industrial water uses that perceivably did not use water. This report of non-consumption of water by a lot of industrial activities was probably a result of the fact that the study area is rural and has few such industries. It is possible that the managers lacked the knowledge of the water used by some of the industrial activities. In municipalities where food processing industries occurred, they were mostly bakeries, maize mills and abattoirs. With regards to drinks, the major industries involved in the study area included the processing of soft drinks, mainly by Coca-cola, processing juice mostly from fruits, and the processing of beer, both by the South African Breweries and by rural households who brew traditional beer.

(c) Perceptions on agricultural water use

Among the various use sectors, agriculture is the world's largest user of water. Rosegrant *et al.* (2002) estimated the consumption of water by agriculture at about 80% of global and 86% of developing country water use in 1995. The global agricultural water consumption was affirmed by Molden *et al.* (2002) who revealed it to be almost 80% of total withdrawals from water sources. Cosgrove and Rijsberman (2000) had estimated the 80% consumption to be for irrigated agriculture alone.

To properly understand the quantity of water consumed by agriculture, we need to examine the amount of water we 'eat' compared to what we use for other purposes. A person's food requirement is estimated at 300 kg/year of cereal equivalent which is sufficient to furnish a daily average per capita caloric intake of about 2 900 kcal. Water productivity on the other hand is estimated at one kg/cubic meter, and subsequently 300 cubic meters of water are consumed per year to grow this annual food requirement (Inocencio *et al.*, 2003). As stated by Inocencio *et al.* (2003), the consumption by agriculture is equivalent to about 850 litres per person per day, which is much more than the 50 litres per person per day needed for household use.

Two out of five (40%) of the municipal water managers could estimate the amount of water used for agricultural purposes in their municipalities. All the respondents identified irrigation as a major agricultural water user. Nine out of ten (90%) of the water managers identified animal drinking while four out of five (80%) identified livestock dipping as a major agricultural water use. With agriculture being a major consumer of water in South Africa (DWAF, 2004a), it is important for municipal water managers to know the relative amounts consumed by different agricultural activities in order to make relevant resource management decisions (Table 6.5).

Irrigation was perceived to have consumed large quantities of water in all the municipalities The amount of water used for animal drinking was perceived to be medium in 90% of municipalities while it was regarded effectively non-significant in 10%. Dipping of animals was perceived to have consumed small quantities of water in 80% of the municipalities and 20% reported the quantity used as non-existent.

Table 6.5 Perceptions of municipal water managers on agricultural uses of water according to quantity consumed by activity

Water Management Area	Municipality	Perceived quantity of water consumed by agricultural activity		
		Dipping	Drinking	Irrigation
Limpopo	Makhado	1	2	3
	Musina	1	2	3
	Lephalale	1	2	3
	Polokwane	0	0	3
	Aganang	0	2	3
Luvuvhu-Letaba	Letaba	1	2	3
	Thulamela	1	2	3
	Tzaneen	1	2	3
	Giyani	1	2	3
	Mutale	1	2	3

Key: 0=None consumed, 1=Small, 2=Medium, 3=Large quantity consumed

These findings confirmed a statement by Cosgrove and Rijsberman (2000) who reported that irrigated agriculture is the dominant user of water, accounting for about 80% of global and 86% of developing country water consumption. Also, DWAF (2004a) reported that irrigation is the largest user of water in South Africa, accounting for 62% of the total water consumed.

Considering the assertion by Inocencio *et al.* (2003) that the productivity of water for cereal production is estimated at one kg/cubic meter and that a person's food requirement is estimated at 300 kg/year of cereal equivalent, it may be understood why irrigation uses that largest amount of water. The study areas are mainly rural with agriculture being the main economic activity and irrigation being an important agricultural activity.

The quantity of water used for livestock drinking and dipping tends to be influenced by such factors as the number of animals in an area and the proportion of the different types of animals. Areas with more animals use more water for livestock drinking and dipping, and the same occurs where large stock comprises a bigger proportion of the livestock in the study area.

A livestock census revealed that four of the municipalities under study had more than 50 000 cattle, namely: Makhado (64 686), Letaba (53 744), Giyani (83 726), and Lephalale (52 885) municipality (LDA, 2008). Based on the consumption rate of 68 litres/head/day (Lowe *et al.*, 2009), the daily amount of water used for cattle drinking in these municipalities would be 4 398.65 m^3 for Makhado, 3 654.59 m^3 for Letaba, 5 693.37 m^3 for Giyani and 3 596.18 m^3 for Lephalale. The other municipalities had fewer cattle each and would accordingly use lesser amounts of water for cattle drinking. For livestock drinking, however, the municipalities used more water than the quantities shown here as other animals would be accounted for, namely donkeys, mules, goats, sheep, pigs etc.

In areas where there are rivers, the animals drink directly from the rivers, and where there are none the water for animal drinking is mostly pumped from boreholes. In some cases the animals drink from the portion of water sourced for household uses. Two municipalities in the Limpopo WMA reported non-consumption of water by agricultural activities of livestock dipping and drinking. These are the Polokwane Municipality that reported non-consumption dipping and drinking and the Aganang Municipality that reported non-consumption for dipping. This report of non-consumption suggests that the water managers had a dearth of knowledge of the amount of water used in these agricultural activities.

The perceptions of municipal water managers that there were activities from various sectors that did not use water suggest that they lacked knowledge of the quantities of water consumed by these activities. This dearth of knowledge was confirmed by the perception that the amount of water used in agriculture is less than that consumed by households contrary to reports that agriculture uses as much as 62% of the water in the study area (DWAF, 2004a). The ratings of the amounts of water used by some activities were rather credible. Objective assessment of the correctness of the ratings of water uses by the municipal water managers would, however, require a detailed study of the actual quantities of water consumed between and within each of the different use sectors.

6.3.3 Perceptions on water restrictions

South Africa is a water scarce country (DWAF, 2004a) and this situation is very true in the WMAs under study. Due to the problem of water scarcity, different municipalities have to impose restrictions during certain months of the year (Figure 6.2).

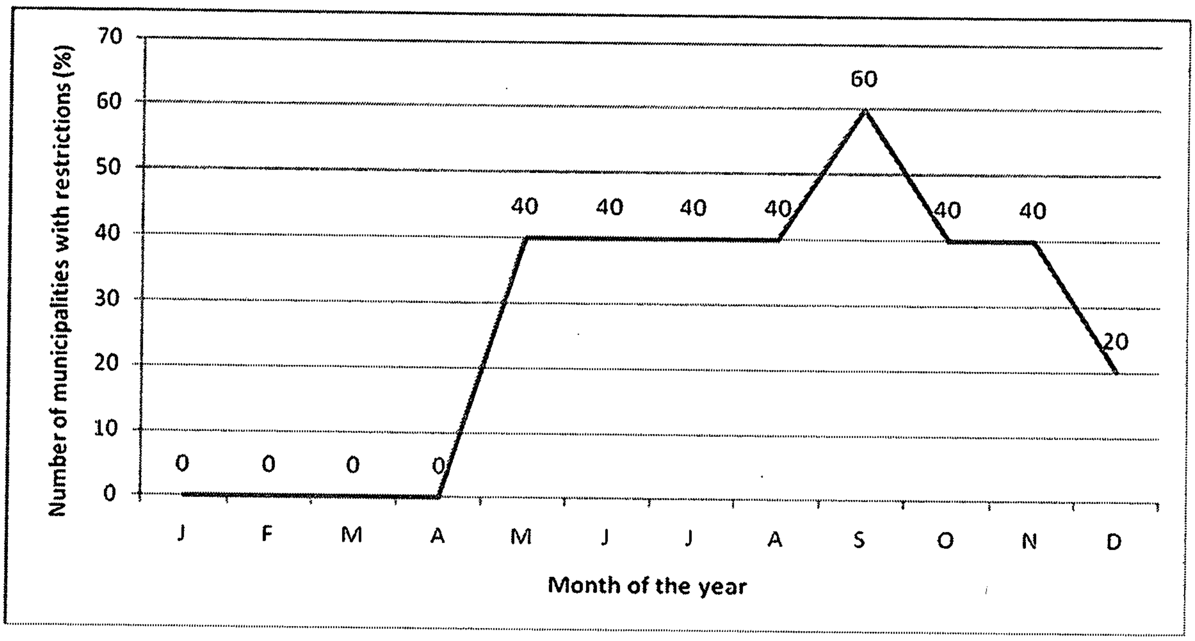


Figure 6.2 Perceptions of municipal water managers on water restrictions across the months of the year

Up to 90% of the municipal water managers interviewed experienced water shortages in their municipalities. All the respondents indicated that water restrictions were imposed in their municipalities during certain months of the year. Municipal water managers' knowledge of the months of the year in which restrictions are imposed guides them in making relevant resource management decisions (Figure 6.2).

As reported by the managers, no municipality imposed water restrictions in the months of January to April. Some 40% of the municipalities imposed restrictions during May to August and in October and November. Up to 60% of municipalities imposed restrictions in September while 20% had restrictions in December (Figure 6.2).

According to the SAWS (undated) the WMAs under study are within a summer rainfall area with low rainfalls reported for May (12.9mm), June (7.6mm), July (7.0mm), August (6.9mm) and September (19.5mm). The imposition of restrictions by 40% of municipalities during May to August and by 60% of them in September could have resulted from water shortage due to the low rainfall during these months. Although rainfall would generally have picked up, 40% of municipalities retained the restrictions in October and November and 20% did so even in December, and that could suggest delayed rainfall in those municipalities or caution not to lift the restrictions until the rainy season had fully set in. The results suggest that the imposition of water restriction was influenced by the occurrence of rainfall (Figure 6.3).

There was a moderate correlation (R^2=0.4555) between monthly rainfall and the number of municipalities that had imposed water restrictions (Figure 6.3). The graph reveals that the number of municipalities that imposed restrictions declined when the rainfall increased. Rainfall is the fundamental driving force of hydrological processes (Schulze, 1995) and is therefore important for water supply, which could be reason for its negative relationship with the imposition of water restrictions.

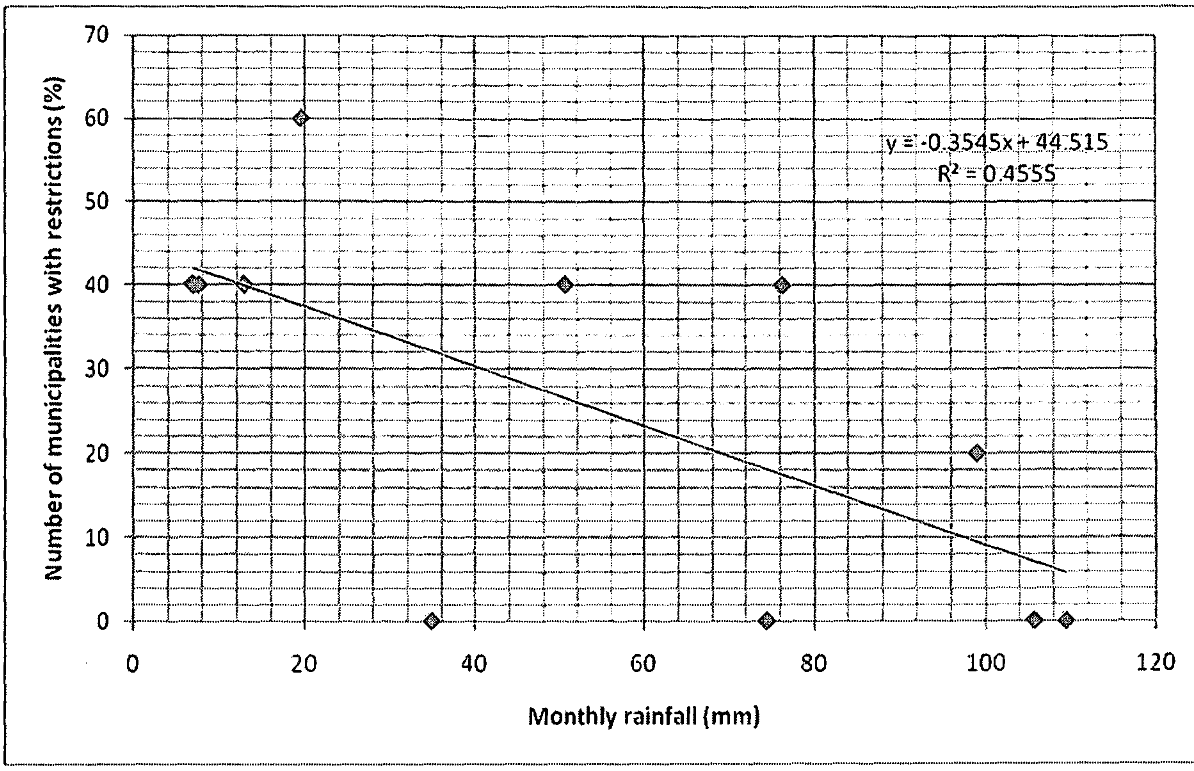


Figure 6.3 Influence of monthly rainfall on number of municipalities imposing water restrictions

From the above discussion, it appears that some municipalities apply restrictions immediately when the rainy season is ending during May to July, others apply the restrictions at the beginning of the rainy season with yet others applying them at the transition from end of dry season to the beginning of the rainy season. Municipal decisions on when to impose water restrictions could be influenced by such factors as the main sources of water (i.e direct from rivers or from dams or from boreholes), the position of the area of the municipality in the catchment (i.e near sources of rivers or mountains or further down) and the average start of the rainy season.

The impositions of restrictions on water supplies are very necessary in the water scarce areas such as the Limpopo Province. The imposition of restrictions results in smaller supplies of water and lesser socio-economic activities. Non-imposition of restrictions could lead to disastrous consequences as a point could be reached were there would be completely no supply of water in some areas. The municipal water managers seemed to know when to impose restrictions in their specific areas. There is a continued need for research on water restrictions as a way of improving the efficiency of water use during times of scarcity.

6.4 Summary and conclusion

The perceptions of the water managers on the water resources of their municipal areas revealed a dearth of knowledge of these resources. This lack of knowledge was shown by the water managers omitting major rivers in their enlisting of the water resources and by their incorrect ratings of the mentioned rivers according to size. With this limited knowledge of the water resources, the water managers are likely to make inappropriate water management decisions that will negatively influence the availability of the resource for socio-economic development in the study area. To avoid this situation, the water managers should be equipped with relevant knowledge of the water resources.

With regards to water uses, the managers had perceptions that activities in some sectors did not use the resource in their municipal areas. While the perceptions of non-consumption could be true for some activities, they may not be credible for other activities. For instance, reports by water managers that there was no water consumed by ecological activities and by livestock dipping and drinking sound incredible. The perceptions suggest that the managers could have lacked knowledge of the amounts of water consumed by these uses.

The lack of knowledge on various water uses was confirmed by the managers' perceptions that the quantity of water used by the agricultural sector was less than that consumed by household activities. For the municipal water managers to make appropriate decisions in their rendering of water services, it is very important for them to be equipped with requisite knowledge of the water uses. The water managers seemed to know when to impose restrictions in their specific areas. It is necessary to further improve the efficiency of water use in the area, and this requires more research on issues of water restrictions.

CHAPTER 7

7 MUNICIPALITY PERCEPTIONS OF STAKEHOLDER PARTICIPATION AND INFLUENCE ON WATER MANAGEMENT DECISIONS

7.1 Introduction

The perception of municipal water managers on stakeholder participation reflects the type of stakeholders that are invited to water management meetings. It is often difficult to select relevant stakeholders for inclusion in community based meetings. The complication results from cases where (1) some categories of stakeholders may be historically marginalized from decisions and may be difficult to identify, (2) conflicts exist among different groups making them reluctant to join a deliberative process, and (3) participatory process accommodate a small group resulting in lack of representativeness (Daniels and Walker, 2001; Grimble and Wellard, 1997).

Appropriate stakeholder selection should be preceded by stakeholder analysis which recognises the role that stakeholders should play in water management decisions (Burroughs, 1999; Selin *et al.*, 2000). According to Mitchell (1997), stakeholders are sometimes selected on the basis of assessment of the urgency, legitimacy and power of potential stakeholders in relation to the aspects under study. These approaches prioritize powerful stakeholders and neglect the lower ranked group and are not desirable (Grimble and Chan, 1995; MacArthur, 1997).

A fair allocation of water requires participation by all stakeholders in the management of the resource (Shah *et al.*, 2001). Effective stakeholder participation entails deliberation, a process of open communication, discussion and reflection among stakeholders who have different viewpoints and understandings (Leeuwis, 2000). According to Schusler *et al* (2003), the deliberation allows for stakeholders to learn from the views and motivations of others. These deliberative processes help policy decision makers and experts to better understand each other (Backstrand, 2003). Community based role players also have legitimate interest in water resources issues and are therefore important stakeholders (Van Hofwegen, 2001) whose views should be considered for sound management of the water resource (Mashau, 2001).

Municipal water managers are important decision makers in the management of water resources in their areas of operation. As a result, the perceptions of the managers on stakeholder participation are important for knowing the stakeholders that are active in water management decision making. The objective of the study was to investigate the perceptions of the managers on water stakeholders and their participation and influence on resource management decision making (Section 1.4, Table 1.3, specific objective 3). The study was necessitated by community discontent about lack of involvement in water management decisions.

7.2 Research methods

7.2.1 Study area

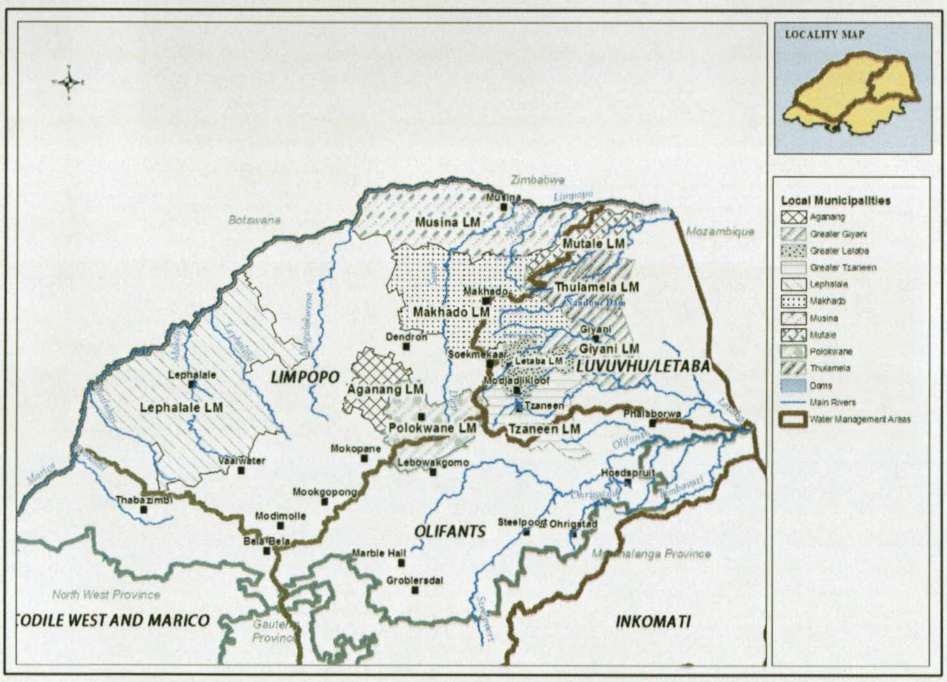


Figure 7.1 Map of Limpopo Province with Water Management Areas (red lines) and municipalities (hatchings) comprising the study area

The study covered ten local municipalities in the Limpopo and the Luvuvhu-Letaba WMAs located in the Limpopo Province of South Africa. Five municipalities were sampled from each WMA (Figure 7.I). The local municipalities covered by the study were Makhado, Musina, Lephalale, Polokwane and Aganang in the Limpopo WMA and Letaba, Thulamela, Tzaneen, Giyani, and Mutale in the Luvuvhu-Letaba WMA.

7.2.2 Sampling procedure

The units of analysis for the study were selected through purposive sampling defined by Welman et al. (2005) as a sampling where researchers rely on their experience, ingenuity and / or previous research findings to deliberately obtain units of analysis that are regarded representative of the relevant population. The two sampled WMAs were administered by the Limpopo Regional Office of the Department of Water Affairs (DWA) and were selected for ease of access to their information while the ten municipalities were purposively sampled for their available information on runoff (Section 4.3.2)

7.2.3 Data collection and analysis

The information for the WMAs was obtained through semi-structured interviews with relevant officers of the Limpopo Regional Office of DWA. The data for the municipalities was collected using a structured questionnaire used to interview water managers of each of the 10 municipalities sampled for the study. A questionnaire may be used to obtain information on opinions, beliefs, convictions and attitudes (Welman *et al.*, 2005) and was therefore relevant for collecting information on perceptions of the water managers on stakeholder participation and influence on water management decisions.

The questionnaire had both closed-ended questions that collected quantitative data and open-ended questions that collected qualitative data and the study was therefore described as a mixed research (Leedy and Ormrod, 2010). The interviews on closed-ended questions were more structured with less flexibility while those on open-ended questions were less structured with more flexibility for respondents to provide information that the researcher had not anticipated.

The interviews with DWA officers dealt with broad policy issues affecting the water sector in the two WMAs. The questionnaire used to interview municipal water managers covered perceptions on stakeholders in water management decisions and their participation in resource management forums with a focus on frequency of meetings and issues discussed. Also covered were the stakeholder influence on water management decisions with particular attention given to their reliability as sources of water management information and their level of influence, both on broad water management decisions and on specific topics discussed in meetings.

Quantitative data was captured and analysed using the SAS package (SAS Institute Inc, 2009). The Proc FREQ procedure of SAS was used to generate simple frequency tables of occurrence in each class utilizing one-way tables. The procedure is appropriate to give descriptive statistics about categorical data such as the demographic datasets. The syntax is provided to the SAS software, which automatically calculates the percentage of observations falling within each category of response. The output contains both the actual and the cumulative frequencies. Qualitative data was summarised and analysed using subjective interpretations (Lee, 1999; Leedy and Ormrod, 2010).

7.3 Results and discussions

7.3.1 Stakeholder organisations and their roles

Stakeholders in water resource management were defined by Van Hofwegen (2001) as people or groups of people with a legitimate interest in water resource issues. Some 90% of the municipal water managers perceived DWA to be a stakeholder, 40% regarded the Limpopo Department of Agriculture (LDA), the same number (40%) identified community based organisations (CBOs), and 80% viewed Water Users Associations (WUAs) as stakeholders in their water management decisions. District Municipalities (DMs) and the Local Municipalities (LMs) themselves were also mentioned as stakeholders participating in water management decisions.

In terms of the roles of the stakeholders, DWA is responsible for administering all aspects of the National Water Act (Act No. 36 of 1998) on behalf of the Minister. The major responsibilities of the department include the development and implementation of strategies and internal policies, plans and procedures, and regulatory instruments. The department is also responsible for planning, developing, operating and maintaining state-owned water resource management infrastructure, and for overseeing the activities of all water management institutions (RSA, 1998a; DWAF, 2004a).

The main interest of the LDA, on the other hand is the availability of water for agricultural use particularly for irrigation purposes. The role of the department is therefore mainly to lobby for water allocations for the agricultural sector directly from DWA with no involvement of the interviewed municipal managers. The CBOs would mostly form part of WUAs and participate in the activities of the associations. The roles of the WUAs differ according to the purpose for which they were formed, and those may include water use for recreational purposes and that for agricultural use (DWAF, 2004a).

The DMs and LMs compose local government, a constitutionally distinct sphere of government. While the DMs are responsible for development of water reticulation infrastructure, the LMs are the sphere of government closest to the communities and according to DWAF (2004a) they were designated as water services authorities and are responsible for the provision of water services in their areas of jurisdiction. The stakeholders identified therefore ranged from national department involved with policy and strategy issues through to local authorities involved with the provision of water services to communities.

The water stakeholder organisations as identified by the municipal water managers seem to have covered all major stakeholders. At the level of individual municipalities, some omissions were noted where, for instance one municipality excluded DWA and 60% of them excluded LDA from their lists of stakeholders. Municipalities should therefore convene public consultative water summits to update their stakeholder databases.

7.3.2 Stakeholder participation in water management decisions

The participation of stakeholders in water management decisions determines the quality of decisions made and the extent to which the stakeholders contribute to the productivity of the water resource. The participation of stakeholders in water management is informed by the frequency of meetings attended, the number of issues discussed and the actual topics discussed in the meetings.

(a) Frequency of stakeholder meetings and number of issues discussed

As indicated by Mashau (2001), greater participation by stakeholders is essential for sound water resource management and therefore the frequency of stakeholder meetings and the range of issues discussed are important. The frequency of meetings reflects the opportunity created for participation by the stakeholders in water management decisions. The frequency of stakeholder meetings for the local municipalities involved in the study and the number of water management issues discussed in those meetings are important indicators of the extent of stakeholder involvement (Figure 7.2).

As shown in Figure 7.2, stakeholders in 60% of municipalities reportedly met monthly (twelve meetings in a year), and those municipalities were Lephalale and Aganang in the Limpopo WMA and Letaba, Thulamela, Giyani and Mutale in the Luvuvhu-Letaba WMA. Monthly meetings in municipalities under the Luvuvhu-Letaba WMA were double those in municipalities under the Limpopo WMA. Stakeholders met quarterly in 30% of the municipalities where all of them (Makhado, Musina and Polokwane) were in the Limpopo WMA. Stakeholder meetings in the Tzaneen Municipality were once in a year with their meetings not having a fixed schedule. The stakeholder forum without a fixed schedule of meetings could have been newly formed and not having strong issues to regularly communicate.

Considering the number of water management issues discussed in meetings in the Limpopo WMA, two municipal stakeholder meetings (Musina and Polokwane) had only one issue each, one municipality (Makhado) had three issues, the other (Lephalale) had four and the last (Aganang) had five issues to discuss.

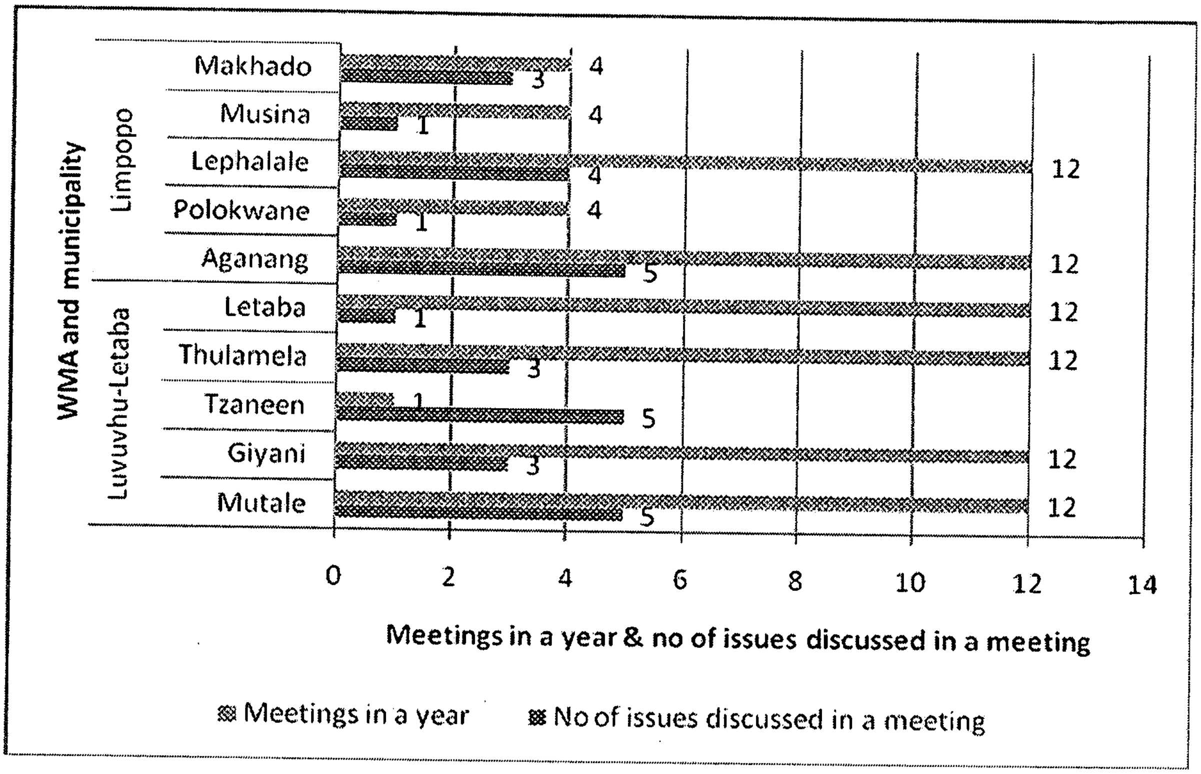


Figure 7.2 Frequency of stakeholder meetings and number of water management issues discussed in each meeting

In the Luvuvhu-Letaba WMA, one municipality (Letaba) reportedly discussed only one issue in their stakeholder meetings, two (Thulamela and Giyani) discussed three issues and another two (Tzaneen and Mutale) discussed five issues. The results suggest that more water management issues were discussed in stakeholder meetings in the Luvuvhu-Letaba (18 issues) than in the Limpopo WMA (14 issues).

With proper planning, quarterly stakeholder meetings would be adequate for good consultative management of the water resource. The Tzaneen municipality convened stakeholder meetings based on need and this would need to improve. The municipality should convene properly planned meetings quarterly with a pre-arranged schedule agreed upon. Monthly meetings as convened by 60% of the municipalities are rather too frequent and could provide too little time for participants to implement the water management decisions made in meetings. This frequency of meetings may be recommended at the start of operation of stakeholder forums for participants to know each other and for systems to be established. The number of issues discuss would continue to vary among stakeholder fora and among different meetings within a forum.

(b) Water management issues discussed in stakeholder meetings

The water management issues discussed in the meetings of water stakeholders would likely be the ones included in strategic and annual performance plans of stakeholder organisations and should therefore receive due attention. The issues reportedly discussed in the stakeholder meetings are those regarded by the stakeholders to be important for the water sector (Table 7.1).

Three municipalities were reported to have discussed five water management issues in their stakeholder meetings, namely: Aganang in Limpopo WMA and Tzaneen and Mutale in Luvuvhu-Letaba WMA. The issues discussed were the same for the three municipalities and were reported to be policy, infrastructure, water allocations, water charges and water use issues. This could be indicative that these municipalities had matters of concern with the five water management issues. The Lephalale Municipality discussed four water management issues and they only left out water charges from the five issues enlisted for Aganang, Tzaneen and Mutale municipalities.

Three municipalities (Makhado, Thulamela and Giyani) reportedly discussed three water management issues in their meetings and they all included infrastructure and water charges. The third issue discussed by each of the three municipalities was water use for Makhado and Thulamela and water allocations for Giyani.

Table 7.1 Issues discussed in water stakeholder meetings of the study municipalities in the Limpopo and Luvuvhu-Letaba WMAs

Water Management Area	**Municipality**	**Issues discussed**				
		Policy	Infrastructure	Water allocations	Water charges	Water use issues
Limpopo	Makhado	2	1	2	1	1
	Musina	2	1	2	2	2
	Lephalale	1	1	1	2	1
	Polokwane	2	1	2	2	2
	Aganang	1	1	1	1	1
Luvuvhu-Letabe	Letaba	2	1	2	2	2
	Thulamela	2	1	2	1	1
	Tzaneen	1	1	1	1	1
	Giyani	2	1	1	1	2
	Mutale	1	1	1	1	1

Key: 1- Issue was discussed; 2- Issue was not discussed

Infrastructure was reported to have been discussed at meetings of all municipalities. This suggested that all municipalities had issues of concern with the water infrastructure, and this could have included siltation of dams, breaking down of boreholes and repeated bursting of reticulation pipes. The stakeholder meetings could therefore have focussed on required interventions such as the development and maintenance of the infrastructure.

Issues of water charges were discussed at water stakeholder meetings of 60% of the municipalities. The water charges were discussed in municipalities that seemed rural with some relatively newly proclaimed urban centres, either towns or townships. Relatively new towns occurred in Aganang, Thulamela, Giyani and Mutale while newly proclaimed townships would be in Makhado and Tzaneen. The systems for implementing the charges in the new urban areas could still not be well established and therefore residents would be over- or under-charged. The discussion of water charges could be a result of the dwellers not used to these charges or being unhappy with the water charge systems themselves. Residents in municipalities with long proclaimed urban centres would be much used to the water charges and their charge systems would be well established and will therefore not have to discuss the charges in stakeholder meetings.

As was the case with water charges, water use issues were also discussed in 60% of the municipalities. Municipalities that discussed water use issues in their stakeholder meetings seemed to be those that had major economic activities that demanded water thereby creating competition with domestic demand. The municipalities of Makhado, Thulamela, and Tzaneen are strong in irrigated agriculture while Lephalale and Mutale are strong in mining.

Water allocations were discussed in meetings in half of the municipalities and these could be where some stakeholders had concerns with this water management issue. Municipalities that discussed water allocations mostly also discussed policy. This suggests a strong link between policy and the implementation of water allocations.

Policy issues were discussed in meetings in only 40% of the municipalities. With DWA being the custodian of water policies, these could be municipalities where the department was most active. Merrey (2000) stated that rural communities were unaware of the provisions of the new water law, and this could be reason for policy issues having been discussed in stakeholder meetings of fewer municipalities.

(c) Relationship between stakeholder participation and municipal runoff

Pretty (1995) argues that the concept of stakeholder participation remains as vague as concepts like sustainability. For this analysis the number of water stakeholder meetings attended is assumed to be an important indicator of stakeholder participation (Figure 7.2). The amount of municipal runoff determines the amount of water naturally available in the municipality and could influence stakeholder participation in resource decision making. The runoffs of the study municipalities (in million m^3) were 269.2 for Makhado, 21.0 for Musina, 282.1 for Lephalale, 17.9 for Polokwane and 12.5 for Aganang in the Limpopo WMA and were 88.2 for Letaba, 359.1 for Thulamela, 352.3 for Tzaneen, 37.5 for Giyani and 61.2 for Mutale in the Luvuvhu-Letaba WMA (Section 4.3.2.1).

There was no correlation noted between the level of water stakeholder participation and the amount of municipal runoff (R^2=0.032). The result reveals that the number of stakeholder meetings was not influenced by the amount of municipal runoff. While stakeholders in wetter municipalities could have had more meetings to discuss strategies of taking advantage of the available water resource, those in drier municipalities could also have had more meetings to discuss strategies of coping with the scarcity of the resource. This could have led to the number of meetings remaining unchanged even though the amount of runoff was changing across municipalities.

A very weak correlation (R^2=0.3474) occurred between participation of external water stakeholders and the amount of municipal runoff. External stakeholders were mostly composed of national and provincial organisations and were more knowledgeable on water resource management. The municipalities with more runoff are of strategic importance and were therefore prioritized by these higher level stakeholders who sought to influence their water management decisions.

It would be necessary for the external stakeholders to also give attention to drier municipalities to assist in programmes such as rainwater harvesting and on efficient use of the water resource. These would reduce the demand for water from runoff collected in wetter municipalities. The DWA is the custodian of water in the country (RSA, 1998a, DWAF, 2004a) and should lead the mobilization of the knowledgeable external stakeholders to the drier municipalities for introduction of efficient water access and use programmes.

7.3.3 Stakeholder influence on water management decisions

The number of stakeholder meetings attended alone does not reflect on the effective contribution of stakeholders to water management decisions. The effective contribution of stakeholders to the water management decisions is determined by their level of influence which is itself dependent on the reliability of the information they provide.

(a) Stakeholder reliability as sources of water management information

Availability of reliable information is necessary for informed decision making. Reliability of the information is dependent on the source of the information. This was confirmed by Bembridge and Tshikolomo (1992) who indicated that communication is more effective when the source of information is considered reliable.

It would be expected for stakeholders that are perceived to be reliable sources of water management information to better influence decisions in the sector. Participation of stakeholders perceived to be reliable sources of water management information would therefore result in them influencing the decisions made. The extent to which water stakeholders are regarded reliable sources of water information is therefore important for them to successfully influence the management decisions of the water resource (Figure 7.3).

DWA was perceived to be a more reliable source of water management information (rating=3.7) followed by LMs who were regarded less reliable (2.3). The rest of the water stakeholders were reported to be least reliable as sources of water management information. Government based stakeholders of DWA, LDA, DMs and LMs provided more reliable water information than their community based counterparts of WUAs and CBOs (Figure 7.3).

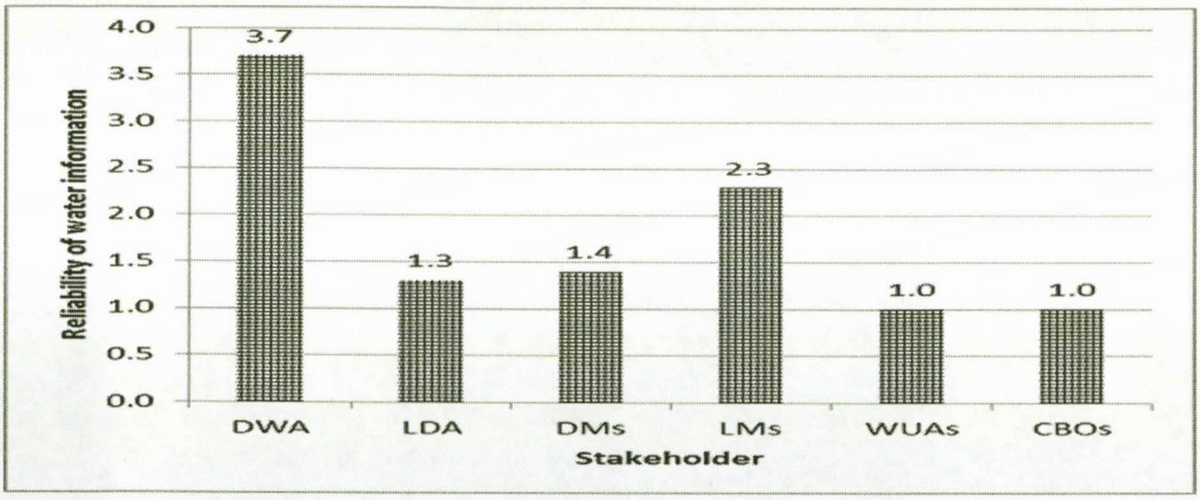


Figure 7.3 Water stakeholders and ratings of their reliability as sources of water management information

Key: 1- Least reliable, 2- Less reliable, 3- Reliable, 4- More reliable, 5- Most reliable

This result suggests that community based stakeholders could not have influenced decisions in water stakeholder meetings as they would reportedly not have reliable information to present. Water management decisions would be made by government based stakeholders perceived to be reliable sources of water information. Communities were therefore justified in their perceptions that municipalities were not taking them on board when making water management decisions.

With the weaker formation of the community based stakeholders, it is likely that they may not have the capacity and the expertise to provide quality and reliable information. These stakeholders are representative of the communities to be served by the government and their views should inform decisions for managing the water resource. Government should therefore develop and empower these community based stakeholders through lead agents such as DWA and the Department of Local Government and Housing.

(b) Stakeholder influence on broad water management decisions

The level of influence a water sector stakeholder has over the other role-players determines the extent to which he/she can influence water management decisions. Lord and Israel (1996) mentioned the need for influential stakeholders to make decisions that take into account the needs and desires of all the different water users and role players. The perceived levels of influence of the stakeholders on broad water management issues determines the degree to which their decisions on the resource will be accepted (Table 7.2).

Table 7.2 Perceived levels of influence of water stakeholders on broad water management decisions in study municipalities under Limpopo and Luvuvhu-Letaba WMAs

Water Management Area	Municipality	Perceived levels of stakeholder influence					
		DWA	LDA	DMs	LMs	WUAs	CBOs
Limpopo	Makhado	4	1	2	3	2	5
	Musina	1	1	1	1	1	1
	Lephalale	5	1	1	1	3	1
	Polokwane	5	1	1	4	1	1
	Aganang	4	1	5	3	1	1
Luvuvhu-Letaba	Letaba	2	1	3	1	4	5
	Thulamela	5	4	1	3	2	2
	Tzaneen	5	1	4	3	2	1
	Giyani	5	2	4	3	1	1
	Mutale	5	2	4	3	2	1
	Mean	**4.1**	**1.5**	**2.6**	**2.5**	**1.9**	**1.9**

Key: 1- Least influential, 2- Less influential, 3- Influential, 4- More influential 5- Most influential

The municipal water manager ratings of the stakeholders according to their levels of influence in water management decisions as presented in Table 7.2 revealed DWA to be more influential (rating=4.1). The department was followed by three other main groupings – firstly the municipalities that were perceived to be influential (ratings were 2.6 for DMs and 2.5 for LMs); secondly community based groups regarded less influential (rating was 1.9 for WUAs and for CBOs); and lastly LDA also perceived less influential (rating=1.5).

With DWA being the custodian of water in the country, it is not surprising that the department was perceived to be more influential. Municipalities also play important roles in water resource management with DMs being responsible for reticulation infrastructure and LMs for water services and it was logical for them to be reported to be influential stakeholders.

Although agriculture consumes the largest quantity (62%) of water in South Africa (DWAF, 2004a), the municipalities rated LDA least in terms of level of influence. This low rating was a result of the interviewed municipal managers having no responsibility for provision of agricultural water. The LDA is therefore more active as a water stakeholder at national and provincial levels. At a provincial level, a Coordinating Committee on Agricultural Water (CCAW) was established where LDA and DWA discuss issues of agricultural water for emerging farmers. Agricultural water for commercial farmers was discussed at meetings of irrigation boards.

As opposed to good ratings of government based stakeholders of DWA and municipalities, the community based group composed of WUAs and CBOs was perceived less influential. DWAF (undated) stated that there were ten WUAs at different stages of establishment in the study area (Mid 2010). Only the Groot Letaba WUA under the Luvuvhu-Letaba WMA was established and operational. Three WUAs were established but were not yet operational, namely: Nzhelele in Limpopo WMA and Mutale and Middle Letaba in Luvuvhu-Letaba WMA. Six WUAs were at different stages of establishment, namely: Mokolo, Glen Alpine and Mogalakwena in Limpopo WMA and Mutshimbwe, Letsitele, and Tzaneen in Luvuvhu-Letaba WMA. It is possibly because the WUAs were not yet operational that they rated so poorly in terms of the level of influence. The results placed stakeholders representing government institutions at the top positions of influence, and this justifies the feeling of exclusion on the part of communities.

For the WUAs to be more influential stakeholders the process of their formation has to be concluded and they must be operational entities as a matter of urgency. Those already formed should be capacitated to function properly, and this could be achieved through funding for training and institutional establishment. The process of formation of the WUAs and their capacitation should be led by DWA and should be regarded critical for communities to actively participate in decisions on water resource management.

(c) Stakeholder influence on specific topics discussed

The influence of stakeholders on specific water management topics discussed is as important to development as the overall influence of the stakeholders on water management issues in general. As is the case with broad water management issues, the perceived levels of influence of the stakeholders on specific water management topics also determines the degree to which the stakeholders' decisions on the resource will be accepted (Figure 7.4).

The results presented in Figure 7.4 revealed that DWA was more influential on policy (rating=3.7) and was influential on water allocations (2.6). The results are not surprising as the department has the mandate of developing the water policies and accordingly transforming the allocations (RSA, 1998a and DWAF, 2004a). The department had less influence on use (rating=2.3) and charges (1.8) for water and on infrastructure (1.5). While the results for use and charges for water would be understood, it would be expected for the department to be influential on infrastructure as they champion the development of major dams. The perception of the department being less influential on infrastructure issues suggests that respondents were less involved in these operations.

The LDA was perceived to have least influence on all the topics discussed. This result could again have been caused by the fact that interviewed municipal managers have no role in agricultural water provision and would therefore not regard LDA an important stakeholder for their water management decisions.

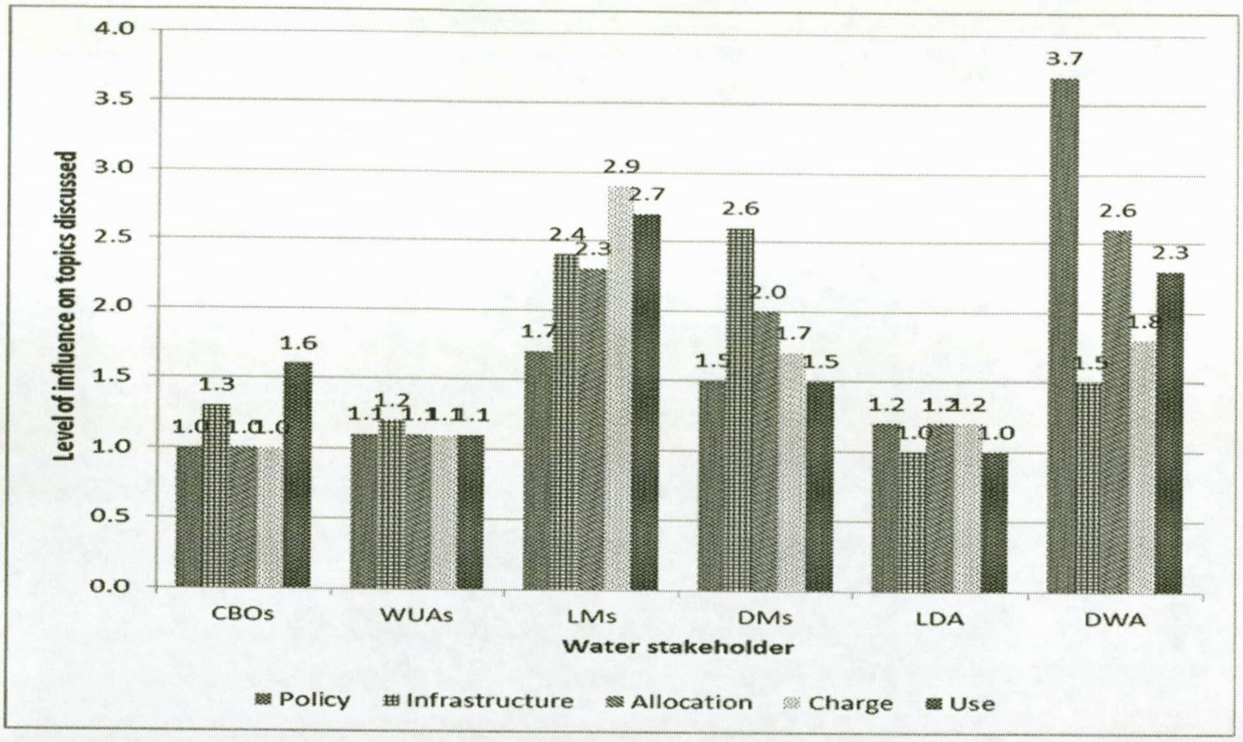


Figure 7.4 Rating of different stakeholders according to their level of influence on specific topics discussed in meetings

Key: 1- Least influential, 2- Less influential, 3- Influential, 4- More influential, 5- Most influential

The DMs were reportedly influential on infrastructure (rating=2.6) and this was logical as the districts were responsible for development of water reticulation infrastructure. The districts had less influence on the rest of the topics discussed as they had lesser roles in those issues. The LMs were influential on the charges (rating=2.9) and use (2.7) of water. Municipalities were mandated to be water services authorities (RSA, 1997) and that would be reason for their influence on water charges and uses. The WUAs were least influential on all topics discussed while CBOs were less influential on policy (rating=1.6) and least influential on the rest of the topics discussed.

The more influential stakeholders on the water management topics discussed were still government in its different spheres, namely: DWA, LMs and DMs. Community based stakeholders such as WUAs and CBOs were not perceived as important leaders of decisions on the water management topics discussed. Kgomotso and Swatuk (2006) revealed that communities have high level of interest for participating in decision making for water projects and their exclusion from this process could be frustrating to them. Accordingly, Nare et al. (2006) reported a lot of frustration for communities in Mzingwane catchment in Zimbabwe arising from their marginalization in a water quality management project.

For sound management of the water resource, stakeholders should be representative and should consider those that were disadvantaged when they make decisions (UNDP, 1995; Chancellor, 1996; Carney, 1988; and Van Koppen, 1990) and these results affirm that communities were not properly represented and could not be catered for by the decisions made. The situation could lead to deeper disgruntlement among members of community expecting improved delivery of water services.

(d) Relationships between perceived reliability of stakeholders as sources of water information and their level of influence

Stakeholders perceived to be reliable sources of water management information would likely have more influence on the water management decisions made. The reliability of the stakeholders as sources of water management information would determine the credibility of the information they provide and subsequently their influence on water management decisions made (Figure 7.5).

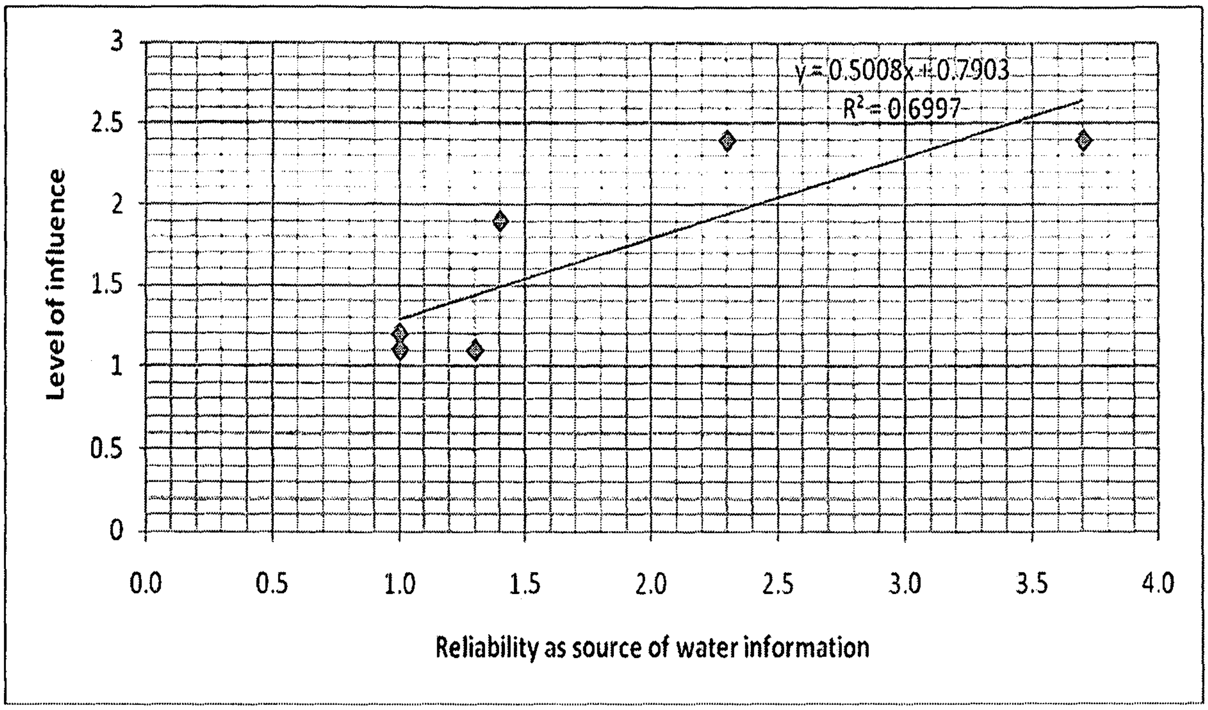


Figure 7.5 Relationship between stakeholder reliability as sources of water management information and their level of influence on resource management decisions

A moderate to strong correlation (R^2=0.6997) was revealed between the reliability of stakeholders as sources of water management information and their level of influence on resource management decision making. An increase in the reliability of a stakeholder as a source of water management information was accompanied by an increase in the level of influence the stakeholder had on resource management decision making (Figure 7.5). The results suggest that stakeholders should be capacitated to be reliable sources of water management information in order for them to influence decision making in the sector. Effectively, sound management of the water resource would be influenced by building the capacity of stakeholders to be reliable sources of water information, and this could be achieved through training these role players on pertinent water issues.

7.4 Summary and conclusion

The organisations perceived to be stakeholders in water management decision making were Department of Water Affairs (DWA), Limpopo Department of Agriculture (LDA), district municipalities (DMs), local municipalities (LMs), Water Users Associations (WUAs) and Community Based Organisations (CBOs).

The issues discussed in stakeholder meetings were reportedly policy, infrastructure, water allocations, water charges and water use issues. Only the three municipalities of Aganang, Tzaneen and Mutale discussed all the five with the rest discussing fewer issues. Infrastructure was the only discussion topic that was discussed by all municipalities and this suggests that it is the most important water management issues in the study area.

DWA was rated a more reliable source of water management information (rating=3.7) followed by LMs rated less reliable (2.3). The rest of the stakeholders were reported least reliable. Government based stakeholders such as DWA were perceived more reliable sources of water information than their community based counterparts of WUAs and CBOs. There was a moderate to strong correlation (R^2=0.6997) between the reliability of stakeholders as sources of water management information and their level of influence on resource management decisions.

Accordingly, DWA was reported more influential (rating=4.1) in broad water management issues, followed by the influential district municipalities (rating=2.6) and local municipalities (rating=2.5) and last the less influential community based stakeholders of WUAs and CBOs (rating=1.9). Considering specific topics discussed, DWA was more influential on policy (rating=3.7) and was influential on water allocations (2.6). The department had less influence on water use (rating=2.3) and charges (1.8) as it had less to do with these topics.

The DMs were reportedly influential on infrastructure (rating=2.6) due to their involvement in developing reticulation infrastructure. The LMs were influential on water charges (rating=2.9) and uses (2.7) as a result of their roles as water services authorities. The WUAs were least influential on all topics discussed while CBOs were less influential on policy (rating=1.6) and least influential on the rest of the topics discussed. Based on this result, community based stakeholders should be empowered to be reliable sources of water information and to subsequently influence decision making in the sector. The government based stakeholders have different complementary roles and should work together to generate better decisions for water resource management.

CHAPTER 8

8 HOUSEHOLD WATER SUPPLY AND REQUIREMENTS

8.1 Introduction

Water is one of the most indispensable substances for human daily life and survival (Aiga and Umenai, 2002). Access to adequate supplies of water is a universal indicator of human well-being and development (Potter and Darmame, 2010). Lack of access to safe and improved water supplies in developing countries is a major concern since water is a basic need for sustenance (Mazvimavi and Mmopelwa, 2006).

Considering the occurrence of natural phenomena such as global warming and the increasing need for water to supply communities that were historically excluded the demand for water is ever increasing (Saleth and Dinar, 2003), in both the Limpopo Province and the broader South Africa. Safe water is important for good health (Mwendera, 2006) and survival, but problems of access to portable water remain high (Jimu, 2008).

The issue of water demand and supply may be explained according to the theory of co-evolution comprised of the policy system which produces supply and the household system which produces demand. Demand and supply are inter-related through positive feedbacks. After a major surface water project is completed, supply capacity exceeds demand and there is a strong economic incentive to utilities to set price to cover only the operating costs. Low water prices instigate consumption, and as consumption increases and reaches the limit of supply, there is a positive feedback to the policy system to expand supply. Continued feedbacks between the policy and household systems result in perpetual urbanization and growth of water consumption (Kallis, 2010).

Household water demand is influenced by socio-economic variables such as user age and these determine the demand for water by households (Fox *et al.,* 2009). The purpose of the study was to characterize the households in the Luvuvhu-Letaba WMA and to investigate their water supply with a focus on sources, proximity of sources to residential sites and quantity fetched. The study will also assess the water requirements of the households and will compare them with the quantity fetched to determine the adequacy of the supply (Section 1.4, Table 1.3, specific objective 5).

8.2 Research methodology

8.2.1 Description of study area

The study was based on the Thulamela, Giyani, and Mutale municipalities under the Luvuvhu-Letaba WMA of South Africa (Figure 8.1).

Figure 8.1 Map of Luvuvhu-Letaba WMA showing the location of the study municipalities and villages

The Giyani Municipality is under the Mopani Water Services Authority (WSA) while Mutale and Thulamela are under the Vhembe WSA. Specific villages selected for the study in each of the municipalities were Siyandani, Makosha and Muyexe in Giyani; Sigonde, Makwilidza, and Lukau in Mutale; and Mavunde, Djilongo, Xigamani, and Dopeni in Thulamela (Figure 8.1).

8.2.2 Smpling procedure

The Luvuvhu-Letaba WMA was purposively selected for the study for its proximity as it is the place of residence of the researcher. Within the WMA, multistage sampling was conducted as described by Leedy and Ormrod (2010) and involved primary area selection of municipalities, location selection of villages and housing unit selection of households.

For area selection of municipalities, the sampling frame was composed of the five municipalities that were representative of the Luvuvhu-Letaba WMA, namely: Letaba and Giyani which were contained in the WMA and Mutale, Thulamela and Tzaneen with larger portion of land area within the WMA (Section 4.2.1). Three municipalities were purposively sampled for their accessibility with lesser transport costs, and those were Giyani, Mutale and Thulamela.

As for location selection of villages, the sampling frame was composed of 413 villages of which 85 were in Giyani, 118 in Mutale and 210 in Thulamela Municipality. From this sample frame, ten villages were randomly sampled for the study (Figure 8.1). Although Dopeni is on the little portion of Thulamela that is outside the WMA, it was included in the study because of its severe challenge of shortage of water supply. For households, the sample frame and randomly selected sample sizes (10% of sample frame) for villages selected for the study were: Siyandane – 521, 52; Makosha – 524, 52; Muyexe – 476, 48; Sigonde – 152, 15; Makwilidza – 108, 11; Lukau – 324, 32; Mavunde – 389, 39; Djilongo – 581, 58; Xigamani – 567, 57; and Dopeni – 1025, 103. The total sample frame was 4667 with a total sample size of 467.

8.2.3 Data collection and analysis

Data was collected from the 467 sampled households through interviews which were conducted by trained enumerators using a structured questionnaire. The questionnaire contained both open- and closed-ended questions which included household socio-economic questions as well as those on water supply and demand. As revealed by Leedy and Ormrod (2010), the closed-ended questions collected quantitative data while the open-ended questions recorded qualitative data. This research method that combines the collection and analysis of quantitative data with that of qualitative data is referred to as a mixed study (Hurmerinta-Peltomaki and Nummela, 2006). The inclusion of open-ended questions was to enable respondents to speak for themselves, voice the constraints they faced, articulate their own accounts of what their routines were and how they satisfied their family's needs.

The data was captured in MS Excel Package and analysed statistically using the SAS Package (SAS, 2009). The Proc FREQ of SAS was used to generate simple frequency tables for each variable of interest. Selected data was summarized in Excel Spreadsheet.

8.3 Results and discussion

8.3.1 Characterisation of households

(a) Age of heads of household

Keshavarzi *et al.* (2006) revealed that there was a significant relationship ($r=0.17$, $p<0.05$) between head of household's age and the amount of water consumed by the household. This could be a result of attitudes toward environmental issues where older individuals possess less information about and give less attention to water conservation. Schleich and Hillenbrand (2009) argued that the cause of the increase of water consumption with age may be the fact that retired people spend more time at home and are likely to use water more frequently, or because health reasons may force older people to use the bathroom more frequently. The profiles of heads of household in the study area with regard to age will therefore influence their expectations regarding water supply to their families (Table 8.1).

Table 8.1 shows Giyani to be the only municipality that had child heads of household (4% under 18 years) and these could be orphans. The municipality also had the most heads of household (28.5%) aged 19-35, suggesting the population there to be more youthful. Mutale had the most heads of household in the middle ages (36-50) with close to half (48.2%) of them belonging to this category. Thulamela on the other hand had most (17.6%) household heads under retirement age (>65 years).

Table 8.1 Distribution of heads of household in the study municipalities under the Luvuvhu-Letaba WMA according to age

	Giyani		Mutale		Thulamela		Luvuvhu-Letaba WMA	
Age	f	%	f	%	f	%	f	%
< 18	6	4	0	0	0	0	6	1.3
19 - 35	43	28.5	7	12.5	55	22.5	105	23.3
36 - 50	49	32.5	27	48.2	81	33.2	157	34.8
51 - 65	37	24.5	18	32.1	65	26.6	120	26.6
> 65	16	10.6	4	7.1	43	17.6	63	14
Total	**151**	**100**	**56**	**100**	**244**	**100**	**451**	**100**

The distribution of heads of household in the study area was such that the least were children (1.3% <18) with the number increasing through youth (23.3% aged 19-35) to the middle aged (34.8% aged 36-50). Thereafter the number declined through the elderly (26.6% aged 51-65) to those of retirement age (14% aged > 65). According to Schleich and Hillenbrand (2009), the 14% of households with heads on retirement would consume more water and these were more in Thulamela.

(b) Size of household

The quantity of water used increased with an increase in the number of people living in a household. However, the increase in water use was less than proportional to the increase in household size (Arbues *et al,* 2003 and Keshavarzi *et al.,* 2006). The relationship between household size and per capita water consumption was further articulated by Schleich and Hillenbrand (2009) who revealed that per capita water consumption decreased as the number of household members increased. This was said to be a result of the fact that several water uses such as laundry, gardening or even preparing food increased less than proportional to the increase in household size. As stated by Schleich and Hillenbrand (2009), an increase in the number of household members by 50%, i.e. from two to three, raised per capita water demand by 22%.

An investigation of the sizes of households is therefore important to obtain an idea of water consumption by the households. Mazvimavi and Mmopelwa (2006) revealed that household sizes in rural villages of Botswana varied from 1 to 10 persons per household. Household sizes in the Luvuvhu-Letaba WMA were reported to be relatively smaller (Figure 8.2).

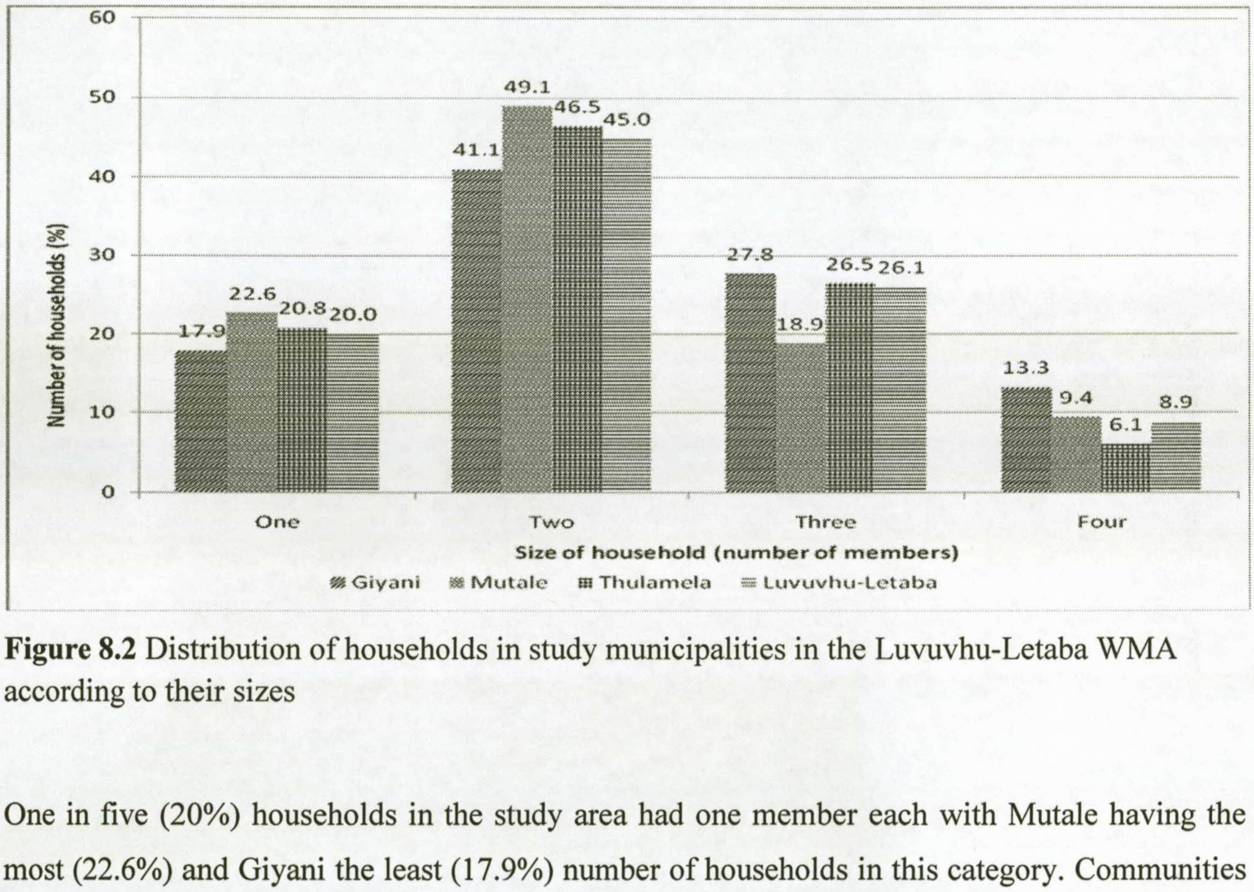


Figure 8.2 Distribution of households in study municipalities in the Luvuvhu-Letaba WMA according to their sizes

One in five (20%) households in the study area had one member each with Mutale having the most (22.6%) and Giyani the least (17.9%) number of households in this category. Communities in this area still attach value to a self-sustaining family where members perform different roles and complement each other, and it is uncommon to have households with one member each. The persons who stayed alone could be the widowed or divorced who did not have children or those whose children could have relocated because of work or other socio-economic demands. There could also be cases where a child remained orphaned when parents passed on, more so in Giyani where child heads of household where reported.

Some 45% of households had two members each with most (49.1%) of those in Mutale and least (41.1%) in Giyani. These could be youthful families who did not have children yet or those affected by death, divorce, separation, or relocation. About a quarter (26.1%) of the households had three members each. Mutale which had the most households with one member and those with two members each had the least households (18.9%) for this group. The largest household was reported to have only four members where 8.9% of households were of this size and were most (13.3%) in Giyani and least (6.1%) in Thulamela.

With this maximum membership, households in the study area could be described as very small compared to those of villages in Botswana that had up to 10 members each (Mazvimavi and Mmopelwa, 2006). According to Stats SA (2009), the household size of four would be an average for the study area and not the maximum. For some reason, the respondents could have reported fewer members of households than the actual figures and this resulted in this impression that the households were small. For purposes of water services planning, the sizes of households should be assumed to average four as reported by Stats SA (2009).

(c) Household income

Household income is a strong determinant of the supply and use of water. It was argued that people could be water poor not because there is no safe water in their area but because they are income poor. In other words, despite water being available within their area, people may fail to get connected and access safe water because they cannot afford the cost of doing so (Dungumaro, 2007).

According to Dungumaro (2007), 99.7% of households that belonged to a poor category in South Africa obtained water from unsafe sources. For the middle income category, a lesser number of 56.8% obtained water from unsafe sources while the rich category had no household obtaining water from those sources. The pattern observed in this analysis was that the number of households depending on unsafe water sources increased with the level of poverty.

Questions about income are not always welcomed by respondents. As a result, estimates of household income could be made on the basis of types and quantities of products consumed by the households (Olvera *et al.,* 2008). As an attempt to increase the quality of responses, respondents were asked to only indicate the income categories as opposed to specific incomes and they responded accordingly (Table 8.2).

Table 8.2 Monthly incomes of households in the study municipalities of the Luvuvhu-Letaba WMA

	Giyani		**Mutale**		**Thulamela**		**Luvuvhu-Letaba WMA**	
Income	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
No response	24	15.7	0	0.0	10	4.0	34	7.4
R0 - R1000	64	41.8	25	44.6	99	39.8	188	41.1
R1001 - R5000	48	31.4	20	35.7	117	47.0	185	40.4
R5001 - 10 000	12	7.8	9	16.1	17	6.8	38	8.3
> R10 000	5	3.3	2	3.6	6	2.4	13	2.8
Total	**153**	**100.0**	**56**	**100.0**	**249**	**100.0**	**458**	**100.0**

Some respondents (7.4%) did not provide information even when they were asked to only indicate the income categories, and those were mostly in Giyani where 15.7% did not disclose their incomes. Two in five (41.1%) households almost evenly distributed across municipalities earned R0-R1000 per month. Those could be households that depended mainly on casual jobs and those reliant on social grants, especially child support paying R250 and disability paying R750 per person per month for the 2010-11 tax year. The same number (40.4%) of households had monthly incomes of R1001-R5000 with most (47%) of them located in Thulamela. The old age grant was the most paying at R1080 per month and therefore some of these households could be reliant on those grants.

Based on a United Nations poverty line of US$1.25 per capita per day (World Bank, 2008) at a US$: Rand exchange rate of 8, the poverty threshold income in the study area will be R10 per capita per day or R1 200 per four member household per month. Based on this information, the 41.1% of households with monthly incomes of R0-1000 will all be poor with some of those with monthly income of R1001-R5000 also falling in this category. In the absence of government interventions on water supply, the households will generally not afford to pay for water and according to Dungumaro (2007) will rely a lot on unsafe water sources.

(d) Size of house owned

Ownership of assets has strong links with the economic well-being of households. An inverse relationship was recorded between ownership of assets and poverty, implying that poverty can be alleviated by increasing people's asset base (Fox *et al.*, 2009; Erenstein *et al.*, 2010). A house is an important asset for any household and its size determines the economic status and subsequently the supply and use of water by the household. The sizes of houses owned by households in selected municipalities in the Luvuvhu-Letaba WMA were much variable (Table 8.3).

Table 8.3 Sizes of houses owned by households in study municipalities in the Luvuvhu-Letaba WMA

Number of rooms	Giyani		Mutale		Thulamela		Luvuvhu-Letaba WMA	
	f	%	f	%	f	%	f	%
1	3	2.0	3	5.4	16	6.4	22	4.8
2	15	9.8	4	7.1	37	14.9	56	12.2
3	13	8.5	14	25.0	39	15.7	66	14.4
4	35	22.9	11	19.6	52	20.9	98	21.4
5	25	16.3	9	16.1	41	16.5	75	16.4
6	16	10.5	6	10.7	23	9.2	45	9.8
7	20	13.1	6	10.7	15	6.0	41	9.0
>7	25	16.4	3	5.4	21	8.4	49	10.7
Total	**152**	**99.4**	**56**	**100.0**	**244**	**98.0**	**452**	**98.7**

Table 8.3 shows that 4.8% of the households had only one room each. This room would be used as a kitchen, dining, lounge and bedroom, reflecting a desperate state of lack of housing accommodation and indeed of poverty. One in eight (12.2%) households had two room houses and that still suggested shortage. Most (14.9%) households with one and two room houses were in Thulamela, implying severe lack of housing development in this municipality.

The majority of houses were 3-4 rooms in Mutale and 4-5 rooms in both Giyani and Thulamela. Some households (29.5%) in the study area had bigger houses with more than five rooms. Some houses were built for the communities by government under its Reconstruction and Development Programme (RDP) at no cost to occupants. The sizes of houses owned by households in the study area could therefore not be a reliable indicator of their economic status.

8.3.2 Household water supplies

(a) Water sources and their safety

The quality of water fetched is influenced by the safety of the sources used and is dependent on the economic status of the household. Poor households in South Africa obtained water from less safe sources of wells, vendors or kiosks while wealthier residents had safer piped connections (Goldblatt, 1999, Aiga and Umenai, 2002, Manase *et al.,* 2009). Household water sources in the area under study were variable and ranged from unsafe to safe sources (Table 8.4).

Some 2.7% of households still obtained water from unsafe rivers with most (5.2%) of these located in the water scarce Giyani Municipality. Fewer (1.4%) households relied on less safe wells for water. Some 5.7% of the households bought water from neighbours again with most (16.5%) of them residing in Giyani, and the safety of such water would depend on the primary source. Up to 15.8% of the households relied on fairly safe boreholes for water with most (21.3%) located in Thulamela Municipality. Although truck delivery was not an important source, its safety would also depend on the primary source of the water. Half (50.1%) of the households obtained water from the safer street taps supplying treated water with most (83.9%) of them located in Mutale and least (33.0%) in Giyani. Combinations of sources supplied 24% of households with water and might have been unsafe or safer depending on the sources used at any time (Table 8.4).

Table 8.4 Sources of water for households in the study municipalities of the Luvuvhu-Letaba WMA enlisted from unsafe (1) to safer (6) sources

Water source	Giyani		Mutale		Thulamela		Luvuvhu-Letaba WMA	
	f	%	f	%	f	%	f	%
1. River	6	5.2	1	3.2	3	1.4	10	2.7
2. Well	1	0.9	0	0.0	4	1.8	5	1.4
3. Buy	19	16.5	0	0.0	2	0.9	21	5.7
4. Borehole	11	9.6	0	0.0	47	21.3	58	15.8
5. Truck delivery	0	0.0	1	3.2	0	0.0	1	0.3
6. Street tap	38	33.0	26	83.9	120	54.3	184	50.1
7. Combinations	40	34.8	3	9.7	45	20.4	88	24.0
Total	**115**	**100.0**	**31**	**100.0**	**221**	**100.0**	**367**	**100.0**

The fact that safe water sources of street taps and fairly safe boreholes were common in the study area suggests that some public investment was made in water infrastructure. This intervention was necessary for the poor community to access safe water; else they would not afford to pay for access to the resource. The development of water infrastructure in an area would depend on availability of water resources. Giyani was highly limited in water resource availability and therefore little infrastructure could be developed.

The supply of quality water still needs to be improved in all the municipalities, and this requires availability of the resource. Rivers in this WMA were already much exploited in terms of construction of dams (Section 4.3.1(b)), and little opportunities would be available for further development of the storage infrastructure. An exception was the Mutale River as it was strongly flowing with catchment mean annual runoff of 157.1 million m^3 and had small storage capacity of only 3.9 million m^3. The Department of Water Affairs (DWA) should explore opportunities for construction of a new dam on this river together with a water treatment facility. The department should also do more scoping for underground water and drill more community boreholes where possible.

(b) Distance of water source from residential site

The distance of water sources from residential sites was influenced by the level of social and economic development of a community. The distance generally shortened with more development (Makoni *et al.,* 2004). Less than half (46.7%) of households in the study area were located less than 1 km from the water sources (Figure 8.3), suggesting a state of under-development.

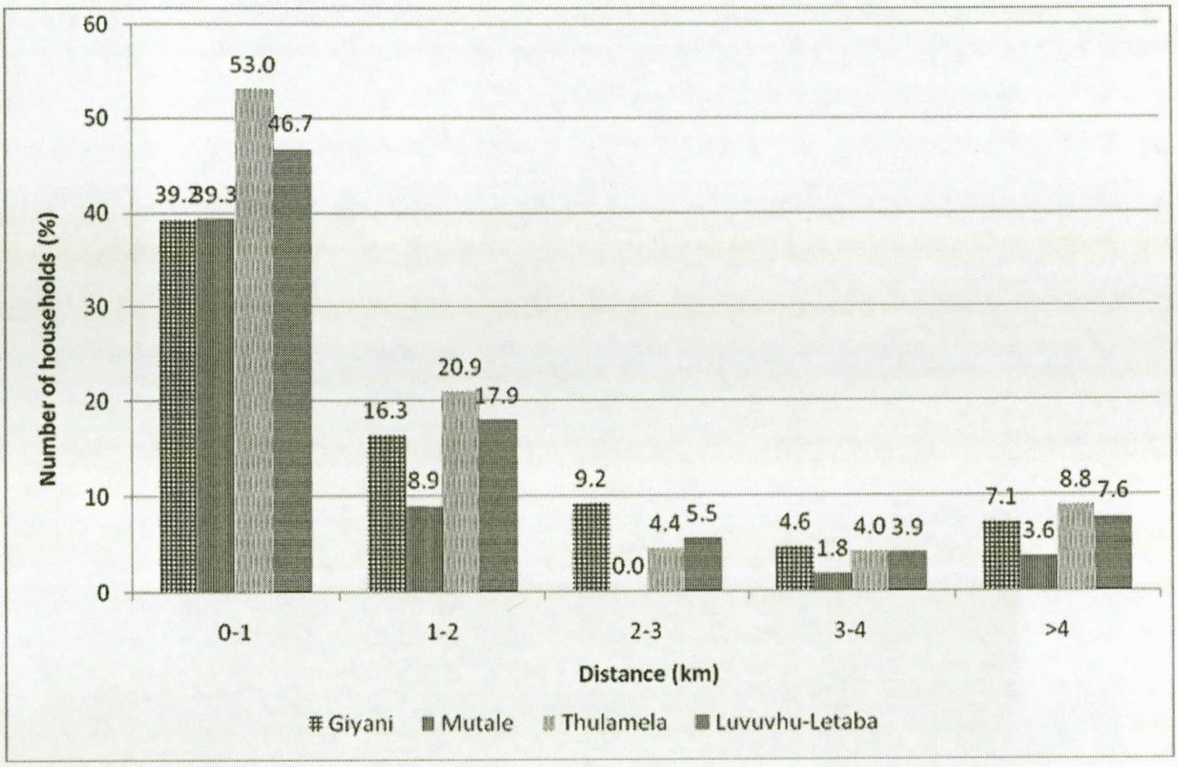


Figure 8.3 Distribution of households in study municipalities of the Luvuvhu-Letaba WMA according to the distance of water source from residential sites

The water sources within 0-1 km of residential sites were more (53%) in Thulamela and fewer in the other municipalities and could be mostly street taps. The water sources were located within

1-2 km from residential sites of 17.9% of the households. These sources were also more (20.9%) in Thulamela and fewer (8.9%) in Mutale. The sources located in this distance could be mainly boreholes as these were reported by more (21.3%) households in Thulamela and by fewer in other municipalities (Figure 8.3).

Less than half (46.7%) of the households in the study area used water sources located within a distance of 1 km from the residential sites. Water sources were mostly located more than 1 km away from residential sites of the majority of the households. According to Mazvimavi and Mmopelwa (2006), the water sources located more than 1km from residential sites as was the case here might be considered inaccessible and would adversely affect the per capita volume of water used to satisfy basic personal hygiene. The Mopani and Vhembe WSAs should develop more reticulation infrastructure to improve access of water in the study area.

(c) Quantity of water fetched

Literature with information on how much water is supplied to a household is very limited (Whittington, 2002). The volume of water collected by a household in rural settlements in Botswana varied from 20 to 400 litres with an average of 100 litres per day. The supply of water to some households in Botswana made provision of less than 20 litres per capita per day, and with this provision, basic personal and food hygiene requirements for water could not be satisfied (Mazvimavi and Mmopelwa, 2006). The supplies of water to households in the study municipalities were variable with some reporting 0-25 litres per day while others received more than 200 litres per day (Table 8.5).

According to Table 8.5, some 7.4% of households in the study area fetched a maximum of 25 litres of water per day with 10.5% located in Giyani, 16.1% in Mutale and 4.6% in Thulamela. One in nine (11.3%) households fetched 26-50 litres per day with Mutale being home to 45.2% of them. Mutale had the most (83.9%) households supplied from street taps (Table 8.4) and those could be closer to residential units, and yet it had the highest numbers that fetched lesser quantities of 0-25 and 26-50 litres per day.

Table 8.5 Distribution of households in the study municipalities of the Luvuvhu-Letaba WMA according to quantity of water fetched

Quantity of water fetched (*litres per day*)	Giyani		Mutale		Thulamela		Luvuvhu-Letaba WMA	
	f	%	f	%	f	%	f	%
0 - 25	12	10.5	5	16.1	10	4.6	27	7.4
26 - 50	10	8.8	14	45.2	17	7.8	41	11.3
51 - 75	37	32.5	6	19.4	45	20.5	88	24.2
76 - 100	15	13.2	0	0.0	17	7.8	32	8.8
101 - 150	11	9.6	1	3.2	49	22.4	61	16.8
151 - 200	8	7.0	3	9.7	27	12.3	38	10.4
> 200	21	18.4	2	6.5	54	24.7	77	21.2
Total	**114**	**100.0**	**31**	**100.0**	**219**	**100.0**	**364**	**100.0**

The lesser amounts fetched could have resulted from the fact that the municipality had smaller households where 22.6% had one and 49.1% had two members (Figure 8.2). With more street taps in the municipality, households could have connected own pipes to convey water to their yards where uses such as crop watering would be catered for directly without the water having to be stored in containers. Only water for important uses such as drinking and cooking would be stored in containers and would accordingly be reported as water fetched and this would result in the impression that households in the municipality fetched lesser amounts of water.

Most households (24.2%) fetched 51-75 litres per day with 32.5% in Giyani, 19.4% in Mutale and 20.5% in Thulamela. Some 8.8% of households fetched 76-100 litres while 16.8% fetched 101-150 litres of water per day. Some 10.4% of households fetched 151-200 litres while 21.2% had daily quantities of water in excess of 200 litres with most of them (24.7%) in Thulamela followed by Giyani (18.4%) and least (6.5%) in Mutale. Such households had water supplies exceeding double the recommended minimum of 25 litres per capita per day for a four person household (DWAF, 1994).

The results indicate that half (51.7%) of the households fetched ≤ 100 litres of water planned for a four member household per day and this affirms the need for improvement of water supplies in the study area to ensure adequate provision for all households. The prospects for constructing a dam in the currently under-utilized Mutale River should be considered. The new Nandoni Dam in Thulamela should improve supplies in the municipality and other needy areas with planned transfers to Nsami Dam likely to address the scarcity in Giyani.

(d) Influence of distance of water sources from residential sites on quantity fetched

A study of household water consumption in Nicaragua revealed that a decrease in the distance to the water source from 1000m to 10m was associated with an increase in per capita water consumption of 20% (Keshavarzi *et al.,* 2006). This view was affirmed by Katsi *et al.* (2007) who stated that water sources nearer to residential sites provided respondents with easy access to water, making it possible for the households to fetch more water. The relationship between distance to water source and the resource consumption per capita as reported by Keshavarzi (2006) and Katsi *et al.* (2007) occurred in the study area (Figure 8.4).

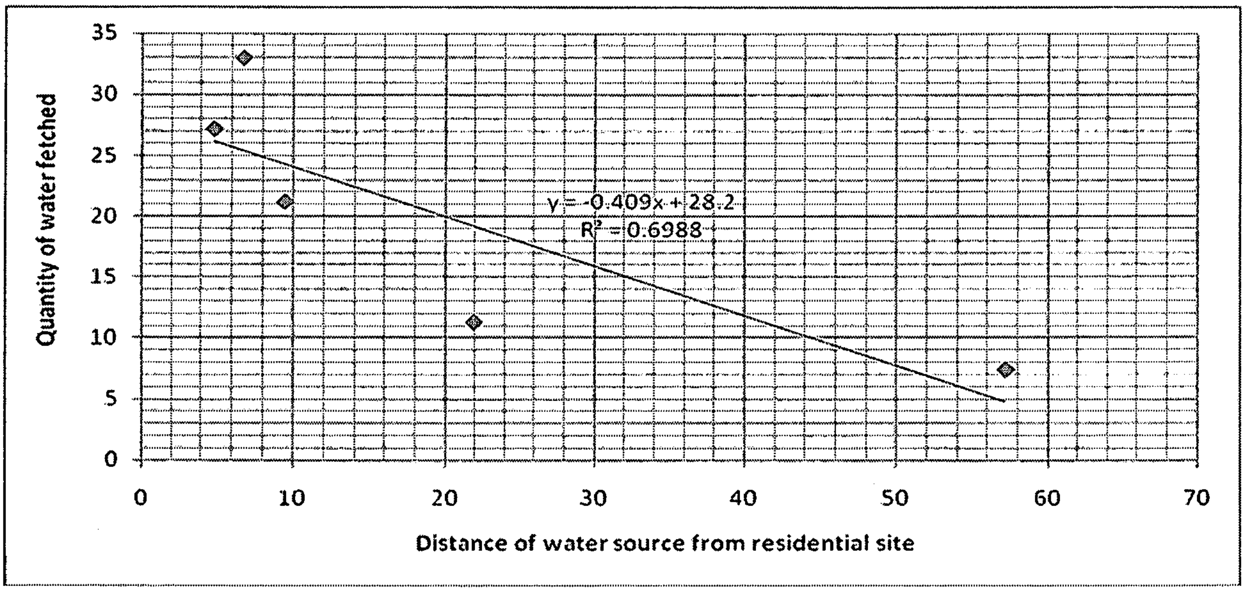


Figure 8.4 Influence of distance of water source from residential site on quantity fetched

There was a medium to strong correlation (R^2=0.6988) between the distance of water sources from residential sites and the quantity of water fetched (Figure 8.4). As revealed by the graph

(Y= -0.409 x + 28.2), the quantity of water fetched increased with a decrease in the distance of the water sources from residential sites. This affirmed Katsi *et al.* (2007) statement that water sources nearer to residential sites provided respondents with easy access to the resource. Where adequate runoff is stored, installation of reticulation pipes will reduce the distance of the water sources to residential sites and will lead to more quantities being fetched by households.

8.3.3 Household water uses

(a) Water use activities

The water use is influenced by population growth and types of socio-economic activities performed (Molden *et al.,* 2000; Saleth and Dinar, 2003). Rural households use water for both indoor and outdoor activities. Indoor water uses include consumption for drinking, preparing food and hygiene activities such as bathing and laundry (Merrett, 2002; Keshavarzi *et al.,* 2006; Katsi *et al.,* 2007). Outdoor activities include car washing, livestock drinking and garden watering (Arbues *et al.,* 2003; Keshavarzi *et al.,* 2006).

Also, water use in rural areas may be classified into basic household and productive uses. Basic household uses refer to water used for drinking, preparing food and personal hygiene. Productive consumption on the other hand highlights economic activities that are highly dependent on availability of water supplies, namely vegetable gardens, animal drinking, traditional beer making and brick making (Makoni *et al.,* 2004; Mazvimavi and Mmopelwa, 2006). The majority of households in the study area used water for basic as opposed to productive consumption (Table 8.6).

The basic household activities reported to have consumed water were drinking by people (95.9% of households), preparing food for home consumption (95.4%), bathing (92.8%) and laundry (90.8%). Most households were reported to have used water for these activities in Thulamela followed by Mutale and Giyani. These activities are the basic requirements for life and it would therefore be expected for all households to have allocated some water to them. The impression that certain households did not use water for some of these activities is incomprehensible, more so for drinking by people and preparing food and this could have been exaggeration of the water scarcity by some respondents.

Table 8.6 Distribution of households in study municipalities of the Luvuvhu-Letaba WMA according to uses of water for basic household and productive activities

Water use	Giyani		Mutale		Thulamela		Luvuvhu-Letaba WMA	
Basic household	f	%	f	%	f	%	f	%
1. Drinking by people	141	92.2	52	92.9	246	98.8	439	95.9
2. Cooking for home consumption	141	92.2	52	92.9	244	98.0	437	95.4
3. Bathing	134	87.6	52	92.9	239	96.0	425	92.8
4. Laundry	130	85.0	46	82.1	240	96.4	416	90.8
Productive								
5. Washing car	5	3.3	9	16.1	16	6.4	30	6.6
6. Irrigating crops	2	2.6	8	16.1	7	5.2	17	5.7
7. Livestock drinking	1	0.7	6	10.7	9	3.6	16	3.5
8. Cooking food for sale	0	0.0	0	0.0	3	1.2	3	0.7
9. Brewing drinks for sale	0	0.0	0	0.0	8	3.2	8	1.8

Fewer households used water for productive activities and this confirmed the scarcity of the resource in the study area. The Mutale Municipality was reported to have used more water for productive purposes than Thulamela and Giyani. Water supply for the productive activities such as car washing and crop watering could have been sourced through connecting own pipes to street taps by the 83.9% of households who relied on these taps (Table 8.4). Such water might not have to be stored in containers and would not be measured, hence the households in the municipality would report having fetched lesser quantities of water (Table 8.5). After Mutale, more households sourced water from street taps in Thulamela than those in Giyani, and accordingly more households used the resource for productive purposes in Thulamela compared to Giyani. Improving access to water would increase the use of the resource for productive activities in all municipalities and would trigger growth of the rural economy.

(b) Quantity of water required by households

There is a dearth of reliable information on quantity of water required by households for different purposes (Merrett, 2002). In Mvunyane village in South Africa, 43% of households used less than 50 litres and a further 49% used between 50 and 100 litres of water per day. With the average household size in Mvunyane being five people, the average quantity of 15 litres of water used per capita per day was far less than the design standard of 25 litres per capita per day (DWAF, 1994 and Goldblatt, 1999).

Households in the study area had no metered connections and that made it difficult to have accurate figures of the quantities of water they used. Whittington *et al.* (2002) revealed that even villages with household connections could lack or have broken meters making it difficult to estimate precisely how much of the water supplied actually reaches the customers. As stated by Whittington *et al.* (2002), households with connections could also use alternative sources of water such as wells and public taps which would complicate calculation of the amount of water consumed. It was for this reason that this study accepted estimates of the quantities of water required as provided by respondents (Table 8.7).

As presented in Table 8.7, the majority of respondents estimated the household water requirements to be 0-25 litres each for drinking (95.6% of households), cooking (91.5%) and bathing (63.1%). Laundry was reported by most households (43.6%) to require more than 50 litres per day and this could be estimated at 75 litres based on the fact that a 25 litre container is commonly used to fetch water. The requirement of more than 50 litres could mean one or more additional containers. Based on these results, a household would require 150 litres of water per day. The 150 litre household water budget could be under- or over-estimated and would require comparison with results of related studies before acceptance.

Table 8.7 Distribution of households in the study municipalities of the Luvuvhu-Letaba WMA according to their daily water requirements for different uses

Specific water use	Quantity of water needed (*litres*)	Giyani		Mutale		Thulamela		Luvuvhu-Letaba WMA	
		f	%	f	%	f	%	f	%
Drinking	0 - 25	149	97.4	53	94.7	236	94.8	438	95.6
	26 - 50	4	2.6	2	3.6	13	5.2	19	4.2
	> 50	0	0.0	1	1.8	0	0.0	1	0.2
Cooking	0 - 25	143	93.5	53	94.7	223	89.6	419	91.5
	26 - 50	8	5.2	3	5.4	26	10.4	37	8.1
	> 50	2	1.3	0	0.0	0	0.0	2	0.4
Bathing	0 - 25	95	62.1	43	76.8	151	60.6	289	63.1
	26 - 50	35	22.9	6	10.7	57	22.9	98	21.4
	> 50	23	15.0	7	12.5	41	16.5	71	15.5
Laundry	0 - 25	93	60.8	34	60.7	65	26.5	192	42.3
	26 - 50	17	11.1	13	23.2	34	13.9	64	14.1
	> 50	43	28.1	9	16.1	146	59.6	198	43.6

The ideal amount of water required per capita per day was estimated at 1.7 (Ershow and Cantor, 1989) to 2 litres (WHO, 1996) for drinking, 10 to 20 litres for cooking (Inocencio *et al.,* 1999), 5 to 15 litres for bathing and 8 to 10 litres for laundry (Gleick, 1996). This makes a lower estimate total water requirement of 24.7 and a higher estimate total requirement of 47 litres per capita per day suggesting an average requirement of 35.85 litres per capita per day. The average water requirement for a four member household is therefore estimated at 143.4 litres and is very close to the 150 litres reported by the respondents. The estimate water demand of 150 litres per day reported for households in the study area may therefore be regarded as credible for an average household.

Rural households are currently supplied based on design standard of 25 litres per capita per day (DWAF, 1994) and for the average household of four members this translates to 100 litres per household per day. Supplies of 150 litres per household would provide 37.5 litres per capita per day. The current design standard for rural water supply is therefore less than the requirement presented by respondents by 50 litres per household per day or 12.5 litres per capita per day.

8.4. Summary and conclusion

Heads of household were mostly in the middle ages of 36-50 (34.8%) years old. Households were poor with low monthly incomes of R0-R1000 for 41.1% and R1001-R5000 for 40.4% of the families.

The study area has a scarcity of water supply exacerbated by the dearth of infrastructure for its reticulation. Half (50.1%) of households obtained water from street taps and 46.7% had good access to water sources with elderly households having better access than their youthful counterparts. The quantity fetched was widely variable, 7.4% of households fetched 0-25 litres and 21.2% fetched > 200 litres per day. Households that are located nearer to water sources fetched more water than those away from the sources.

As a result of the scarcity of the water supply, more households only used water for basic activities such as drinking (95.9%), preparing food (95.4%) and bathing (92.8%) compared to those who used it for productive activities such as washing cars (6.6%) and watering crops (5.7%). Half (51.7%) of the households fetched less water than the 25 litres per capita per day supply standard. Analysis of the requirements revealed that the 25 litres per capita per day did not meet the average requirement of 37.5 litres per capita per day.

CHAPTER 9

9 CHALLENGE AND CAPACITY CONGRUENCE ANALYSIS FOR DEVELOPMENT OF A WATER MANAGEMENT DECISION MODEL

9.1 Introduction

Periodic droughts and population growth have placed burdens on water supply and demand. This results in communities being faced with challenges such as resource scarcity resulting in negative socio-economic impacts. In order to successfully address water challenges, an appropriate resource management decision model that takes into account the relevant capacity of service organisations is required.

The major challenges affecting the water sector in the Limpopo Province include resource scarcity exacerbated by inadequate storage (Chapter 4), failure of some reservoirs to fill up which confounds water management decisions by resource managers (Chapter 5), poor resource knowledge of managers (Chapter 6), lack of effective stakeholder participation in water decisions (Chapter 7) and ultimately inadequate water supply to rural households (Chapter 8). These challenges were investigated (chapters 4 to 8) and proposals made on how they may be addressed.

The purpose of this study was to (1) highlight the challenges faced by the water sector in the study area, (2) identify relevant water service organisations authorised to address these challenges and assess their capacity to do so, (3) analyse the degree of congruence between the challenges and the capacity of identified water service organisations, and (4) to subsequently propose a water management decision model (Section 1.4, Table 3, ultimate objective). High levels of congruence between the challenges and the capacity of water service organisations to address these challenges suggest future improvement of water supply and *vice versa* and therefore the Congruence Model of Nadler and Tushman (1980) provides a suitable framework for developing the water management decision model.

9.2 Description of the Congruence Model

The Congruence Model views organisations as made up of components that interact with each other (Figure 9.1). These components are **inputs** that include environment, resources, history and strategy; **transformation** that is influenced by tasks, human resources, financial resources and formal and informal organisational arrangements; and **outputs** that may be organisational, group or individual (Nadler and Tushman, 1980) as alluded to in Section 3.5.5(b).

The model provides for information flow from a source component to a recipient component and this information may (or not) be subjected to congruence rating to assess its relevance (Figure 9.1). Also, the model provides for flow of action which is rated for congruence with the available challenge to assess the degree to which the action is relevant. Interactions within a service organisation influence its performance and are therefore also included in the model. The model provides for feedback which informs improved strategy for the next cycle of action. The description of Nadler and Tushman (1980) was affirmed by Gill (2000) and Mertikas (2008) who indicated that an organisation as represented by the Congruence Model take input, put them through transformation and produce outputs.

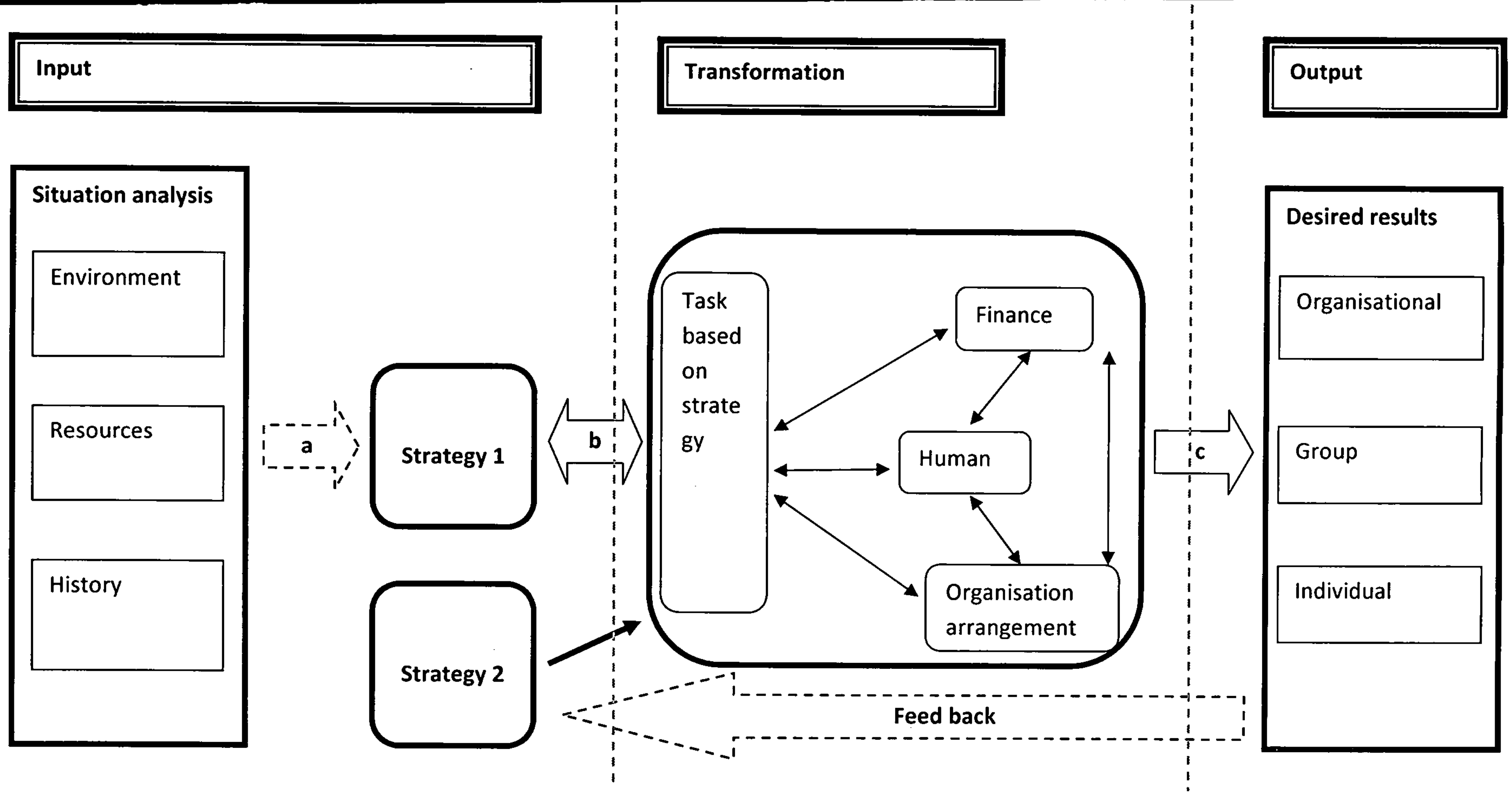
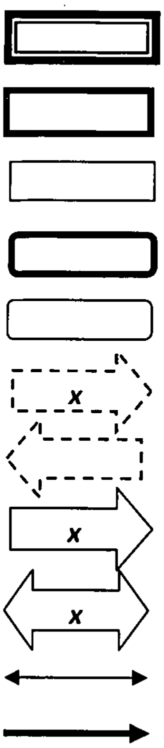


Figure 9.1 Adjusted Congruence Model of Nadler and Tushman (1980)

Meanings of diagrams in the model as adapted from Forrester diagrams



Component of Congruence Model

A state variable; Final results of what happened

Element of a state variable

Auxiliary or intermediate variable

Element of auxiliary or intermediate variable

Unidirectional flow of information with congruence rating (*x*)

Unidirectional flow of information without congruence rating

Unidirectional flow of action with congruence rating (x)

Two directional flow of action with congruence rating (x)

Interaction

Future flow of action

A relative degree of congruence or fit exists between each pair of components of the model. The congruence between two components is defined as the degree to which the needs, demands, goals, objectives, and structures of one component satisfy (or not) those of the other (Nadler and Tushman, 1980). Congruence therefore is a measure of how well pairs of components fit together.

9.2.1 Congruence between units across components: Person-Environment Fit

According to the Congruence Model, the achievement of positive outputs is dependent upon the degree of congruence between the inputs and the transformation components. A high degree of congruence is realised between inputs and transformation when a similar extent of congruence occurs between pairs of units across these components. Knowledge of congruence between pairs of units across components of the model is therefore necessary to understand the congruence between components themselves. The unit of environment under input and person or individual under transformation component was used as example to discuss the issue of congruence between units.

The concept of 'person-environment (P-E) fit' refers to similarity or convergence between a particular set of person-related attributes and a set of environment-related attributes (Schneider *et al.,* 1992). The underlying assumption is that organisations will be more effective when the attributes of a person and those of environment match or are highly congruent (Ostroff, 1993). The P-E fit has been positively related to job satisfaction, organisational commitment and career success (Bretz and Judge, 1994; Chatman, 1991 and Kristof, 1996).

Considering the water sector, a high degree of congruence between the unit of *environment* under input and that of *person* under transformation (within the water service organisation) will contribute to a more effective service organisation. Similarly, high degrees of fit between pairs of other units across the two components of environment and transformation in water service organisations will make the organisation to be more effective.

9.2.2 Congruence between units within a component: The example of transformation

In addition to congruence between units across components of the model, the effectiveness of organisations is also dependent on the degree of congruence between pairs of units within a component. With the transformation component playing a critical role of converting inputs to outputs, it was used as an example for discussing the congruence between pairs of units within the component. Again the person or individual was adopted as a key unit that was matched with other units such as organisation, group and job to assess the degree of congruence.

(a) Person-organisation fit

The concept of 'person-organisation (P-O) fit' refers to a match between individual and organisational characteristics (Kristof, 1996). The P-O fit may be defined as the congruence between individual values and organisational values (Boxx *et al.,* 1991; Chatman, 1989, 1991; Judge and Bretz, 1992; O'Reilly *et al.,* 1991). Organisational values include such aspects as culture which informs people about the appropriate way things are done in the organisation (Balkin and Schjoedt, 2012). Some organisational cultures are rigid and do not provide for employees to make independent decisions while others are flexible and allows the employees to make decisions.

Self-motivated employees (persons) would want to decide on their own goals, work schedules, methods of work and outputs (Cascio, 1999; Sparrow and Daniels, 1999) and would therefore fit in flexible work situation such as that offered by virtual organisations (Boudreau *et al.,* 1998; Jarvenpaa and Leidner, 1999). These organisations that offer a flexible work situation are often multicultural (DeSanctis *et al.,* 1999; Jarvenpaa and Leidner, 1999) and are therefore able to accommodate employees from different cultural backgrounds.

The attainment of P-O fit is very necessary for water service organisations to be effective. Lack of P-O fit results in disharmony between employees and the water service organisations and this leads to poor performance of the organisations.

(b) Person-group fit

The person-group (P-G) fit is defined as the compatibility between an individual and his or her workgroup (Kristof, 1996). The P-G fit is a measure of the similarity in personality among group members (Ferris *et al.,* 1985) or possession of effective interpersonal skills (Werbel and Gilliland, 1999).

Models such as the Congruence Model that advocate for P-G fit promote (1) congruence between the demographic characteristics of an individual and those of their workgroups (Jackson *et al.,* 1991); (2) similarity among group members personality, values, and goals (Klimoski and Jones, 1995); and possession of interpersonal skills that are necessary for effective cooperation with other group members (Werbel and Gilliland, 1999). It may be inferred that attainment of a high degree of similarity among the personality and values of different group members requires regular communication among the members. The regular communication allows the group members to share their diverse personality and values and to gradually establish a state of homogeneity with regards to these personality and values.

(c) Person-job fit

The concept of 'person-job (P-J) fit' refers to the degree of congruence between individual characteristics and job requirements (Edwards, 1991; Caldwell and O'Reilly, 1990). The P-J fit commonly lacks where employees have a shortage of competence that is critically required by the job (Cascio, 2000).

Issues resulting in employees lacking critical competence required by their jobs could include problems at recruitment. In situations where employees do not have the required competence for their jobs, attainment of P-J fit will require the organisations to invest in interventions such as human resource development or to outsource the lacking expertise. Persistent lack of P-J fit will result in the organisation not performing to its plans and subsequently being ineffective.

9.2.3 Congruence and water sector effectiveness

The effectiveness of an organisation in achieving its output requires some degree of congruence between pairs of components such as input and transformation and between pairs of units within each component. Effectiveness was defined as the degree to which actual organisational outputs are similar to expected outputs (Nadler and Tushman, 1980; Wyman, 1998; Bezboruah, 2008). For this study, the congruence between the water challenge and the capacity of service organisations as described by their strategies, tasks and the allocation and use of resources is critical.

A higher degree of congruence between the water sector challenge and the capacity of service organisation to address the challenge will result in increased effectiveness of the water sector. The capacity of the service organisations to address water challenges is dependent upon the level of congruence between the pairs of components defined by the Congruence Model and between pairs of units within each component.

The expected outputs of the water sector in the Limpopo Province are a well-managed, water resource with appropriate storage and other water infrastructure, availability of research knowledge for resource management, active participation by all relevant stakeholders and adequate supply of water to communities. If the capacities of relevant service organisations are congruent with the sector challenges, they should be focussed on achieving these outputs.

9.3 Research methodology

9.3.1 Rationale for selecting the Congruence Model

The research identified major challenges experienced by the water sector in the study area, and relevant research objectives were developed (Section 1.4, Table 1.3). The investigations conducted in chapters 4 to 8 were based on the identified research objectives and had each important recommendation(s). In order to successfully address the water sector challenges, water service organisations would have to implement the recommendations of the investigations and this would depend on availability of relevant organisational capacity.

Deciding on whether a water service organisation has relevant capacity to resolve a water sector challenge or not necessitated matching of appropriate attributes of the organisation with the water challenge to determine the degree of fit. A high degree of fit would suggest that the organisation has relevant and adequate capacity to resolve the water challenge and *vice versa*. The Congruence Model emphasizes the essence of fit between relevant components for organisations to be effective in producing desired outputs. Upon evaluation of different models (Section 3.5.5(b)), the Congruence Model proved to be suitable for assessing the degree of fit between the water sector challenges and subsequent strategies of service organisations and between strategies and transformation components (within organisations) and was therefore selected.

The proposed congruence based model for water management decision making for Limpopo (Figure 9.3) highlights the three main components of the Congruence Model, namely: input, transformation and output. Under the input component, focus was provided to environment which was considered under the **P**olitical, **E**nvironment, **S**ocial, **T**echnology, **E**conomic and **L**egal (PESTEL) framework to highlight the water sector challenges. The symbols used were as defined under the description of the model (Section 9.2, Figure 9.1). Although the model was recommended at a provincial level, it may be used to assess the capacity of water service organisations to address sector challenges at all levels, e.g. catchment, WMA or nationally by DWA.

9.3.2 Sampling procedure

Purposive sampling was used to select the water service organisations to be evaluated for development of a water management decision model within the framework of the Congruence Model. The Limpopo Regional Office of DWA was selected as it is the custodian of water in the province. The WSAs of Mopani District Municipality (MDM) largely in the Luvuvhu-Letaba WMA, Vhembe District Municipality (VDM) across both Limpopo and Luvuvhu-Letaba WMAs and the Polokwane Local Municipality (PLM) in the Limpopo WMAs were deliberately selected for their proximity to the place of stay of the researcher.

9.3.3 Description of the study area

In addition to the Limpopo Regional Office of DWA located in Polokwane, three WSAs were targeted by the study: MDM, VDM and PLM which cover both the Limpopo and Luvuvhu-Letaba WMAs (Figure 9.2). Mainly due to topography, rainfall in the WMAs varies from well over 1000 to less than 300 mm per annum. The mean annual runoff of the Limpopo WMA is 985.9 million m^3 while that of the Luvuvhu-Letaba WMA is 1 183.9 million m^3 (section 4.3.1(a)). The water resource is more used in the Luvuvhu-Letaba WMA.

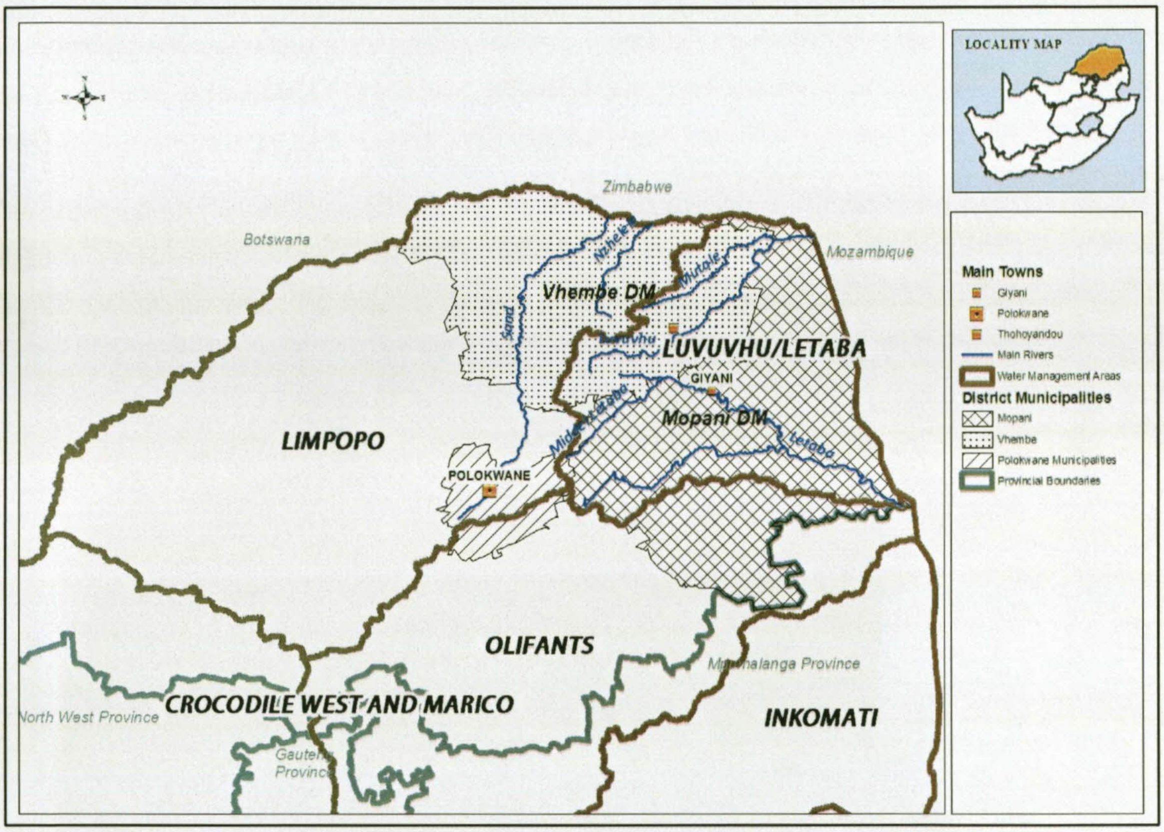


Figure 9.2 Map of Limpopo Province showing the Limpopo and the Luvuvhu-Letaba WMA (red line), Mopani and Vhembe District Municipalities and the Polokwane Local Municipality (hatchings)

The current shortfalls and the future growth in requirements will be supplied from water which becomes available as a result of interventions such as improved water management (DWAF, 2004a). Such interventions require the water services organisations to have relevant capacities that are congruent to the challenges faced by the sector.

9.3.4 Data collection and analysis

Proposed solutions of challenges faced by the water sector in the province was obtained from the results of investigations in chapters 4 to 8 while information on capacity of water service organisations came from the strategic and integrated development plans and annual reports of these organisations. The WSAs are newly developing organisations without some of the necessary information available over the years, especially that on resource allocations and utilisation. Where information was provided, the plans and reports dealt with different issues across the WSAs and across the years and this made analysis difficult.

A fair amount of information with some degree of convergence on issues covered was obtained for the 2009-10 financial year and hence analysis was based on this year. The documents used to obtain information on the capacity of water service organisations were the 2007/08-2009/10 Strategic Plan for DWA (DWA, 2007), 2006-12 Integrated Development Plan for MDM (MDM, 2009), 2009-10 Integrated Development Plan for VDM (VDM, 2009) and 2009-11 Integrated Development Plan for PLM (PLM, 2009). Information was also obtained from other relevant literature.

In order to ensure consistence in the type of information collected from the plans of the water service organisations, the major challenges experienced by the water sector were highlighted. The statements in the plans of water service organisations that proposed solutions to the sector problems were noted and used to assess the congruence between the capacity of the organisation and the water sector challenge. The congruence analysis is based on the plans of the water service organisation and hence estimates the prospects for the organisations to successfully address the water sector challenges.

Although the information was mainly qualitative, some quantitative data was used and that included data on the amount of resources allocated and those utilized by the organisations. Spread sheet calculations were performed on quantitative data and objective rating of congruence between planned and utilized human and financial resources was conducted. The qualitative information on different aspects of organisational capacity was properly summarized, organised and subjectively rated for congruence with the water sector challenges (Lee, 1999; Leedy and Ormrod, 2010).

Arbitrary numerical scores were decided upon and used for the rating of the degree of congruence between aspects of capacity of water organisations and the sector challenges. The scores were in a scale of 0-3 where 0 indicated no congruence, 1 indicated low, 2 indicated moderate and 3 indicated a high degree of congruence. This type of research where both quantitative and qualitative data is collected and analysed is described as a mixed study (Hurmerinta-Peltomaki and Nummela, 2006).

The congruence scores were accordingly interpreted in the context of determining the prospects for water service organisations to successfully address sector challenges. Higher congruence scores for both quantitative and qualitative aspects suggested a higher degree of fit between the water sector challenge and the capacity of the service organisation to address it and *vice versa.*

9.4 Results and discussion

9.4.1 Input components and their influence on the water sector

Inputs are factors that characterise the water sector and include the environment, resources and history (Nadler and Tushman, 1980; Wyman, 2003; Bezboruah, 2008). These inputs define the conditions of the water sector and are described as follows:

(a) Environment

Analysis of the water sector environment highlights the demands, constraints and opportunities availed to water service organisations (Nadler and Tushman, 1980). Sound description of the water environment includes factors such as resource scarcity and storage development, reservoir hydrology, knowledge systems acquired by different stakeholders, stakeholder interactions and resource allocations to different users etc. The status of these factors in the study area has some influence on the performance of relevant water service organisations (Table 9.1).

As presented in Table 9.1, water service organisations in the study area operate under a stressful environment. Well thought through logical strategies would be necessary for the situation to be turned around. Important strategies to address water scarcity would include the development of storage capacity to capture water in the season of abundance and make it available during that of scarcity (Keller *et al.,* 2000).

Table 9.1 Water sector environment of the Limpopo Province

Environmental factor	**Status in the water sector in Limpopo Province**	**Influence on performance of water service organisations**
Water scarcity and storage development	Physically water scarce confirmed by low rainfall and runoffs but still has opportunity for storage development. Poor in water conservation.	Water scarcity with inadequate storage reduces economic activities and threatens political stability. This stresses the service organisations as users keep demanding more water.
Reservoir hydrology	Dams were built in different river catchments with more in the Luvuvhu-Letaba than the Limpopo WMA. Some dams never fill up and this confuses stakeholders in decision making.	Inappropriate water management decisions, exacerbates the effect of resource scarcity. Relevant information / technologies are needed to guide reliable decision making.
Resource knowledge of water managers	Water managers have little knowledge of the water resources but are more knowledgeable on resources uses.	The managers make decisions that do not promote availability of water to the economy and this threatens social and political stability.
Sector stakeholder participation	Government stakeholders dominate in meetings and other social events of provincial and district water sector forums, coordinate committee on agricultural water, and water summits.	Communities feel excluded and do not support the decisions made. This negatively influences the performance of the service organisations.
Water allocations to different users	Water is non-equitably allocated across sectors and geographic areas (rural vs urban) based on political power and legal instruments such as the 1956 Water Act. Equitable allocation requires allocation reform which is constrained by uncontrolled water trading	As a result of inequitable resource allocations, some people have little or no supply at all, and this makes them disgruntled.

The water economy in South Africa is characterized by high demand for the resource and competition among use sectors (Randall, 1981; Backeberg and Groenewald, 1991) and hence development of storage capacity should be accompanied by efficient use of the water resource for the strategy to be more effective.

Sound management of the water resource necessitate knowledge of the hydrologic responses of the developed storage facilities (Kongo and Jewitt, 2006). The water managers are important decision makers in water resource management and are among those who should be knowledgeable in various water supply and use issues. Other relevant stakeholders should also have knowledge of the hydrologic response of storage facilities as the stakeholders play an important role in water management decisions such as resource allocation (Shah *et al.*, 2001). It is when all these stakeholders are equipped with relevant knowledge that they will be able to make correct resource management decisions. Lack of such knowledge resulted in inappropriate water management decisions being made and resource scarcity exacerbated.

(b) Resources

Resources are the assets available to water service organisations and include human, finance, technology and information (Nadler and Tushman, 1980; Gill, 2000; Wyman, 2003). Availability of human and financial resources differs across the water service organisations and will be discussed separately for each organisation under section 9.4.2(b). The situation regarding technology, information and public perceptions on water service organisations in the study area is described as follows:

(i) Technology

Major technologies necessary for the water sector to function properly include that for measurement of climatic factors, geo-hydrological monitoring, mechanization and equipment for infrastructure development and maintenance as well as information technology. Important climatic factors to be measured would include temperature and rainfall which determine the amount of runoff and hence water availability. Proper geohydrological monitoring provides information on ground water fluctuation and in this way shows the status of ground water availability. Mechanization and equipment for development and maintenance of water infrastructure are important for the water supply system to be there in operational condition.

Measurement of all these aspects of water management requires availability of relevant technologies. Computation and analysis of the collected data requires information technology. Although the technologies are available on the South African market, their supply in the study area is limited and this constrains the performance of water service organisations.

The weather stations are sparsely distributed across Limpopo Province and certain agro-climatic zones in the study area do not have a representative weather station. Climate information such as rainfall and temperature must therefore be estimated. Limited supplies of facilities for geo-hydrological monitoring in some areas make knowledge of the underground water resources very limited. Scarce supply of mechanization and equipment coupled with lack of expertise limit the capacity of water service organisations to develop new water infrastructure and to maintain the existing ones. Scarcity of required information technology on the other hand makes collection of information such as weather data expensive as a person often has to go to a manual weather station to record the measurements. The dearth of a wide range of technology supplies therefore constrains the performance of water service organisations in the Limpopo Province.

(ii) Information

Information is critical for all stakeholders to make correct decisions on water issues. The information may be of the water resource itself or of its uses. According to Schreiner and van Koppen (2000), the water stakeholders should be informed about poor people's water needs for multiple uses in order to make appropriate decisions for meaningful management of the resource. The essence of information about the water needs of all resource users was affirmed by Lord and Israel (1996) who mentioned that influential stakeholders should make decisions that take into account the needs and desires of all the different water users and role players. Without the information about the resource needs of the different water users and role players, the stakeholders are likely to take decisions that do not address the needs of these groups.

Although communities represented by non-governmental stakeholders have high levels of interest for participating in decision making for water projects (Kgomotso and Swatuk, 2006), they were often excluded from water meetings and were not informed about the challenges and other issues faced by the sector (section 7.3.3.(a), Chapter 7). Sound management of water requires stakeholders to be representative (UNDP, 1995; Chancellor, 1996; Carney, 1998; and Van Koppen, 1990) and well informed about the challenges facing the sector.

The community based water stakeholders in the study area were uninformed about the issues facing the sector and had less influence on water issues discussed (section 7.3.3.(c)). As a result, the stakeholders could not be representative of the communities and subsequently water decisions did not address the needs of the communities. It could be a result of this lack of informed influential representation that communities often embarked on protests to demand water supplies. Also, the communities were often not effectively informed when dam levels were very low and hence they continued to expect regular supplies of the resource.

(iii) Public perceptions of service organisations

Public perceptions of water service organisations were generally negative. Up to 84.2% of households were not satisfied with the water services in the area under study. Also, the exclusion of rural communities from water sector decision making (section 7.3.3.(a)) could have exacerbated the situation. The poor public perceptions of water service organisations therefore constituted an unfavourable input for the operation of these organisations. The situation could have been different if the water service organisations had outreach or public education programmes.

(c) History

The water sector in South Africa is greatly influenced by historical events and key strategic decisions (Nadler and Tushman, 1980; Gill, 2000). The history that influenced the water sector includes the change of political order and therefore legislation over time. Having had changes of water legislation over time, it was necessary to analyse the impact of past and current laws on the sector (Table 9.2).

As revealed in Table 9.2, the Water Act of 1956 provided for water to be managed as a fragmented resource with some recognised as private and the balance public with no provision for environmental nor for international obligations. Water was prioritised for irrigation, commerce and mining due to highly centralised decisions with no system for disseminating information on those decisions (RSA, 1956).

Table 9.2 The impact of the Water Act of 1956 and of the National Water Act of 1998 on water sector performance (RSA, 1956; RSA, 1998a; de Coning, 2006; Woodhouse, 2008)

Water Act of 1956	**National Water Act of 1998**	**Expected impact of reform**
Provides for both public and private water linked to land ownership	Declares all water a national asset, abolishes riparian rights and private ownership	Equitable access independent of land ownership
No priority for water for environmental and international obligations	Water prioritised and reserved for environmental and international obligations;	Resource sustainability and harmony with neighbouring states
Legislate for only public water on effluent handling-Return to public stream	Legislates for all water as indivisible national asset-All polluters pays	Holistic quality management of water resources
Minister may establish and operate government water works.	Minister may establish and operate government water works after EIA and public involvement.	Environmental and social sustainability
Decisions mostly centralised to President and Minister	Decisions de-centralised to CMAs, WUAs and public, Minister overall responsible	Stakeholder involvement results in social stability
No provision for national information system	Provides for national information systems	Public information results in social stability
Prioritises water for irrigation, commerce and mining	Water prioritised and reserved for basic human needs	Improved rural supply allows for socio-economic development

The National Water Act of 1998 provided for reversal of the negative stipulations of the Water Act of 1956. The Act described water as an indivisible national asset with some reserved for environment to provide for sustainable supplies and for international obligation to promote regional stability. Decisions were decentralised to CMAs and WUAs. Provision was made for national information systems and water was prioritised and reserved for basic human needs.

9.4.2 Major challenges faced by the water sector

In accordance with the negative influences brought by the different components of input to the water sector, various challenges were identified which require major attention. The challenges were presented as real life problems and informed the development of research objectives (Section 1.4, Table 1.3) were mentioned as environmental factors (Section 9.4.1(a)) in this chapter.

These water challenges are:

(a) Scarce water resource availability and inadequate storage

A study on runoff and storage capacity revealed the study area to be water scarce (Chapter 4) and yet the storage capacity was not adequately developed, especially in the Limpopo WMA. As a result, the supply of the resource is insufficient for meeting the demands for social and economic activities in the province.

(b) Some dam never filled up

Some dam never filled up except during floods and this confused water managers who could not reliably predict the supply and as a result could not make appropriate resource management decisions. The dam of concern in this regard is the Middle Letaba Dam in the Luvuvhu-Letaba WMA (Chapter 5). Inappropriate water management decisions were made and these did not improve the effectiveness of the water sector.

(c) Poor resource knowledge of water managers

Water managers lacked knowledge of the water resources in their areas (Chapter 6). They did not know all the major rivers and dams from which water is supplied in their areas. Instead of understanding the entire value chain of the water resource, the managers only had a fair understanding of the consumption of the resource and would therefore not make comprehensive decisions on management of the resource.

(d) Lack of stakeholder participation

In a survey of the perceptions of rural municipal water managers on stakeholder participation on water issues in the area under study, it was shown that the involvement of stakeholders in decision making for water issues is very poor. Government based stakeholders were more influential in water issues than their counterparts from communities (Chapter 7).

(e) Poor resource allocations to rural communities

A study of water supplies and uses by rural households in the province revealed that the supplies were very low. As found in Chapter 7, more households in the study area reserved water for only basic activities of drinking by people (95.9% of households), preparing food (95.4%), bathing (92.8%) and laundry (90.8%) compared to those who used the resource for productive activities of washing car (6.6%), irrigating crops (5.7%) and livestock drinking (3.5%) due to scarcity of supply. Water supply to urban centres is generally higher. Inequitable allocations were also recorded across different use sectors.

9.4.3 Organisational strategies and their congruence with water sector challenges

Strategy entails the whole set of decisions that are made about how a water service organisation will configure its resources taking into consideration the demands, constraints, and opportunities of the environment within the context of its history. The strategy refers to the issue of matching the service organisation's resources to sector inputs, or making a fundamental decision of the business the organisation is in (Nadler and Tushman, 1980) and should address the needs of the clients.

The DWA and the three WSAs of MDM, VDM and PLM presented the strategies in their planning documents that sought to address the needs of the water sector through responding to the major challenges presented by the stakeholders. The extent to which the strategies were relevant to solving the sector challenges is illustrated by the analysis of congruence between these two factors (Table 9.3).

There was a high degree of congruence (rating=3) between the challenge of water resource scarcity and inadequate storage and the responsive strategies of each of the water service organisations. The DWA and MDM reported in their strategies the need for resource conservation, the VDM mentioned resource protection while PLM identified the use of rainwater harvesting to reduce resource scarcity. The DWA reported the establishment of an infrastructure agency to manage infrastructure development and this includes storage infrastructure. Although MDM and PLM reported the building of dams, this is the mandate of DWA (DWAF, 2004a) and the WSAs' involvement is mainly in community mobilization. The infrastructure construction by VDM included community participation in development of storage facilities.

The MDM and VDM are largely located in the Luvuvhu-Letaba WMA where available storage capacity constitutes 64.2% of mean annual runoff (Section 4.3.1(b)). The decision to develop additional storage in this area should consider the availability of water for further impoundment without contravening international agreements with neighbouring Mozambique located downstream of the rivers flowing through this WMA. As revealed in Section 4.3.1(b), the available storage capacity of the Limpopo WMA where the PLM is located is only 33% of mean annual runoff which suggests a higher potential for development of additional storage capacity.

As for the challenge of dams not filling up, the strategies of DWA, MDM and PLM were to conduct research and to properly manage information and were highly congruent (3) with the challenge. The strategy of VDM was 'proper planning' and was rather broad and was not specific to the challenge and hence the congruence was low (1), resulting in a mean congruence rating for this challenge to be between moderate and high (2.5).

Table 9.3 Congruence rating between water sector challenges and responsive organisational strategies of Limpopo Regional Office of DWA and the WSAs of MDM, VDM and PLM

Challenge	Strategy and congruence rating								Mean
	DWA	Rate	MDM	Rate	VDM	Rate	PLM	Rate	
Water resource scarcity & inadequate storage	Conserve water resources; Establish infrastructure agency	3	Conserve water resources; Build dams and raise dam walls	3	Protect resource; Build infrastructure	3	Promote use of rainwater harvesting; Build reservoirs	3	3.00
Some dams do not fill up and water supply remains low	Research by WRC; Water resource plan & information management	3	Research & development; information management	3	Proper planning;	1	Undertake research & development Implement e-governme-nt strategy	3	2.50
Poor resource knowledge of water managers	Establish academy for water sector skills development	3	Capacity building and training	2	Work place skills planning and reporting;	2	Ensure municipality has capable managers	2	2.25
Lack of stakeholder participation	Involve stakeholders throughout	3	Involve stakeholders in IDP and implementation	3	Involve stakeholders in IDP and implementation	3	Municipality to have functional community participation	3	3.00
Poor resource supply to rural households	Promote access to basic water supply by all	3	Water provision made top priority	3	Water provision made top priority	3	Provision of water to those with no access	3	3.00
Mean		**3.00**		**2.80**		**2.40**		**2.80**	**2.75**

Congruence Rating: 0 = None; 1 = Low; 2 = Moderate; 3 = High

For the challenge of poor resource knowledge of water managers, the strategy of DWA of establishing an institution for skills development for water engineering and science was highly congruent (3) with the challenge. Although the strategies recorded by the three WSAs (MDM, VDM, PLM) were about human resource development, they were not specific on water resource issues and hence moderate congruence (2) occurred between each strategy and the challenge resulting in a moderate mean congruence (2.25). The strategies of the four water service organisations were highly congruent (3) with the challenge of lack of stakeholder participation and with that of poor resource supply to rural households.

With DWA being the custodian of water resources (DWAF, 2004a), it would be expected that the department should have a full understanding of the challenges faced by the water sector. It was therefore not surprising that all the strategies of DWA were highly congruent (3) with the corresponding challenges faced by the water sector. This resulted in a high mean congruence (3) for the department, suggesting that it had highly relevant strategies for addressing the water challenges. Although smaller than that of DWA, the mean ratings of strategies of MDM and PLM were each also highly congruent (2.8) with the challenges faced by the water sector while the mean rating of congruence of VDM strategies was moderate (2.4). With the exception of the VDM whose strategies were moderately relevant, the water service organisations had highly relevant strategies to address the challenges of the water sector.

9.4.4 Transformation components and their congruence with strategies

The transformation process in water service organisations entails the use of inputs to produce a set of outputs. Some components influence transformation within water service organisations, and those include: (1) tasks, (2) human and (3) financial resources (Nadler and Tushman, 1980; Gill, 2000; Wyman, 1998; Wyman, 2003). According to Nadler and Tushman (1980), the formulation of strategies should take into account the sector challenges which are in turn informed by the other inputs of environment, resources and history. Analysis of the congruence of transformation components with organisational strategies therefore indirectly addresses the sector challenges.

The importance of congruence between a person as a unit under the transformation component and environment as a unit under input on the effectiveness of a water service organisation cannot be over-emphasized (section 9.2.1). Water service organisations will be more effective when the attributes of a person and those of environment and subsequently the broad components of input and transformation are highly congruent (Ostroff, 1993). The environment and strategy are both units of input in the Congruence Model. A high degree of fit between the strategy and a unit under transformation will promote congruence between the components of input and transformation and hence the effectiveness of water service organisations.

(a) Congruence between strategies and tasks

Although the water service organisations used different statements to reflect their strategies to address the challenges faced by the water sector, the strategies generally captured similar messages. The strategies of the water service organisations may be summarized as: (1) conserve water and develop storage capacity, (2) research and manage information on dam hydrology (3) build managers' knowledge of water resources, (4) promote stakeholder participation, and (5) improve water supply to rural households.

In addition to development of strategies to address water sector challenges, the service organisations also identified specific tasks to be performed to implement the strategies. The success of implementation of the tasks will depend on the degree to which the tasks are aligned to the strategies. The alignment of the tasks with strategies is determined through analysis of congruence between the two components, i.e. tasks and strategies (Table 9.4).

As shown in Table 9.4, the DWA and of PLM recorded tasks of promoting efficient water use to provide for resource conservation while also including tasks of storage development and were highly congruent (rating=3) with the strategy of conserving water and developing storage capacity. The tasks of MDM and VDM only focused on promotion of efficient resource use with no provision for development of storage capacity and were moderately congruent (2) with the strategy.

Table 9.4 Analysis of congruence between strategies and tasks of water service organisations of Limpopo Regional Office of DWA, MDM, VDM and PLM

Strategy	**Task and congruence rating**								**Mean**
	DWA	Rate	**MDM**	Rate	**VDM**	Rate	**PLM**	Rate	
Conserve water and develop storage capacity	Promote efficient use; Increase storage	3	Prioritise domestic use	2	Adopt user pay principle for non-indigents	2	Educate on efficient use; proper pricing;	3	**2.50**
Research and manage information on dam hydrology	Research on water; Manage knowledge on water	3	Manage information effectively; Manage data & keep records	2	Develop credible & reliable geographic information	2	Identify research areas; Use informatio n technology	3	**2.50**
Build managers' knowledge of water resources	Skilling in water engineering & science; Graduate training	3	Ensure skilled & capacitated workforce	1	Develop officials' competence; water and sewerage skilling	3	Introduce planning & technical developme nt program	2	**2.25**
Promote stakeholder participation	Form CMAs and WUAs	3	Form IDP forums and facilitate imbizos	1	Form IDP forums and facilitate imbizos	1	Communit y outreach; Participati on in water issues	3	**2.00**
Improve water supply to rural households	Provide support to districts and municipalitie s	3	Expand reticulation and improve access	3	Improve supply of free basic water, increase use of tankers.	3	Upgrade reticulation & improve access to all; Free basic water	3	**3.00**
Mean		**3.00**		**1.80**		**2.20**		**2.80**	**2.45**

Congruence Rating: 0 = None; 1 = Low; 2 = Moderate; 3 = High

The omission of development of storage capacity by these WSAs was possibly due to the fact that they are located in the Luvuvhu-Letaba WMA with highly developed water resources (Chapter 4). The subsequent mean congruence rating for the tasks planned by the water service organisations and this strategy was moderate to high (2.5).

The tasks of DWA and PLM were highly congruent (3) with the strategy of investigating and managing information on dam hydrology. The tasks of the MDM and VDM only focused on issues of information management with no provision for research and were therefore rated moderately congruent (2) with the strategy. The mean congruence rating for the tasks planned by the water service organisations and this strategy was also moderate to high (2.5).

As for the strategy of building managers' knowledge of water resources, it was the DWA and the VDM that stated specifically issues of water resources in their human resource development interventions and hence their tasks were rated highly congruent (3) with the strategy. The tasks of the PLM highlighted the essence of technical development and were rated moderately congruent (2) with the strategy as they will possibly include water resources. The task pledged by the MDM was too broad with no sense of focus on water resources and was therefore rated lowly congruent (1) with the strategy. The mean congruence rating for the tasks recorded by the water service organisations and the strategy of building managers' knowledge of water resources was therefore moderate (2.25).

The task of DWA of forming CMAs and WUAs and those of PLM of reaching out to communities and promoting active participation in water issues were highly congruent (3) with the strategy of promoting stakeholder participation. The MDM and VDM pledged to form IDP forums and facilitate politically driven community gatherings and these are often too broad to give the water sector fair attention. The tasks of these WSAs were general and not focused on water and so were given low congruence (1) with the strategy. A moderate mean congruence (2) rating was recorded for the tasks planned by the service organisations and this strategy. The tasks of the four water service organisations were highly congruent (3) with the strategy of improving water supply to rural households. Although the tasks were different, they complemented each other.

The mean rating of congruence between the tasks recorded by water service organisations and the strategies for addressing water sector challenges was high for DWA (3.00) and for PLM (2.80). The mean rating was moderate for MDM (1.80) and VDM (2.20). The high congruence rating for DWA could be due to the fact that the department has water resource management as its only mandate while the high rating for PLM could have resulted from the WSA being relatively more urbanized and with financially sound basis. In addition to water services, the MDM and VDM have a lot of other functions to take care of and are relatively more rural with limited financial and personnel resources. The role of DWA of supporting the municipalities is therefore critical for these WSAs to successfully manage the challenges faced by the water sector in the Limpopo Province.

9.4.5 Congruence between allocated and utilized organisational resources

According to Nadler and Tushman (1980), human and financial resources are very important for water service organisations to implement their strategies. The allocation and utilisation of these resources according to the five water service strategies was only available for DWA and not for the three WSAs. The WSAs neither included resource allocation nor used information according to water service strategies in their integrated development plans for the period under investigation (2010).

With regards to human resources, the allocations and utilisation for the three WSAs was done according to departments such as (1) Corporate Services, (2) Financial Management, (3) Development Planning, (4) Technical Services and (5) Community Services without revealing the resources specifically for water services. With financial resources, however, the WSAs reported allocations and utilisations for water services separately, but without apportioning the resource to the five strategies addressing the water sector challenges.

As shown in Table 9.5, the analysis of the allocation and utilisation of human resources by DWA revealed a low degree of congruence (1). Only 64.9% of the 37 posts allocated were filled (2009), suggesting a probability that the water service organisation would under-perform as a result of 35.1% of the posts being vacant. The analysis of the allocation and utilisation of financial resources revealed that the department over-spent its R143 million budget for water issues by 39.9% and this resulted in a negative and low degree of congruence (-1) between the allocation and the expenditure.

Table 9.5 Analysis of congruence between allocation and utilisation of human (posts) and financial (budget) resources of water service organisations of Limpopo DWA, MDM, VDM and PLM (DWAF, undated; MDM, 2009; VDM, 2009 and PLM, 2009)

Water service organisation	Human resource				Financial resource			
	Allocation	Use	% Use	Rate	Allocation	Use	% Use	Rate
DWA	37	24	64.90	1	142 963 037	200 012 993	139.90	-1
MDM	283	133	47.00	1	323 470 851	323 470 851	100.00	3
VDM	314	263	83.80	2	270 750 271	213 892 714	79.00	2
PLM	1 796	1 463	81.50	2	116 276 917	163 593 034	140.70	-1
Total	**2 430**	**1 883**	**77.49**	**1.50**	**853 461 076**	**900 969 592**	**105.57**	**-1.75**

Congruence Rating: **0** = None, ≥ 67% gap from 100%; **1** = Low, 66 – 33% gap from 100%
2 = Moderate, 33 – 10% gap from 100%; **3** = High, < 10% gap from 100%
+ = Allocation ≥ utilisation; - = Allocation < utilisation

With some posts not filled, the department still exceeded the planned financial spending for water services, suggesting that the available personnel had a high spending capacity in order to surpass the budgeted financial resources. The high capacity to spend with only 65% of the posts filled could be a result of some functions being outsourced. It would therefore be advised that the department fills the vacant posts, especially if there are functions that they are not doing themselves due to under-staffing. With the plan of decentralising some functions (DWAF, 2004a), it may be necessary to conducts an organisational restructuring to review the number and levels of posts linked to the water services function.

As for the MDM, the human resource allocation was 283 posts of which only 133 (47%) were filled and hence the degree of congruence between the allocation and the use was low (1). With this low (47%) post filling rate, the WSA spent all (100%) of its allocated water budget of R323 million revealing the degree of congruence between the budget allocation and its spending to be high (3). As was the case with DWA, the congruence analysis for MDM suggests that the WSA could be outsourcing some of its functions for them to spend the entire budget with only 47% of the posts filled.

The VDM had a human resource allocation of 314 posts of which 263 (83.8%) were filled, suggesting a moderate degree of congruence (2) between the allocation and the filling of the posts. With more posts filled and lower budget allocated compared to the MDM, the VDM only spent 79% of its budget allocation of R270 million, resulting in a moderate congruence (2) between the budget allocation and its spending. The result of the congruence analysis of the VDM reveals that non-filling of some posts leads to poor spending and subsequently poor performance. The VDM probably relied on their staff for job performance and did not outsource, hence the underperformance when some posts are vacant.

The human resource allocation of 1 796 posts for PLM far exceeds those of the other WSAs of MDM and VDM. This large number of posts for PLM includes those allocated for non- and semi-skilled jobs such as gardening and cleaning while those of the other WSAs are only for high skills jobs. Of the allocated posts in the PLM, 81.5% are filled and this translates to a moderate level of congruence (2) between the allocation and the filling. The WSA over-spent its water services budget of R116 million by 40.7% and this resulted in a negative low degree of congruence (-1). With this very large staff complement, the over-spending of the budget is not surprising as part of it could have been consumed by personnel related activities. With the allocation seeming too large, it would be advised that this WSA undergoes an organisational restructuring to review the number and level of posts necessary for the municipality to operate smoothly.

As shown in Table 9.5, a total of 2 430 posts were allocated among the four water service organisations and 77.49% of them were filled. The mean congruence rating was low to moderate for human resource allocation and use (1.50) and moderate for financial resource allocation and use (-1.75) and therefore the non-filling of posts (human resource) was the most significant constraint to organisational effectiveness.

9.4.6 Congruence flow analysis

The purpose of congruence flow analysis was to assess the variation in levels of congruence along the input and transformation components. High levels of congruence along the input and transformation components of a service organisation imply better capacity for the organisation to successfully execute strategies to address water challenges. Various levels of congruence were noted between input and transformation components of the service organisations (Table 9.6).

Table 9.6 Congruence flow analysis of input and transformation components of four water service organisations: DWA, MDM, VDM and PLM

Component of capacity	**Water service organisations and congruence ratings of components**				**Component mean**
	DWA	**MDM**	**VDM**	**PLM**	
Strategy	3.0	2.8	2.4	2.8	**2.75**
Task	3.0	1.8	2.2	2.8	**2.45**
Human resource	1.0	1.0	2.0	2.0	**1.50**
Financial resource	-1.0	3.0	2.0	-1.0	**-1.75**
WSA mean	**2.0**	**2.15**	**2.15**	**2.15**	

Congruence Rating: 0 = None; 1 = Low; 2 = Moderate; 3 = High

The congruence for DWA was high for strategy (3) and for tasks (3) and was low for both human (1) and financial (-1) resources (Table 9.6) and hence the last two components were the most significant constraints to successful implementation of water programmes by DWA. For MDM, the congruence was high (2.8) for strategy and financial resource management (3), moderate (1.8) for task and low (1) for human resources, implying that the human resource provision was the largest constraint to successful implementation of water programs. Similarly, the largest constraints to successful implementation of water programmes were human and financial resources for VDM and were financial resource for PLM.

With DWA being the custodian of water resources (RSA, 1998a; DWAF, 2004a), it would be expected for the Department to have appropriate allocation and utilisation of the human and financial resources and subsequently a high degree of fit between the supply and use of these resources. The resources in the department are units within the transformation component of the

Congruence Model and the lack of congruence between their provision and use reduces the effectiveness of the Department in rendering its functions (Wyman, 1998; Bezboruah, 2008). Similarly, the components with low congruence in the WSAs need attention; else they render these service organisations less effective.

Considering the different components defining the capacity of service organisations, congruence was high (2.75) for strategy, moderate for task (2.45) and financial resources (-1.75) and low (1.50) for human resources. According to these results, the human resources were the most significant constraint to successful implementation of water programmes. Moderate congruence was recorded for all the four water service organisations of DWA (2), MDM (2.15), VDM (2.15) and PLM (2.15). With DWA being the custodian of water resources in South Africa, it would be expected for the department to have shown a higher degree of congruence to indicate higher capacity for addressing water sector challenges.

As revealed in Table 9.6, the congruence rating for all the water service organisations investigated was only moderate, suggesting that the organisations have moderate capacity to address water sector challenges. The study area is water scarce (DWAF, 2003; DWAF, 2004b) and subsequently community access to water is limited (Stats SA, 2009; Manase *et al,* 2009). The water economy in South Africa is characterized by high demand for the resource due to intensive competition among users (Randall, 1981; Backeberg and Groenewald, 1991) which exacerbate the scarcity of the water resource. It is important that the capacity of the service organisations be improved for these organisations to adequately address sector challenges. The strategies for improving the capacity of the water service organisations constitute a proposal of a water management decision model for the study area.

9.4.7 Proposal of a water management decision model

In accordance with the results of congruence analysis, an appropriate water management decision model for Limpopo Province should address the following issues:

(a) Strategy

Although there was an overall high degree of congruence (2.75) between strategies and challenges, some issues require attention, e.g. (i) VDM should develop focused strategies involving research and information management to address the challenge of dams not filling up; (ii) MDM, VDM and PLM should have in place human resource development strategies that are specific to water resources.

(b) Tasks

There was overall a moderate degree of congruence (2.45) between tasks and strategies and: (i) MDM and VDM should develop specific tasks on research aspects of dam hydrology (in addition to information management) and promote stakeholder participation on water issues; (ii) As was the case with strategies, MDM and PLM should implement human resource development tasks that are specifically focussed on water resources.

(c) Human resources

There was overall a low degree of congruence (1.50) between human resource (post) allocation and their utilisation (filling), and: (i) All the water service organisations had vacant posts which should be filled. The DWA should review its post allocation as part of its restructuring where some functions will be decentralised while the PLM should do the same check if the large number of posts is indeed needed. (ii) In addition to allocation according to departments within WSAs, human resources should also be allocated according to types of services to be executed such as water and electricity and according to major strategies within each type of service.

(d) Financial resources

The degree of congruence between the allocation and spending of financial resources was poor (-1.75) in overall. The service organisations except MDM should allocate financial resources according to needs and informed by the capacity to spend, more so for DWA and PLM. In addition to service areas such as water and electricity, the three WSAs should also reveal the allocation of funds according to strategies (activities) within a service.

In accordance with the above proposals based on the congruence analysis, a water management decision model as shown in Figure 9.3 is proposed for Limpopo Province.

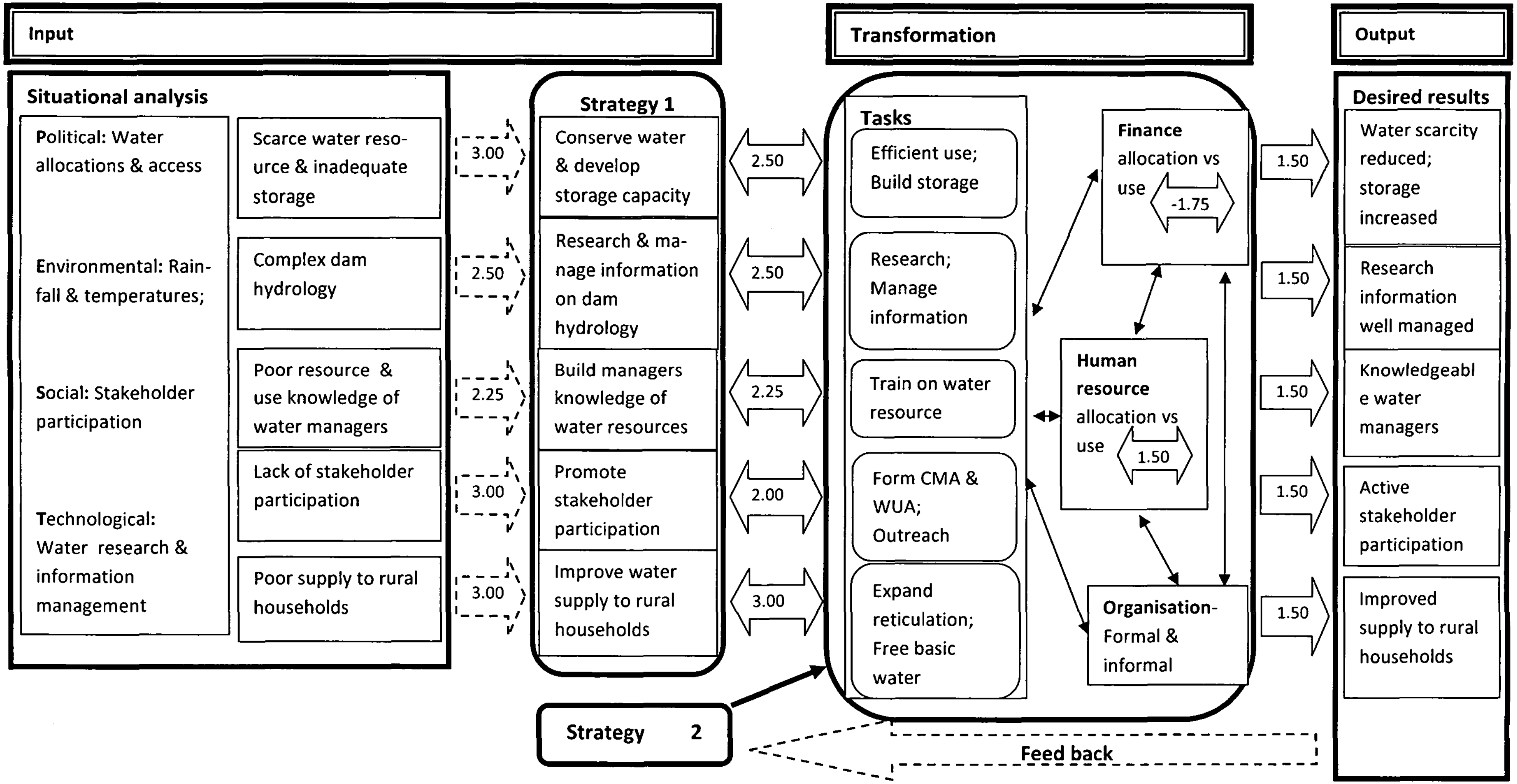


Figure 9.3 Capacity assessment of water service organisations of Limpopo Province using the adjusted Congruence Model

(e) Model discussion

The degree of congruence was mostly high between challenges and strategies, moderate to high between strategies and tasks (which are important part of transformation) and low to moderate between transformation and output (Figure 9.3). Results for challenge-strategy assessment show a high degree of congruence (rating=3) between the challenge of scarce water resource and the strategies presented by service organisations to address the challenge. This suggests that accurate situational analysis was conducted and correct information obtained about the problem, hence an appropriate strategy.

The degree of congruence between the strategy and the tasks (transformation) was moderate to high (2.50), indicating a reduced congruence compared to that between the strategy and the water challenge. The appropriate strategic plan was therefore not translated to fully relevant tasks and hence the reduction in congruence. The cause of the strategic plan not being highly congruent with the implementation tasks could be planners not adequately informing implementers about the plan. Without adequate understanding, the implementers could have misinterpreted portions of the strategy and therefore developed some irrelevant tasks. Strategic planning is often done by managers of water service organisations while implementation is done by field staff.

As revealed under transformation, the implementation of tasks was influenced by their interaction with human resources, financial resources and organisational systems. A low to moderate congruence (1.50) was noted between allocation and use of human resources due to some allocated posts remaining unfilled. A moderate congruence (-1.75) was registered between the allocation and use of financial resources and this mostly resulted from overspending (Section 9.4.2(b), Table 9.5).

The existence of vacant posts suggests that the human resource was limiting to the implementation of the tasks while the overspending suggests that the allocation of financial resources was also limiting. As revealed by the congruence ratings, the human resource was the most significant constraint to the implementation of tasks and was therefore adopted as the congruence rating between transformation and output.

The organisational system influences the implementation of tasks by defining organisational values which control the work environment of a water service organisation. Organisations are more effective in implementing tasks where a high level of congruence occurs between preferences of human resources and organisational values (Boxx *et al.*, 1991; Chatman, 1989, 1991; Judge and Bretz, 1992; O'Reilly *et al.*, 1991). As stated by Balkin and Schjoedt (2012), organisational values include such aspects as culture which informs people about the appropriate way things are done in the organisation. Some organisational cultures are rigid and do not provide for employees to make independent decisions while others are flexible and allows the employees to make decisions.

As shown in Figure 9.3, moderate to high degree of congruence (2.50) occurred between the challenge of dams not filling up and strategy and between the strategy and tasks. The situational analysis by water service organisations was probably not fully accurate in defining the challenge and hence the congruence between the challenge and the strategy could not be high. With the congruence between challenge and strategy being only moderate to high, the congruence between strategy and tasks was also only moderate to high.

The interactions among human resource, financial resource and organisational systems and the subsequent influence on task implementation were similar to those for the challenge of scarce water resource and inadequate storage. A similar degree of congruence was therefore recorded between the transformation and output for the challenge of dams not filling up. Related results were obtained for the challenge of poor resource and use knowledge where the congruence rating between the challenge and strategy and between the strategy and tasks was 2.25.

Related to the situation with the challenge of scarce water resource and inadequate storage, the degree of congruence between the challenge of lack of stakeholder participation and strategy was high (3.00) while that between strategy and tasks was moderate (2.00). As for the challenge of poor supply to rural households, the degree of congruence was high (3.00) between the challenge and the strategy and between the strategy and the tasks. The congruence between transformation and output was low to moderate (1.50) for all the challenges. The output generates a feedback which is used by planners to formulate revised strategies (Strategy 2) and these are implemented through the next cycle of transformation.

While finance is often cited as the most limiting factor for water service delivery, the results revealed that the human resource is in fact the most limiting factor. The posts that are vacant are likely those requiring people with scarce skills such as engineering and hydrology. With the scarce supply of such skills, it would be necessary for relevant learning institutions to be supported to train in those skills areas. Without such interventions, the water service organisations will continue to affirm that they have service delivery plans while the public will remain impatiently waiting for such services.

9.5 Summary and conclusion

The results of the congruence analysis revealed the service organisations to have achieved overall ratings of 2.00 for DWA, 2.15 for MDM, 2.15 for VDM and 2.15 for PLM, implying a moderate ability of all organisations to address the water sector challenges. The overall degree of congruence was high (2.75) between strategies and challenges, moderate between tasks and strategies (2.45) and between allocation and use of financial resources (-1.75) and low between allocation and use of human resources (1.50).

Although the service organisations mentioned the challenges faced by the water sector and presented strategies and tasks to address them, it was noted that some strategies and tasks were either not focused or did not address the challenge in its entirety. The service organisations seemed to experience major challenges with resource allocations and their subsequent utilisations. Although posts were created by the water service organisations, they were mostly not all filled and that resulted in the low level of congruence (1.50) between the allocation and the use of the posts. The under-filling of posts was the most significant constraint to the performance of water service organisations. The proposed water management decision model takes into account the major challenges experienced by the sector, the relevant strategies and tasks to address them as well as the proper allocation and use of resources to execute the strategies and tasks.

CHAPTER 10

10 POLICY RECOMMENDATIONS

10.1 Focus of the study

The investigation was on the water situation of the Limpopo Province with a focus on:

(a) Water resources, mainly runoff and storage capacity of the target Water Management Areas and municipalities, and the water gain and loss factors of the Middle Letaba Dam;

(b) Water management, mainly perceptions of municipal water managers on the water resource and its uses, and their perceptions on stakeholder participation; and

(c) Household water supply and requirement.

10.2 Main findings

10.2.1 Water resources

The Limpopo WMA has a MAR of 611.4 million m^3 for possible development of new dams compared to only 365.2 million m^3 for the Luvuvhu-Letaba WMA with similar results for municipal implementation of strategic water related projects.

Storage volume for the Middle Letaba Dam increased with rainfall with a time lag of two months from peak rainfall to maximum storage volume. The dam storage volumes were very small compared to design capacity, affirming that the dam could not be filled from only rainfall, but will need to be filled through transfers from other catchments.

10.2.2 Water management

The municipal water managers lacked knowledge on water resources and were relatively more knowledgeable on water use. In order to make appropriate water management decisions, the water managers should be equipped with required knowledge.

Water management decisions were made by government based stakeholders, mainly of Department of Water Affairs, Limpopo Department of Agriculture, District Municipalities and Local Municipalities. Community based stakeholders such as Water Users Associations and Community Based organisations did not influence water management decisions.

10.2.3 Household water supply and requirement

There was a lack of access to safe water sources with only half (50.1%) of households obtaining water from street taps. The quantity of water fetched ranged from approximately 25 to more than 200 litres per household per day, and the amount fetched increased with a decrease of distance of the water source from the residential site. As a result of scarcity, water was mostly used for basic activities such as drinking, preparing food and bathing. Half (51.7%) of the households fetched less water than the 25 litres per capita per day supply standard. The 25 litres per capita per day did not meet the average requirement of 37.5 litres per capita per day.

10.3 Policy recommendations

10.3.1 Water resources

(a) Catchment runoff and storage capacity

Catchment runoff and available dam storage capacity are important indicators for decision making on whether additional storage should be built or not. The occurrence of runoff in excess of the available dam storage suggests availability of additional water for development of more storage capacity. The occurrence of runoff in excess of the available dam storage also presents an opportunity for community based projects to be initiated at a municipal level, and these include rainwater harvesting for households, agriculture and for industrial uses of water.

Based on the results of the analysis of runoff and storage capacity, it is recommended that the Limpopo WMA be the focus for possible construction of new dams. The Mogalakwena, Lephalale and Mokolo catchments were shown to have more available mean annual runoff for possible development of new dams. Although the Luvuvhu-Letaba WMA was shown to be well developed in terms of storage dams, the Mutale Catchment had more available mean annual runoff for possible development of new dams.

It is also recommended that regular investigations be conducted of runoff and available dam storage capacity. Such investigations are necessary as the phenomenon of climate change is negatively influencing the rainfall and temperature regimes such that the results of previous audits may not always be relevant. The occurrence of dam silting reduces the storage capacity of existing dams, making it indeed necessary for regular audits to be conducted. Decisions to build new dams or to initiate new water related projects should be based on credible results of new runoff and dam storage capacity audits.

(b) Dam not filling up except during floods

Time lags were recorded from the occurrence of rainfall on the Middle Letaba Dam to the increase of inflow from the source river (1 month) and the increase of dam storage volume (2 months). The increase of dam storage volume inform the operation rules of the dam and therefore it is recommended that investigations be conducted on the extent of the time lag in other reservoirs and the possible causes of such lags.

The dam storage volume of the Middle Letaba Dam was very low compared to the design capacity. It is therefore recommended that water be transferred to the dam from other catchments in order to maintain this dam at a full level and consequently to improve the supply of the resource to planned areas. Initiatives of transferring water from the Nandoni Dam in the Luvuvhu Catchment are in order.

10.3.2 Water management

(a) Municipal water managers' knowledge of the resource and its uses

Appropriate water resource planning and use requires that relevant decision makers have adequate knowledge of the water resource and its current uses. From the results of the study it was shown that the municipal water managers are important decision makers and had little knowledge about the water resources and their consumptions.

In order to address the municipal water managers' relative lack of knowledge of water resources and uses, it is recommended that appropriate training be implemented. The training should build adequate knowledge capacity of the water managers for them to make correct decisions on the management and use of the resource.

(b) Stakeholder participation in water decision making

Water decision makers should have the participation of all relevant stakeholders in order to make appropriate water resource management decisions that are acceptable to the broader community. The study revealed that government based stakeholders were perceived to be more reliable sources of water information than their community based counterparts of Water Users Associations and Community Based Organisations. The government based stakeholders were resultantly more influential in water sector decision making than the community based stakeholders who had very little if any influence at all.

It is therefore recommended that community based stakeholders be empowered to be reliable sources of water information for them to subsequently have some influence in the sector decision making. Empowerment of community based stakeholders could be achieved through involving them more in meetings where decisions about water resource planning and uses are made and through improving their access to important information about the sector.

10.3.3 Household water supply and requirement

The amount of water supply has a strong influence on living conditions among rural households where more supply results in improved living conditions. The rural households in the study area have scarce supply water. Half of the households actually fetched less than the 25 litres per capita per day supply standard. Analysis of water requirement revealed the average demand in the study area to be 37.5 litres per capita per day and therefore the households that fetched less water than the supply standard had much less resource than the actual demand. The households therefore resorted to mostly using the water for basic activities of drinking, preparing food and bathing with less resource being used for productive activities of washing cars and crop watering.

It is therefore recommended that the Department of Water Affairs reconsider the 25 litres per capita per day as a supply standard as it does not suffice for the average requirement of 37.5 litres per capita per day proposed in this study. Also, programmes for increasing the supply of water to rural households should be strengthened to be more effective.

10.3.4 Water management decision model

Implementation of the policy recommendations made in items 10.3.1-10.3.3 require appropriate actions by relevant water service organisations, namely: Department of Water Affairs and Water Services Authorities such as Mopani District Municipality, Vhembe District Municipality and the Polokwane Local Municipality. The appropriate actions by these water service organisations include understanding the challenges faced by the water sector and developing relevant strategies and tasks to address them. Development of appropriate strategies and tasks should be followed by correct allocation and use of resources, both human and financial resources.

The study revealed that some strategies and tasks developed by the water service organisations were either not sufficiently focused or did not adequately address the challenge. Also, the service organisations had shortcomings with the allocation and use of their human and financial resources. The human resources were not sufficiently provided for as there were posts that were not filled, hence the allocation (posts) and use (filling) of human resources recorded the lowest degree of congruence. Human resources and not financial resources were the most significant constraint to the performance of water service organisations. Improved performance by the service organisations requires the vacant posts to be filled by adequately qualified and competent personnel.

The other pairs of components with low congruence ratings should be attended for the water service organisations to be effective in rendering quality water services. Initiatives for improving the performance of water service organisations should be guided by the proposed congruence based model for water management decision making (Figure 9.3) and should be aimed at increasing the congruence between (1) Challenges and strategies (Table 9.3); (2) strategies and tasks (Table 9.4); and (3) allocated and utilised organisational resources (Table 9.5).

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