MONASH University

The Diffusion of Phytotechnological Floating Treatment Wetland Technology in Integrated Watershed Management in the City of Johannesburg, South Africa

Yolandi Schoeman

National Diploma Nature Conservation (TUT)
BTech Nature Conservation (TUT)
Masters in Environmental Management (UFS)

A thesis submitted for the degree of *Master of Philosophy* at
Monash University in 2017
Water Node
School of Social Science

Copyright notice

Abstract

The biggest threat to the sustainable supply of water in South Africa is not the lack of water storage facilities, but the contamination of available water resources through pollution. The development of new technologies that address problems with anthropogenic origins will therefore play a major role in securing a sustainable future and addressing problems regarding water supply, such as water quality. These technologies, also termed eco-innovations or green infrastructure, diffuse slowly into society. Understanding this process of the diffusion of green infrastructure is crucial, as it is usually slow and its path unclear. Indeed, green infrastructure such as floating treatment wetlands require a long time frame to be adopted, as is the case with the adoption of Sustainable Urban Drainage Systems (SuDS) by the Department of Water and Sanitation. Although the SuDS approach has been widely adopted internationally, there is still some resistance experienced in South Africa to its implementation and use. However, little is known about the importance of the various factors that affect the acceptance and use (diffusion) of eco-innovations in society and in particularly floating treatment wetland technology.

Given these current challenges, this research will contribute towards understanding the process of diffusion and the components of sustainability that are associated with the development and introduction of green infrastructure, especially those pertaining to constructed wetland technology such as floating treatment wetland technology. As yet, the sustainability components of introducing and sustaining new technologies or innovations are not well documented, especially for floating treatment wetland technology as a tool in sustainable urban drainage systems and integrated watershed management. This research will therefore provide new insights regarding the above as a tool in SuDS and integrated watershed management. The expected contribution of this study will be a better understanding of the diffusion process and the sustainability components of floating treatment wetland technology (from the perspective of government, business, non-governmental organizations and communities) in the City of Johannesburg, South Africa

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signature:[redacted]

Print Name: Yolandi Schoeman

Date: 07 March 2017

Acknowledgements

I have made use of the services of a professional editor, Kelly Gilbertson that edited the thesis regarding spelling and grammar.

I would like to express my sincere gratitude and appreciation to my main supervisor, Associate Professor Bimo Nkhata, and to my co-supervisor, Dr Wietsche Roets, for their patience, assistance and guidance throughout my studies and thesis writing.

I also thank Linda Downsborough for her continued assistance and guidance throughout my studies at Monash South Africa.

I am grateful to the Water Research Node for partly funding and taking a special interest in my studies, as well as giving me the incredible opportunity to attend the Lloyds Register Foundation Conference in London during October 2016, which further inspired me in the field of ecological engineering and water security.

I would also like to extend a word of thanks to the University of Johannesburg, which, through the Green City Startup Competition, provided me with grants to deploy various floating treatment wetlands across the City of Johannesburg. Thank you also to Hydromulch, which partly funded greenhouse trials on plants used in floating treatment wetlands. Further, I would like to thank the Resolution Circle, Endangered Wildlife Trust, Greenhouse Trial and Research Centre, Silverlakes Golf Estate, City of Johannesburg and City Parks for their contribution and assistance on the floating treatment wetlands project. Thank you to the Global Cleantech Innovation Programme and also to the United Nations Industrial Development Organization for the opportunity to compete in the Global Cleantech Innovations Programme competition in San Francisco during February 2017.

Thank you also to all the participants who participated in the workshops, interviews and forum sessions on floating treatment wetlands.

I am also grateful to Etienne Schoeman and my family who have provided me with immense support throughout my studies.

Finally, this thesis is dedicated to my father, who has been, and will always be, an inspiration to me.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

1.1. Background and rationale for study

Even though South Africa has been richly endowed with an enormous range of natural resources, freshwater has been identified as a scarce resource in the country (Heathcote, 2009). There are continuous efforts being made to meet growing demands for fuel, fibre, food and drinking water, owing to projected population increases coupled with continued consequences of past political inequities (CSIR, 2010). The exponentially growing demands place exacerbated pressure on both South Africa's limited water resources as well as on institutions responsible for water management in South Africa (CSIR, 2010). Thus, developing solutions to enhance water quality, whilst simultaneously promoting ecosystem services that are cost effective, sustainable and promote community sustainability, is an integral part of the researcher's interest. This study specifically focuses on the diffusion of phytotechnological floating treatment wetland technology in integrated watershed management in South Africa.

Water is not only important for power generation, industry, tourism and mining (CSIR, 2010), but is also crucial for drinking, health, agriculture and sanitation (CSIR, 2010). In addition, South Africa's geographical circumstances, socioeconomic trends and political imperatives have implications on the future water security of the country and also for its neighbours (CSIR, 2010). The National Water Policy (1997) and the National Water Act (1998) have been founded on Government's vision of a transformed society, in which every person has the opportunity to lead a dignified and healthy life and participate in productive economic activity (DWAF, 2004; CSIR, 2010). Importantly, the South African government's national vision emphasises that water is central to social and economic development as well as to human dignity and health (DWAF, 2004; CSIR, 2010).

However, CSIR (2010) has emphasized that the contamination of available water resources through pollution is the biggest threat to sustainable water supply. For instance, anthropogenic effects resulting from the expanding human population in South Africa include the introduction of chemical and critical nutrients, which elevate concentrations of nitrogen and phosphorus in water bodies, consequently contributing to poor water quality (CSIR, 2010). These chemical and critical nutrients originate from sources such as municipal sewage, industrial and mining activities, livestock waste and crop fertilisers (CSIR, 2010). According to the Department of Environmental Affairs, in the next 10 years, South Africa will need R570 billion of investment to ensure the sustainability of the water value chain (Mail and Guardian, 2012).

Stewart *et al* (2008) identify two possible solutions that can be applied to address the metal and nutrient enrichment of water bodies (lakes, rivers and pools). These solutions are 1) preventing enrichment through a fundamental change in lifestyle and a "business-as-usual" approach, and 2) using water treatment to remove existing and potential contamination, including excess nutrients. A component of this study is concerned with the use of natural agents for the removal or degradation of pollutants, a technique that is known as bioremediation. This study places particular emphasis on the use of phytotechnology, which, according to Rock (2000), ITRC (2009) and Kennen and Kirkwood (2015), is the use of vegetation or plant biomass to prevent, contain or remediate contaminants in groundwater, soils, sediments, and/or to add nutrients, porosity and organic matter. Phytotechnology also includes a set of design, planning and engineering tools (including cultural practices) that can assist a variety of professionals (such as site designers, landscape architects and environmental planners) working on site contamination challenges on current and future individual sites, the urban setting and regional landscapes (Rock, 2000; ITRC, 2009; Kennen and Kirkwood, 2015).

Stewart *et al* (2008) recognize constructed wetlands treatment systems as being effective mechanisms for water treatment, noting that they are applied to a variety of environmental challenges. Fountoulakis *et al* (2009) and Saeed (2014) write that these constructed wetland treatment systems are technologies that are low-cost and "green". They also note that these technologies are dependent on a network connecting biomass, media, plants and water, which facilitates the removal of contaminants from wastewater through chemical, biological and physical processes. Armitage (*et al* 2013) identify constructed wetland treatment systems as an alternative approach to traditional storm water drainage practices, stating that these systems attempt to manage surface water drainage systems in an integrated and holistic manner that is aligned with sustainable development ideals.

Floating treatment wetlands are known as a variation of constructed wetland treatment systems (according to Lu *et al*, 2015) that can be applied as a tool in habitat conservation, water treatment and purification, green landscaping and in the prevention of the spread of contamination (Lu *et al*, 2015). This type of technology has been slow to diffuse, a process Rogers (2003) defines diffusion as one "…in which an innovation is communicated through certain channels over time among the members of a social system". Rogers (2003) further explains that diffusion is a distinct type of communication –defined as "…a process in which participants create and share information with one another in order to reach a mutual understanding" (Rogers (2013) – where messages are concerned with new and upcoming ideas. Another important term regarding floating treatment wetlands is sustainability.

The World Commission on Environment and Development (WCED)(1987) states that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In constructing this definition, WCED relied on two key concepts, namely "needs" and "meeting point" (Sianipar *et al*, 2013). "Needs" refers to an overriding priority that must be provided to the poor communities of the world (Sianipar, *et al*, 2013), and "meeting point" is defined as the intersection of the needs of present and future generations through technology and social organization to the ability of the environment to meet such needs (Sianipar *et al*, 2013). Other important aspects that need to be taken into account here are social, environmental and economic values, which together are also referred to as the "triple bottom line". Businesses (which includes community members as a main business party) have evolved and continue to evolve in their understanding of these values so as to address environmental sustainability, economic viability and social responsibility (Jamali, 2006).

In this study, sustainability was addressed through technology. However, such technology, also referred to as eco-innovations or green infrastructure, diffuses slowly into society. Sianipur and Adhiutama (2012) outline three factors that need to be taken into account when deciding upon the most appropriate technology that will facilitate technology acceptance in communities. A major problem regarding the acceptance of such technologies lies in the fact that globally, there is a tendency to see green issues as business discourse (Springett, 2003). Thus, owing to exploitation of businesses towards people and resources (Willers, 1994 and Escobar, 1995), the view of green issues as business discourse (Springett, 2003) has resulted in the failure of such technology to be accepted by these people and communities. To address this preconception, a broader meaning of green has been proposed from an engineering perspective (Sianipar *et al*, 2013). Sianipar *et al* (2013) argue that green is an ultimate goal in environmental challenges and issues and thus needs to be understood through a "technical perspective", rather than that of business. Sianipar *et al* (2013) further emphasise that green can be reached when joint efforts in environmental sustainability are not be based on fiction or slogans, but on technical efforts that are applied to measure environmental impacts through technology and technological assessments.

The purpose of this research study was to investigate the diffusion of using phytotechnological floating treatment wetland technology in South Africa as a tool in water quality enhancement, whilst improving ecosystem services, in the context of integrated watershed management in South Africa.

1.2. Objective and extent of the study

The broad objective of this research was to investigate the diffusion of floating treatment wetland technology in South Africa as a tool in water quality enhancement in the context of integrated watershed management. The acceptance of such systems, their applicability to various water challenges and the sustainable development components of floating treatment wetland technology were investigated by assessing the social, economic and environmental aspects of floating treatment wetland technology.

1.2.1. Specific objectives

The following are the specific objectives of this research:

(a) To identify the factors contributing to the diffusion of floating treatment wetland technology amongst various stakeholders;
(b) To identify the process of diffusion to be followed that will contribute to the widespread acceptance of floating treatment wetland technology as a tool in water quality enhancement; and
(c) To investigate the sustainable development components of floating treatment wetland technology in South Africa by selected and strategic stakeholder groups.

1.3. Aim of the study

1.3.1. Problem statement

According to CSIR (2010), the biggest threat to the sustainable supply of water in South Africa is not the lack of water storage, but the contamination of available water resources through pollution. The development of new technologies that address problems with anthropogenic origins will therefore play a major role in securing a sustainable future (Timma *et al*, 2015) and addressing problems such as water quality. However, such technologies diffuse slowly into society. According to Karakaya *et al* (2014), understanding the process of diffusion is critical, since it is usually slow and its path unclear. Green infrastructure such as floating treatment wetlands therefore require an extensive time frame over which to be adopted, as is the case with the adoption of Sustainable Urban Drainage Systems (SuDS) by the Department of Water and Sanitation.

Given these challenges, this research will contribute to our understanding of the process of diffusion, and the components of sustainability associated with the development and introduction of green infrastructure, especially with regards to constructed wetland technology such as floating treatment wetland technology. The components of introducing and sustaining new technologies or innovations through the process of diffusion are not well documented, especially for floating treatment wetland technology as a tool in SuDS and integrated watershed management. This research will therefore provide new insights in this field. The expected contribution of this study will be an improved understanding of the diffusion process and relevant components of floating treatment wetland technology (from the perspective of government, business, non-governmental organizations and community) in the City of Johannesburg, South Africa. It is also expected to confirm floating treatment wetland technology as a viable phytotechnology that may be utilized as a tool in water quality improvement in South Africa.

1.4. Delimitations of scope of research

The dissertation focuses on:

- The diffusion of floating treatment wetland technology as a tool in water quality enhancement in South Africa through a case study at the Modderfontein Nature Reserve and Rockville, Soweto, both located in Gauteng, City of Johannesburg;
- Sustainability components associated with floating treatment wetland technology;
- Integrated watershed management principles and practices;
- Floating treatment wetland areas in urban regions;
- The integrated water resource management (IWRM): from theory and practice, from policy to outcomes report;
- The use and role of green infrastructure in IWRM.

The dissertation does not investigate the performance of floating treatment wetland technology but in this regard rather relies on earlier research, where the positive performance has been demonstrated by the researcher.

Owing to the occurrence of knowledge transfer, the sample size was kept small to allow for in-depth interviewing and participation.

1.5. Assumptions of the study

The following assumptions were made:

- The researcher would be able to efficiently explain and demonstrate how floating treatment wetland islands work, while identifying the associated sustainability components;
- Participants in the study would provide truthful answers and comments based on their own framework of reference; and
- IWRM: from theory to practice report would provide sufficient information concerning the applicability of integrated water resource management in South Africa.

1.6. Structure of dissertation (overview)

The study used interpretivist/constructivist procedures, where the theoretical lens of diffusion of innovation theory (Craig, 2012) was used as the overarching perspective within the research design, which relied upon qualitative data collection methods. An attempt was made to understand the diffusion of floating treatment wetland technology in an urban setting through (amongst other) a focus group meeting conducted with the environmental group of Modderfontein Nature Reserve, where two floating treatment wetland islands were earlier installed by the researcher. The study concludes by identifying the important components of the diffusion process as well as those of sustainability relevant to floating treatment wetland technology, proposing a model for the development and implementation of floating treatment wetland technology in the City of Johannesburg and in South Africa.

Chapter Two of this dissertation consists of the Literature Review, where integrated water resource management and integrated watershed management is discussed. This chapter refers to existing information and literature on floating treatment wetlands, their application and performance; includes a discussion on sustainability and associated approaches; and incorporates an overview of eco-technology, possible areas of national initiatives into which floating treatment wetlands can be integrated and the factors that influence the introduction of floating treatment wetland islands into communities in order to address specific problems.

Chapter Three discusses the setting of the case study, and includes site characteristics and current environmental challenges with which both Modderfontein Nature Reserve and Rockville, Soweto are faced. This chapter also includes information on the four floating treatment wetland islands installed at the Modderfontein Nature Reserve and Rockville, Soweto in the City of Johannesburg (Gauteng Province), together with a short description of their current performance.

Chapter Four comprises of an explanation of the methodology followed, focusing on sample design, collection and analysis.

Chapter Five is concerned with the results emanating from the data collection process. The results are discussed in accordance with the aims and objectives of the study.

Chapter Six includes the conceptual model developed for the development and introduction of floating treatment wetlands adapted for the South African environment and sustainability requirements in integrated water resource management.

1.7. Overview of methodology

This research process included six phases, each of which is discussed below.

Phase 1:
This phase included experimental research conducted by the researcher for the purpose of understanding the mechanics, operation and performance detail of floating treatment wetlands. The researcher constructed two floating treatment wetlands based on an extensive literature review and introduced them into a protected area in South Africa to monitor their performance. This phase provided invaluable information towards understanding the technical details of floating treatment wetland islands.

Phase 2:
A literature review formed phase 2 of the research process. The purpose of the literature review was to further review floating treatment wetland island research and associated social sustainability factors that influence the adoption of green infrastructure.

Phase 3:
Phase three includes the preparation phase for data collection by means of focus group meetings, interviews and an on-line survey.

Phase 4:
Phase 4 included data collection by means of two focus group meetings.

The participants in two focus group meetings included:

(a) Participants from the Environmental Forum of the Modderfontein Nature Reserve; and
(b) Participants from a wetland workshop, which included environmental professionals.

The focus group meetings began with an introduction to the aim of the focus group meeting and emphasis on voluntary participation. The discussion also included a short introduction on how floating treatment wetland islands function. Media used by the researcher as part of this presentation included videos and a presentation on floating treatment wetlands.

Phase 5:
Interviews were held with business and governmental representatives concerned with water quality.

These interviews aimed at investigating the viewpoint of the participants towards floating treatment wetland islands as a tool in water quality enhancement in South Africa. It was also examined whether there is an absorptive capacity for floating treatment wetlands as a tool in water quality enhancement.

Phase 6:
Phase six included an additional data collection method by means of on-line participation by members of the Southern African Wildlife Management Association, which was also voluntary. The vehicle used for the on-line surveys was “SurveyMonkey”. This phase also included the physical installation of two floating treatment wetland systems in Rockville, Soweto to observe the social acceptance of floating treatment wetlands as a green infrastructure innovation.

Phase 7:
Data collected by means of phases four to six, together with knowledge gained in phases one to three, was utilized to develop a conceptual model.

CHAPTER TWO: LITERATURE REVIEW

2.1. What is Integrated watershed management all about?

Water is possibly our most precious resource (Heathcote, 2009). The functioning of biotic organisms and human systems are driven by the quality and abundance of water (Heathcote, 2009). Water also has broad ecological and social values that form part of accounting (Figure 1) (GreenCape, 2016). Figure 1 describes the extent of water value from the monetary to the societal (WWF and IFC, 2015).

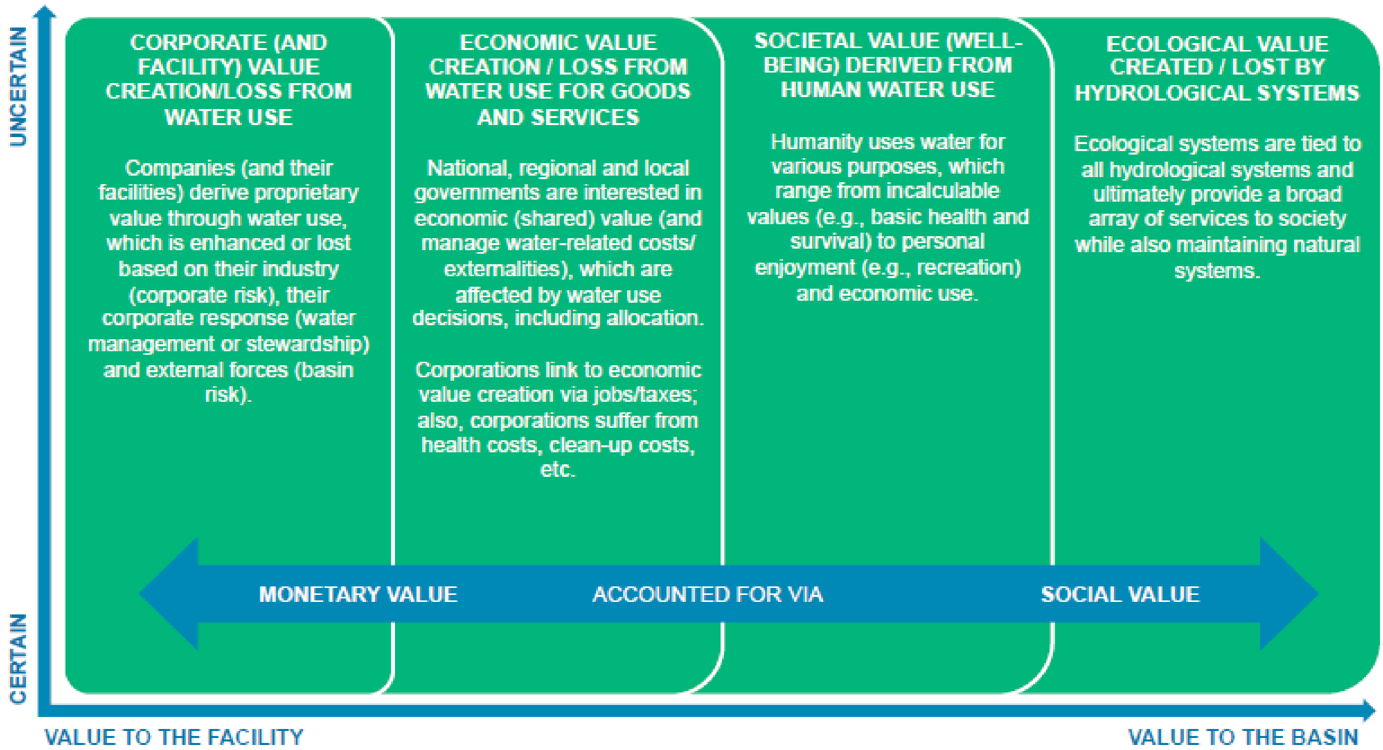

Figure 1: The value of water to an economy, a company, society and nature (WWF and IFC, 2015).

However, serious challenges exist today in the management of water (Viessman, 1990; Heathcote, 2009), as summarized in Table 1 (Viessman, 1990; Heathcote, 2009), given the current situation where "integrated" watershed management is still a relatively new concept (Heathcote, 2009). In some cases, efforts towards effective water management have been unsuccessful because focus has been placed on a single medium (water) rather than on other environmental components such as sediment, air or biological tissue (Heathcote, 2009). In many cases, water management strategies have also failed because they neglected to incorporate the full range of values and perspectives present among water users or agencies with an interest in water management (Heathcote, 2009).

Heathcote (2009) emphasizes that water management can only be considered effective when it allows for an adequate, sustainable supply of water over many years. It must maintain water quality at levels that meet government standards and other societal water quality objectives, and protect key ecological functions. Water management must allow for sustainable economic development over both the short and long term.

Table 1: Current issues facing water managers across the globe (Viessman, 1990; Heathcote, 2009)

Water Management and Institutions	**Water Quality**	**Water Availability, Requirements and Use**
Coordination and consistency	Coastal and ocean water quality	Protection of aquatic and wetland habitat
Capturing a regional perspective	Lake / dam and reservoir protection and restoration	Management of extreme events (droughts, floods, etc.)
The respective roles of federal and state/ provincial agencies	Water quality protection, including effective enforcement of legislation	Excessive extractions from surface and ground waters
The respective roles of projects and programmes	Management of point- and non-point – source pollution	Global climate change
The economic development philosophy that should guide planning	Impacts on land/water/ air relationships	Safe drinking water supply
Financing and cost sharing	Health risks	Waterborne commerce
Information and education		
Appropriate levels of regulation and deregulation		
Water rights and permits		
Infrastructure		

Population growth		
Water resources planning, including: - The watershed considered as an integrated system; - Planning as a foundation for decision making which should not be reactive; - Establishment of dynamic planning processes incorporating periodic review and redirection; - Sustainability of projects beyond construction and early operation; - Allowance for more interactive interface between planners and the public; - Identification of sources of conflict as an integral part of planning; and - Fairness, equity, and reciprocity between affected parties.		

Heathcote (2009) elaborates that most water management practices up to 1970 only sought to solve single and localized problems without considering the associated impacts of such actions on the biophysical, economic and social elements of a larger watershed system. The past 20 years, however, have seen the development of strong global recognition of the fact that the watershed is the best unit for the management of water resources (Heathcote, 2009) (Figure 1). Today, countries situated in every part of the world include water management actions in the context of natural and human systems, integrating watershed and the communities located within them (Heathcote, 2009).

As part of the research undertaken by the researcher, integrated watershed management is used in the context of integrated water resource management purely because of the need for the management of systems, not for the management of system components as identified by Heathcote (2009). The Guide to the National Water Act (DWAF, 2008) also refers to integrated water resource management as a process where environmental, land and water resources need coordinated planning and management. This process takes into consideration water quality, water use, environmental issues, social issues, the amount of available surface and groundwater, and is henceforth referred to as an integrated (meaning "combined") process that aims to ensure equitable, sustainable and efficient water use (DWAF, 2008).

An important component of integrated water resource management is the provision of sufficient information concerning water resources, which is required for informed decision making and proper planning between development planners and water resource managers (DWAF, 2008). Indeed, co-ordination and co-operation between institutions, planners and individuals is necessary where planning takes place that is related to water issues and challenges (DWAF, 2008). The participation of stakeholders in decision making is a critical aspect in integrated water resource management that cannot be overlooked, in particular where decisions are decentralized (DWAF, 2008).

In addition, Lee (1992) argues that the over centralization of water management (as is the case of over centralization of social and economic systems) has failed, and needs to be replaced with locally responsive systems at the watershed level. Heathcote (2009) refers to the watershed as the boundary of a drainage basin, and can also be referred to as being an integrated system (Schramm, 1980). The watershed continues to be viewed as the most appropriate unit for water management (Newson, 1992; Lee 1992; Koudstaal et al, 1992; King et al, 2003; Orr et al, 2007). Koudstaal *et al* (1992) support this idea, stating that there is no singular and clear water management "problem", hence the difficulty experienced in focusing public attention on water related issues and the subsequent need to develop a uniform and centralized water management approach. This widely endorsed perspective clearly supports water management on a watershed scale, not on a national or provincial scale (Heathcote, 2009). Figure 2 below illustrates the interplay of forces affecting integrated watershed management.

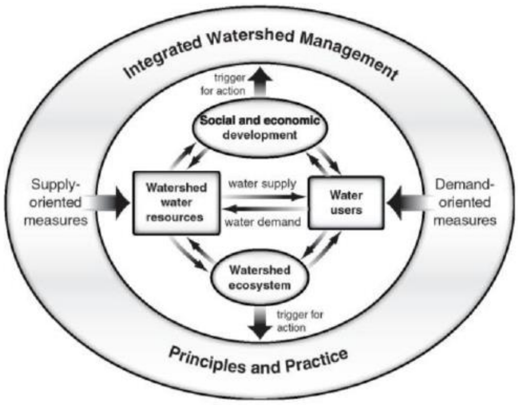

Figure 2: Interplay of forces affecting integrated watershed management (Heathcote, 2009)

2.2. An introduction to water quality

Water is a finite resource, and requires conservation and management (Naidu-Hoffmeester, 2014). However, owing to worsening water quality and quantity, freshwater ecosystems are among the most degraded ecosystems on the planet (UN WWAP, 2009). The coming years will potentially see an increase in freshwater ecosystem deterioration, which will lead to greater species and habitat losses (Revenga *et al*, 2000). Coinciding with irreversible species loss is the reduction of the economic value of services provided by freshwater systems. It becomes impossible to address water quality challenges with the aim of both providing clean water for human uses while also preserving the habitat for aquatic species (UNEP, 2010).

Rivers and streams, lakes and dams, groundwater, coastal zones and vegetated wetlands all form part of the aquatic freshwater infrastructure that provides critical services to the natural environment and its people (UNEP, 2010). As much as two-thirds of terrestrial species use streams, rivers and their associated riparian corridors at some point in their existence (Naiman *et al*, 1993), while, according to UN WWAP (2009), surface waters also generally supply approximately half of the world's drinking water supply and about 20 percent of the world's electricity. Subsequently, with the reliance on flowing water by humanity, anthropogenic activities have contributed to degrading the quality and quantity of streams and rivers globally, leading to a reduction in their ability to provide valued ecosystem services and ultimately driving species to extinction (UNEP, 2010). The following paragraphs will look at the individual effects on the different types of water resources.

Large water impoundments such as lakes provide many valuable ecosystem services: lakes are both sources of water and food, buffer flood flows and support extensive biodiversity (UNEP 2010). Indeed, lakes can have high degrees of biodiversity endemism. Furthermore, lakes support recreation, transportation and other cultural amenities (WLVARC, 2007). Consequently, lakes are vulnerable to a wide range of water quality threats, including increased salinity, temperature changes and unnatural fluctuations, and industrial and agricultural chemical contamination with excessive nutrient loads, which ultimately leads to eutrophication, resulting in algal blooms, oxygen concentration depletion and the occurrence of potential toxic cyanobacteria blooms (UNEP, 2010).

Groundwater is a valuable water provider, also offering surface water recharging services, and plays a vital role in regulating ecosystem services (UNEP, 2010). Although groundwater typically enjoys greater protection by virtue of its location, is not totally immune from pollutants (UNEP, 2010). It can take years for a contaminant plume to pollute a groundwater source because of the slow movement of contaminants and subsurface water (UNEP, 2010). However, once polluted it is difficult and expensive to remediate (UNEP, 1996).

Coastal zones, characterized often with a high concentration of industry and population, are frequently plagued by pollution resulting from industrial waste, dam development, land construction, mangrove conversion, urban waste, coral mining and wetland canalization (UN WWAP, 2009). Pollution in coastal zones can be detrimental to both freshwater and marine habitats (UNEP, 2010).

Several critical ecosystem services are also performed by wetlands. Wetlands are characterized by the presence of specific types of emergent vegetation (including pedology), and may have no open water at all (Mitsch and Gosselink, 2000). Such wetlands involve the transition between terrestrial and aquatic ecosystems (Mitsch and Gosselink, 2000). Several critical ecosystems are provided by wetlands, such as improving and filtering water quality; moderating and attenuating flood water flows, providing a natural replenishing function for underlying groundwater, providing goods and services to communities, supporting extensive biodiversity and recharging underlying aquifers (Mitsch and Gosselink, 2000). However, wetlands are becoming threatened owing to various anthropogenic activities such as wetland draining and dredging, pollution from mining and manufacturing activities, wetland destruction, wetland channeling and wetland modifications (to name but a few).

Maintaining these sources of water is critical. According to the World Health Organization (WHO, 2002), inadequate or unsafe water and lack hygiene and sanitation cause approximately 3.1 percent of all deaths worldwide and 3.7 percent of disability adjusted life years worldwide. In addition, inadequate or unsafe water causes approximately 1.7 million deaths a year (WHO, 2002). The majority of health threats that are posed by poor water quality is the direct result of microbial contaminants and subsequent disease, especially in developing countries (WHO, 2002). The current and historical use of chemicals for agricultural and industrial purposes together with the chemical byproducts of waste management compromise water quality, ultimately leading to other serious health problems for both humans and wildlife around the world (WHO, 2002).

Poor water quality also has an impact on the quantity of water in a number of ways (UNEP, 2010). When water cannot be utilized for bathing, drinking, industry or agriculture effectively because of pollution, the amount of water is reduced that is available in a certain area, hence directly impacting on water quantity (UNEP, 2010). Thus, the more polluted water we have, the more difficult it is to treat the water to useable standards. In turn, there is a reduction in the quantity of clean water (UNEP, 2010).

Apart from the devastating impacts water quality can have on biodiversity and natural ecosystems, vulnerable communities are disproportionately affected by poor water quality (UNEP, 2010). Vulnerable communities include communities living near waterways of compromised qualities that are forced to travel long distances to reach water that is safe, and often suffer the most from diseases caused by polluted and unsafe water (UNEP, 2010). Marginalized communities that often lack political and economic power are also impacted the most by poor water quality (UNEP, 2010), including the poor in developing and developed countries, children and women (UNEP, 2010). Subsequently, the need for adequate water quality to support livelihoods has not been emphasized as much as the need for adequate water quantity (UNEP, 2010). Both water quantity and quality is necessary; however, polluted water can eliminate or reduce the viability of many livelihoods in communities (UNEP, 2010).

Many economic costs are also associated with poor water quality, including health-related costs; impacts on economic activities such as agriculture, tourism and industrial production; degradation of ecosystem services; increased water treatment costs and reduced property values (UNEP, 2010).

2.3. South Africa's water environment

2.3.1. Introduction

South Africa characteristically experiences high temporally and spatially variable rainfall (DWA, 2014). There is also a substantial difference between water demand and availability patterns in South Africa (DWA, 2014), which has resulted in the country being classified as a water-stressed country, with alternating periods of floods and drought accompanied by high evaporation rates (WaterWise, 2016). Moreover, the eastern half of the country is wetter than the western half (WaterWise, 2016), contributing to a further unique water supply, demand and quality challenges. It is also inevitable that South Africa will suffer water shortages in 2020 (Naidu-Hoffmeester, 2014).

Water resources in South Africa are also facing exponential pressure from population growth, climate change, pollution and overutilization (DWA, 2014), and is therefore presently facing a multi-faceted water crisis (Naidu-Hoffmeester, 2014). Key concerns and threats include the incongruity between water supply and demand, theft of water resources, ageing and deteriorating water infrastructure, a strangling educational pipeline and the ongoing loss of essential skills, failure in management and the ongoing deterioration of water quality (Naidu-Hoffmeester, 2014).

In addition, South Africa faces a multitude of water quality problems particular to acid mine drainage (AMD), salinization, eutrophication and fecal pollution. These problems are further exacerbated by anthropogenic activities such as:

- Agriculture: Agricultural activities result in salinity, sedimentation and the introduction of nutrients (nitrogen and phosphorus) – all of which contribute to eutrophication;
- Industries: Industrial activities generate effluent that contains a cocktail of toxicants and chemicals;
- Mining: Mining activities generate leachate and decant from abandoned and closed mines, which, together with operational mining activities, also contributes to AMD and metal contamination;
- Urbanization: Urbanization activities generate storm water runoff that contains land-deposited human and animal waste, which can potentially result in fecal contamination of water resources; and
- Wastewater treatment works: Wastewater treatment works generate untreated or partially treated waste effluents that can potentially introduce high levels of nutrients and microbial contamination into water resources (DWA, 2014).

According to the Annual National State of Water Report for the Hydrological Year 2012/2013, there is a need to strengthen the protection and restorations of natural ecosystems, enhance ecological production capacity and promote pollution control. Strategies also need to be developed to prevent, treat and remediate water pollution so as to solve water quality problems (UNEP, 2010). There are three strategies of intervention: 1) pollution can be prevented before entering waterways; 2) wastewater can be treated before discharging it, and 3) the biological integrity of polluted watercourses can be physically restored (UNEP, 2010).

Various technological tools and approaches are available to address water quality goals (UNEP, 2010). Non-physical approaches include economic incentives, pricing and legal/regulatory tools (UNEP, 2010). In South Africa, non-physical legal/regulatory tools are mostly used to address water quality issues resulting from non-parastatals, but there is still a challenge in addressing pollution created by the actions of parastatals. However, there are also other methods to address water quality so as to restore water quality of a particular nature to a certain standard. Such restoring methods can be done by means of ecohydrological approaches (UNEP, 2010).

2.3.2. Water governance in South Africa

Policies and regulation

Policies applicable to water sector regulation are formulated by the Department of Water and Sanitation (DWS), where the DWS plays a dominant role in providing strategies for water sector support (GreenCape, 2016). The DWS executes policy regulation and strategy provision by operating across the water value chain as an entity in the national government in South Africa (GreenCape, 2016). What needs to be emphasized at this point is that DWS does not execute all functions, as some of the functions are assigned constitutionally to sector partners, such as Catchment Management Agencies (CMAs) (GreenCape, 2016).

The main legal mechanisms that exist in South Africa for water include the National Water Act (Act 36 of 1998) (NWA), the Water Services Act (Act 108 of 1997) (WSA) and the National Water Resource Strategy 2 (DWS 2013a) (GreenCape, 2016). A recently promulgated regulatory mechanism is the National Water Amendment Act (NWAA), which includes the following key updates (GreenCape, 2016):

- Regulatory impediments that can impact on growth need to be urgently addressed by the National Development Plan;
- Two key aspects that form part of the DWS's primary objectives, namely 1) decreasing timeframes for license application processes and 2) the alignment of water license appeal processes so as to include an internal appeal authority, as both the Department of Mineral Resources (DMR) and the Department of Environmental Affairs (DEA) have internal appeal panels;
- A time frame for respective authorization processing – a cumulative period of 300 days with a further 90 days for internal appeal processes; and

- Effect given to “the one environmental system”, reflecting the formal agreement between DEA, DWS and DMR. The NWAA content further reflects an integrated water use licensing process with aligned internal appeals and shortened timeframes (DWS, 2015a).

With the recent legislative developments, it is evident that DWS is aiming to establish and implement a smoother and more expeditious licensing process together with measures that can potentially eradicate problems and challenges associated with the independent Water Tribunal, which is still in reconstitution phase (GreenCape, 2016). Moreover, statistics indicate that since the promulgation of the NWA, 4000 water use licenses have been successfully issued, amounting in total to six billion cubic meters of water being formally allocated (GreenCape, 2016). Of these six billion cubic meters of water, approximately 54% has been allocated for irrigation in the agricultural sector, totaling approximately 314 000 hectares of land (GreenCape, 2016).

Institutional structure

Managing water resources – an already complex water sector – involves collaboration and obtaining contributions from various stakeholders located at different points in the value chain (GreenCape, 2016). In the value chain, there are eight broadly defined stages: basin/catchment management, abstraction, storage, treatment, distribution, use, wastewater treatment and discharge (GreenCape, 2016). In South Africa, there is a dedicated institutional structure of the water sector, as outlined by the National Water Resources Strategy 2 (NWRS2) (DWS 2013a) (GreenCape, 2016). The Institutional structure highlights the roles fulfilled by the water service providers, water services authorities, regional water utilities, catchment management agencies, catchment management forums and water user associations (GreenCape, 2016). The national organizational structure of water resource management in South Africa is illustrated in Figure 3.

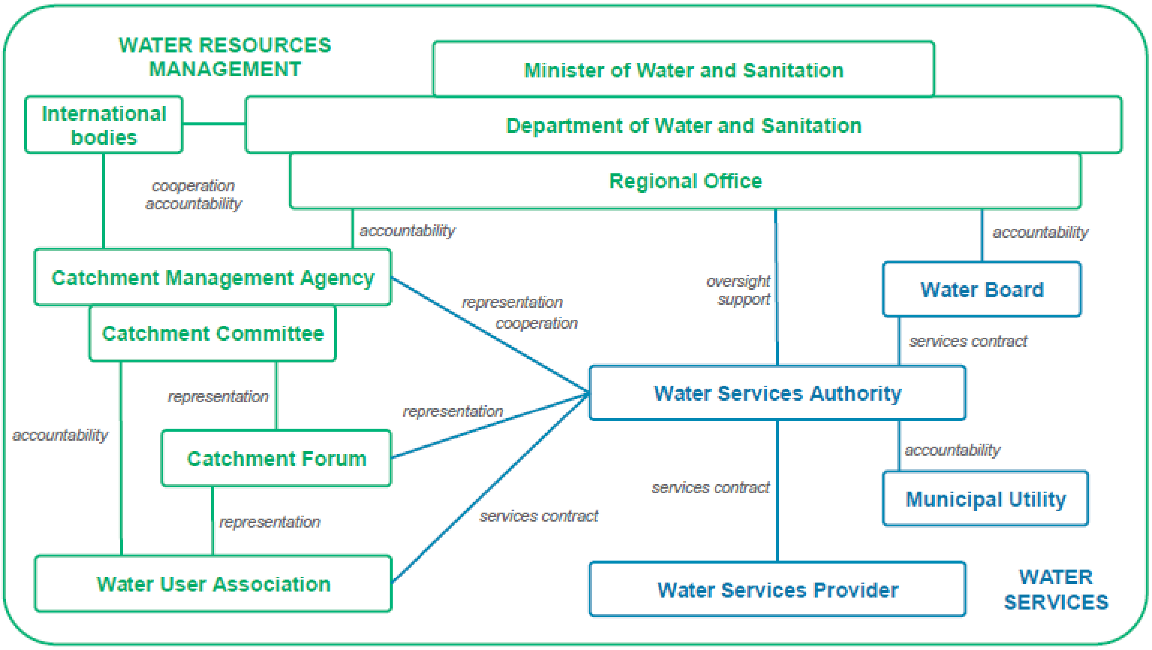

Figure 3: Water resource governance organizations in South Africa (GreenCape, 2016)

Catchment management agencies

Catchment management agencies have been established to facilitate water resource management in South Africa. There are nine catchment management agencies (Figure 4) in the country (GreenCape, 2016).

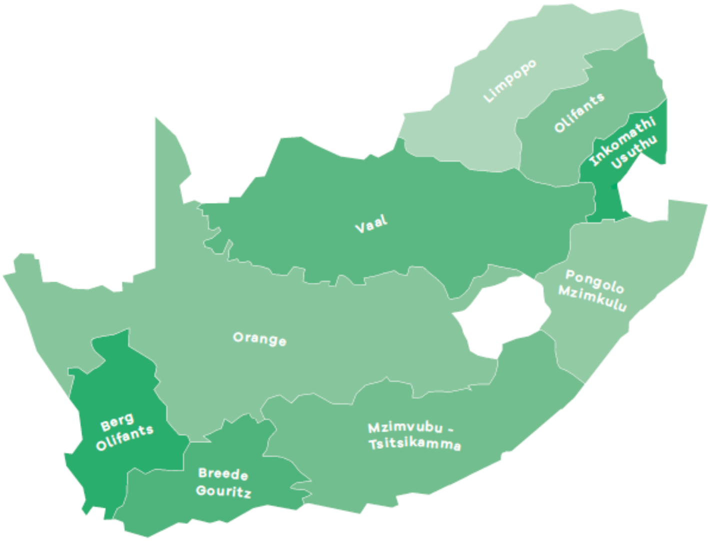

Figure 4: The designated catchment management agencies and boundaries in South Africa (GreenCape, 2016)

Within defined water management agencies, catchment management agencies are responsible for water resource management in the following ways (GreenCape, 2016):

- They are the first port of call for issues relating to water resource management;
- They are responsible at the regional or catchment level for delegating water resource management, involving local communities and appropriate stakeholders where required; and
- They contribute in progressively decentralizing national management at to realize the integrated water resource management ethos of the National Water Act (NWA) (WC-DEADP, 2013).

Catchment management forums

The purpose of catchment management forums, according to NWRS2, is to act as non-statutory agencies or bodies to encourage and democratize water resource management participation and support catchment management agencies (GreenCape, 2016). Furthermore, catchment management forums provide a means to engage with stakeholders and participating parties on catchment management agency formation and, subsequently, assist in the implementation of catchment management strategies in the catchment (GreenCape, 2016).

Water user associations

Water user associations are defined in the NWA as operations "to operate at a restricted localized level and in effect be co-operative associations of individual water users who wish to undertake water related activities for their mutual benefit" (GreenCape, 2016).

Water services authorities

Municipalities that have the mandate and constitutional responsibility within their area of responsibility to regulate water services provision, ensure access to water and plan water services provision are termed water services authorities (DWS, 2013b). Apart from the aforementioned responsibilities, water services authorities are also responsible for abstracting and discharging water and securing licenses from the DWS (or from catchment management agencies, depending on current establishments and power delegation structures) (GreenCape, 2016). Concerning the procurement chain, water service authorities can either provide services themselves or make use of water services providers that are contracted in

(GreenCape, 2016). The number of designated water services authorities amounts to 152, which are included among the 278 municipalities countrywide (GreenCape, 2016).

Water boards

The function of water boards is to provide potable water services in bulk to municipalities, major customers and other water service institutions in designated water service areas (DWS, 2014). They are required to be self-funding, are included in the National Government Business Enterprises Category (GreenCape, 2016) and are separate legal entities that have their own governance assets and structures (GreenCape, 2016). Board members and chairpersons are appointed by the Minister of Water Affairs (GreenCape, 2016).

The consolidation of 12 existing water boards to nine water boards is in the pipeline, in a move towards establishing regional viable water utilities according to the NWRS2 (DWS, 2013a). The function of the regional water utilities will include managing bulk water services infrastructure and supplying bulk water to water services authorities and water consumers (GreenCape, 2016). The regional water utilities will also be responsible for operating existing regional water resources infrastructure, developing new water resources infrastructure on a regional level, providing support to catchment management agencies and water service authorities and managing bulk sanitation infrastructure for wastewater treatment (GreenCape, 2016).

2.4. Phytotechnology as a solution to water quality challenges

2.4.1. Introduction to phytotechnology

Bioremediation refers to the technique of using biological agents for the degradation of pollutants (Rock, 2000; ITRC, 2009; Kennen and Kirkwood, 2015). Phytotechnology, according to Rock (2000), ITRC (2009) and Kennen and Kirkwood (2015), refers to the use of vegetation or plant biomass to prevent, contain or remediate contaminants in groundwater, soils, sediments, and/or add nutrients, porosity and organic matter. Phytotechnology also includes a set of design, planning and engineering tools (including cultural practices) that can assist a variety of professionals (such as site designers, landscape architects and environmental planners) working on site contamination challenges on current and future individual sites, the urban setting and regional landscapes (Rock, 2000; ITRC, 2009; Kennen and Kirkwood, 2015).

Phytotechnology applications have the capacity to play a significant role in transforming contaminated urban and aquatic land (Kennen and Kirkwood, 2015). Plants can, in some cases, take up, break down and hold pollutants in place, providing a more sustainable choice for remediation when combined with short and long-term land planning (Kennen and Kirkwood, 2015). In addition, phytotechnologies, when compared with other remediation options, offer significant cost saving when feasible (see Figure 5) (Reynolds, 2012; Kennen and Kirkwood, 2015).

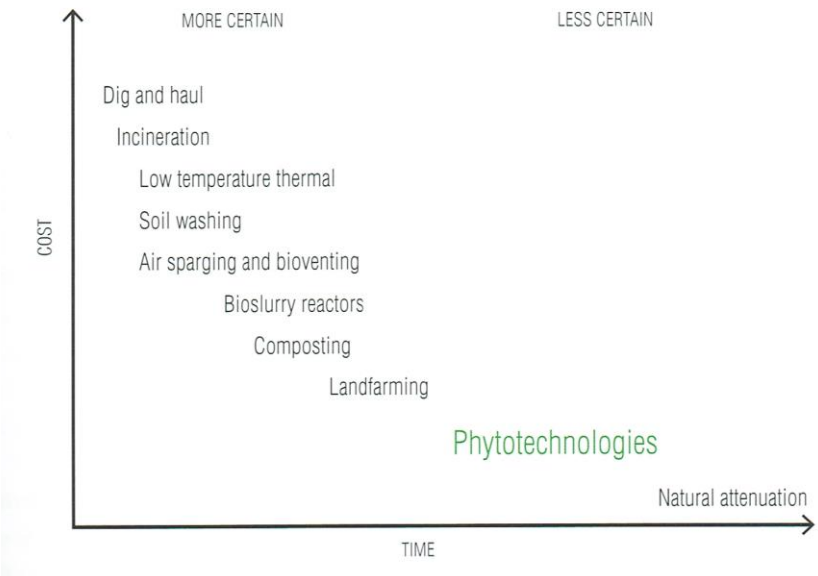

Figure 5: Phytotechnologies: Cost benefits versus treatment time (Kenner and Kirkwood, 2015)

It is important to note that there is a difference between the common term used, called "phytoremediation", and "phytotechnology". The term phytoremediation, or remediation by plants, basically describes the degradation and/or removal of a particular contaminant on a polluted site by a specific plant or groups of plants (Kenner and Kirkwood, 2015). According to Kenner and Kirkwood (2015), phytotechnology also includes techniques such as the stabilization of pollutants within the immediate and surrounding soil, media or plant root structures, together with pre-emptive installations to mitigate an ecological problem or treat a pollutant, by means of plant-based approaches before an ecological problem actually occurs.

In summary, and according to Rock (2015), phytotechnologies include any plantings that improve the environmental goals of the planet and use specifically selected plants, installation techniques and creative design approaches to rethink the landscapes of the post-industrial age. The focus of phytotechnologies is on the design of plant characteristics to sequester, take up or break down contaminants in soils and groundwater (Kenner and Kirkwood, 2015).

2.4.2. Phytotechnology programmes and initiatives in South Africa

2.4.2.1. Water sensitive urban design

Storm water management in the urban areas of South Africa has focused on collecting runoff and channeling it to the nearest watercourse, and continues to do so (Armitage *et al*, 2013). Storm water drainage currently prioritizes quantity (flow) management, with little or no emphasis on the preservation of the environment and ecological functioning. The result has been a significant impact on the environment through resulting erosion, siltation and pollution. An alternative approach here is to consider storm water as part of the urban water cycle, a strategy which is being increasingly known as Water Sensitive Urban Design (WSUD), with the storm water management component being known as Sustainable Drainage Systems (SuDS) (Armitage *et al,* 2013). According to Armitage *et al* (2013), SuDS attempts to manage surface water drainage systems holistically in line with the ideals of sustainable development. It further aims to allow for water quantity management, water quality treatment, enhanced amenity and the subsequent maintenance of biodiversity, mitigating many of the negative environmental impacts of storm water and realizing environmental benefits.

SuDs options are grouped into three main categories, called Source, Local and Regional Controls (Table 2) (Armitage *et al*, 2013).

Table 2: Categorization of SuDS options

Source controls	**Local controls**	**Regional controls**
Green roofs	Filter strips	Detention ponds
Rainwater harvesting	Swales	Retention ponds
Soak-aways	Infiltration trenches	Constructed wetlands (*including floating treatment wetlands)
Permeable pavements	Bio-retention areas	
	Sand filters	
	*Floating treatment wetlands	

*It is the opinion of the author that floating treatment wetlands can be included under local and regional controls.

2.4.3. Wetlands as a phytotechnology solution

2.4.3.1. Natural wetlands

Mitsch and Gosseling (2015) recognize wetlands as being among the most important ecosystems on earth, and are extremely valuable as sources, sinks and transformers of a multitude of chemical, biological and genetic materials. Wetlands are defined as being land that is a transition between aquatic and terrestrial ecosystems, where the water table is close to or at the surface, or where the land is covered periodically with shallow water, supporting (or would support) vegetation that is typically adapted to life in water saturated soil (NWA, 1998). An aquatic ecosystem, in contrast, is described as an ecosystem that has the characteristics of being periodically or permanently inundated by standing or flowing water, or has soils within 0.5m of the surface of the soil that is periodically or permanently saturated with water (Ollis *et al*, 2013).

Different wetland types share certain characteristics (Mitsch and Gosselink, 2015). Apart from their characteristically being found at the interface of terrestrial ecosystems (such as upland forests and grasslands) and aquatic systems (Figure 6), Mitsch and Gosseling (2015), other similarities between wetlands have been identified, namely: all wetlands have saturated or shallow water; all wetlands accumulate organic plant material that decomposes slowly; and all wetlands, under saturated conditions, support a variety of animals and plants adapted to wetland conditions.

According to Mitsch and Gosseling (2015), wetland definitions thus contain three main components:

1. Wetlands are distinguished by the presence of water, either at the surface or within the root zone;
2. Wetlands often have unique soil conditions that differ from adjacent uplands; and
3. Wetlands support biota such as vegetation adapted to the wet conditions (hydrophytes) and, conversely, are characterized by an absence of flooding- intolerant biota.

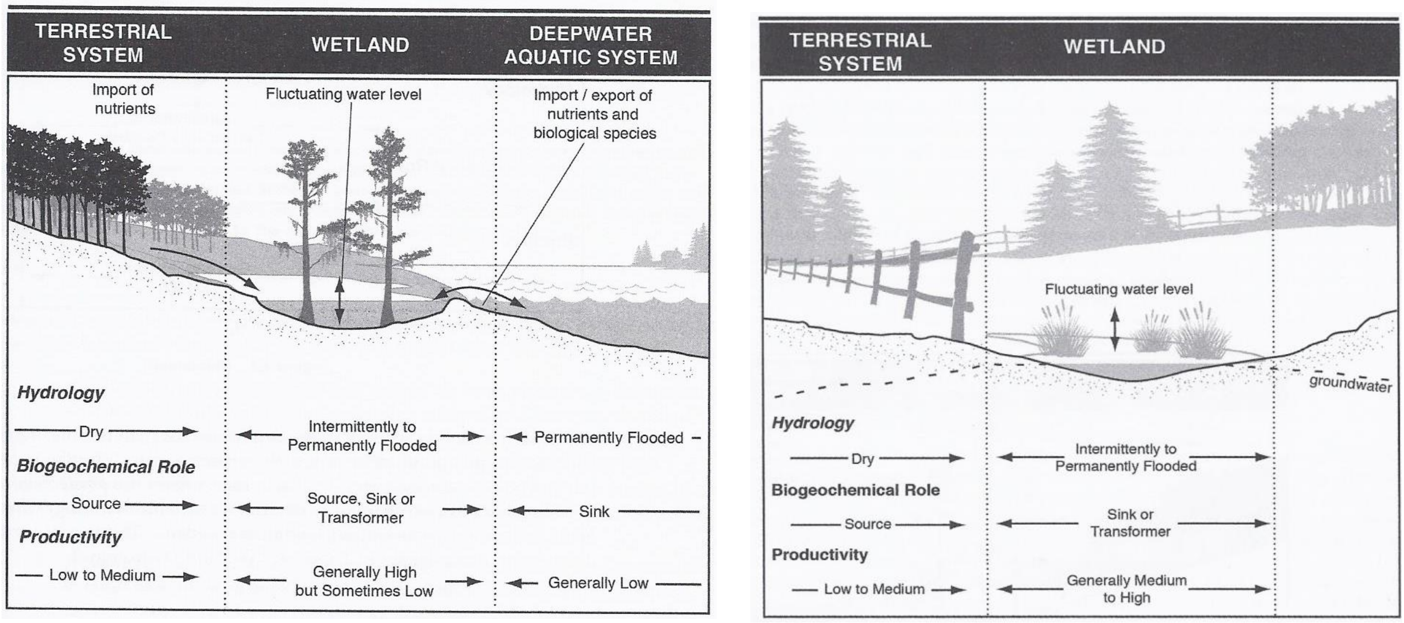

Figure 6: Wetlands are (a) often located between dry terrestrial systems and permanently flooded deepwater aquatic systems such as rivers, lakes, estuaries, or oceans or (b) are isolated basins with little outflow and no adjacent deepwater systems (Mitsch and Gosselink, 2015)

In South Africa, a wetland classification system was developed for the South African National Botanical Institute (SANBI), and was previously known as the "National Wetland Classification System" (Ollis *et al*, 2013). This name was changed to a "Classification System for Wetlands and other Aquatic Ecosystems in South Africa". The inland component of the Classification System consists of a six-tier structure that progresses from systems (Marine vs Estuarine vs Inland), which is the broadest spatial scale (Level 1), through Regional Setting (at Level 2), to Landscape Units (level 3), followed by Hydrogeomorphic (HGM) Units, which is the finest spatial scale (level 4) (Ollis *et al*, 2013). Level 5, the Inland Systems, is categorized according to open waterbodies, the hydrological regime and the inundation depth class (Ollis *et al*, 2013).

A hydrogeomorphic (HGM) approach is used to classify wetlands further (Brinson, 1993) where the geomorphological and hydrological characteristics are used to distinguish between primary wetlands (Ollis *et al*, 2013). Figure 7 illustrates the seven primary HGM Units and their typical landscape settings. The basis on which HGM Units are distinguished include (Ollis *et al*, 2013):

i) The landform that defines the localized setting and shape of the aquatic ecosystem;

ii) The hydrological characteristics that describe the nature of the water through, into and out of the aquatic ecosystem; and

iii) The hydrodynamics that describe the strength of flow and the direction of flow through the aquatic ecosystem.

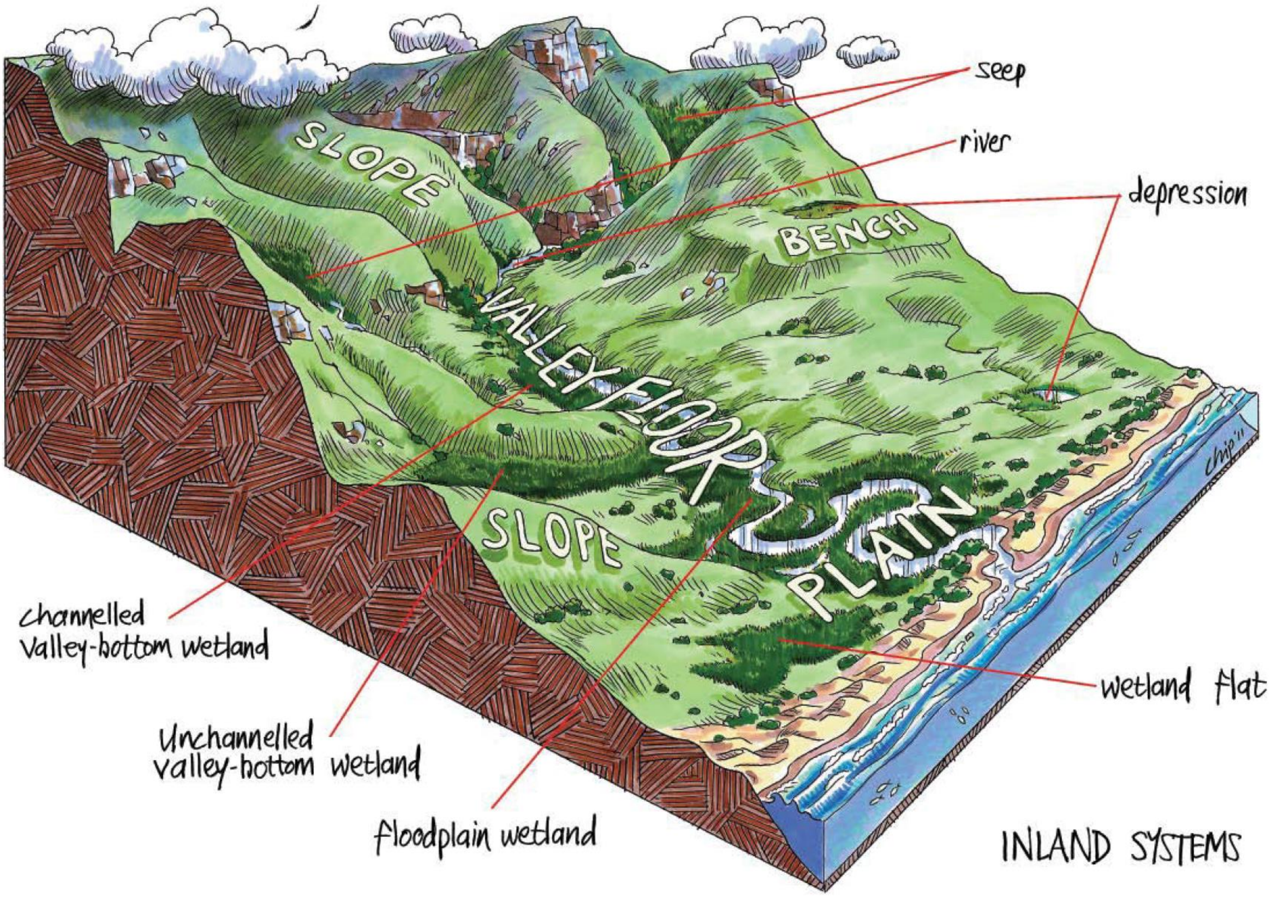

Figure 7: Illustration of the seven primary HGM Units and their typical landscape setting (Ollis *et al*, 2013)

The HGM Units for inland systems are further illustrated in Table 3, which shows the primary HGM Types at Level 4A and the subcategories at levels 4B to 4C. Further classification of primary categories is possible for certain levels of the Classification System (Ollis *et al*, 2013). The primary categories, for these levels, are mainly referred to as Level A Units, and the subsequent sub-divisions are then labelled with letters that follow on, up to level D (Ollis *et al*, 2013).

Table 3: Hydrogeomorphic (HGM) Units for inland systems, indicating the primary HGM Types at level 4A and the subcategories from levels 4B to 4C (Ollis et al, 2013)

Level 4: Hydrogeomorphic (HGM) Unit		
HGM	*Longitudinal zonation/ Landform/Outflow drainage*	*Landform/Inflow drainage*
A	**B**	**C**
River	Mountain headwater stream	Active channel and riparian zone
	Mountain stream	
	Transitional	
	Upper foothills	
	Lower foothills	
	Lowland river	
	Rejuvenated bedrock fall	
	Rejuvenated foothills	
	Upland floodplain	
Channeled valley-bottom wetland	Not applicable	Not applicable
Unchanneled valley-bottom wetland	Not applicable	Not applicable
Floodplain wetland	Floodplain depression and floodplain flat	
Depression	Exorheic	With channeled inflow and without channeled inflow
	Endorheic	With channeled inflow and without channeled inflow
	Dammed	With channeled inflow and without channeled inflow
Seep	With channeled outflow and without channeled outflow	Not applicable
Wetland flat	Not applicable	Not applicable

The dominant movement of water through, out and into the various HGM Units is demonstrated in Figure 8, which illustrates the primary HGM Types (Ollis *et al*, 2013).

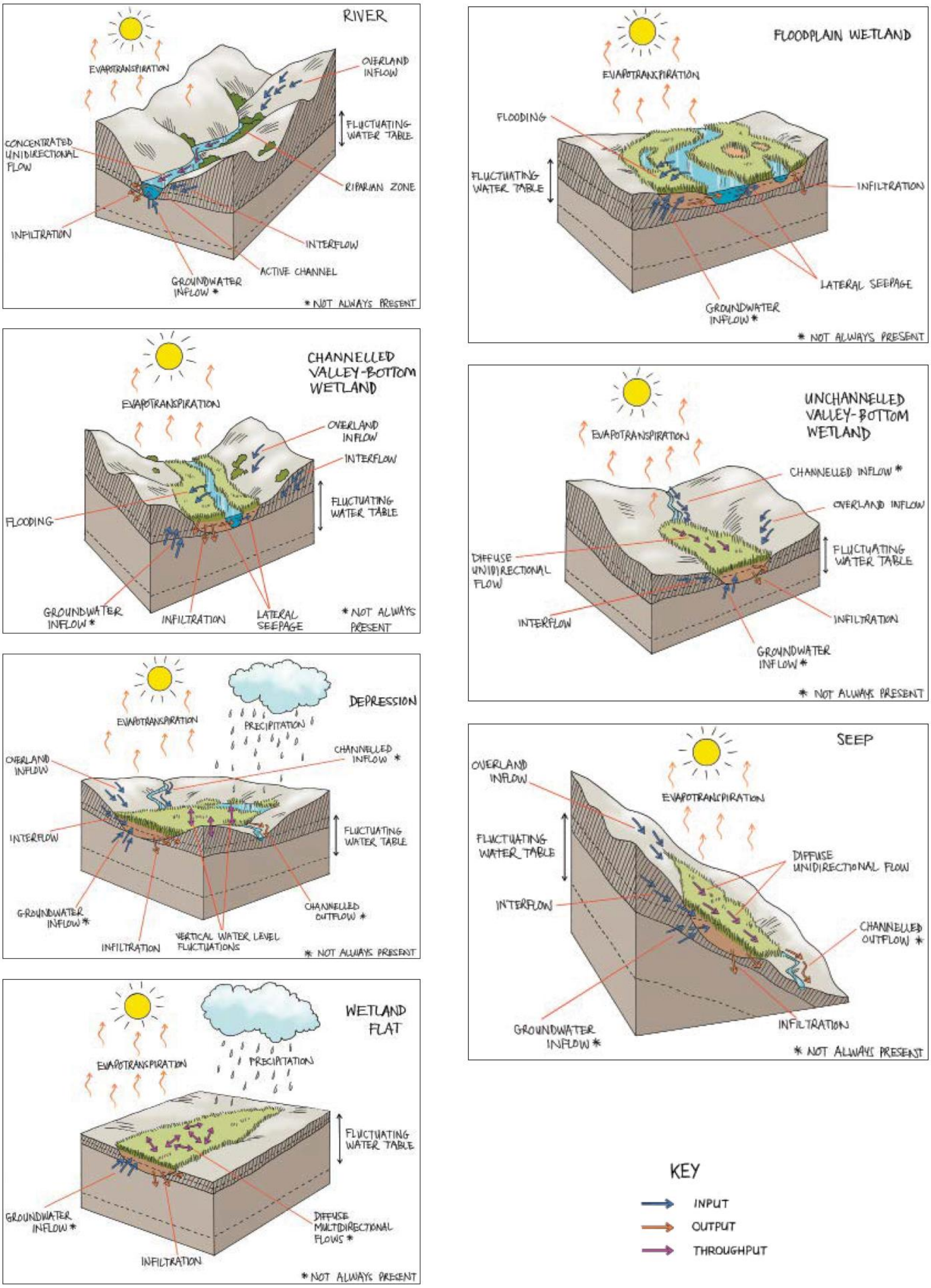

Figure 8: An amalgamated illustration of the primary HGM Types that highlights water movement (Ollis *et al*, 2013)

Although the value of wetlands for wildlife and fish conservation has been known for a century, some other benefits have been identified more recently (according to Mitsch and Gosselink, 2015):

- As the kidneys of the landscape, wetlands function as the downstream receivers of water and waste from both natural and human sources;
- Wetlands also have the ability to stabilize water supplies and mitigate floods and drought;
- They have been found to treat and cleanse polluted waters, protect shorelines and recharge groundwater aquifers;
- Wetlands have also been called nature's supermarkets because of the extensive food chain and rich biodiversity that they support;
- They play major roles in the landscape by providing unique habitats for a wide variety of flora and fauna; and
- Wetlands have been described as being important carbon sinks and climate stabilizers on a global scale.

2.4.3.1. Constructed treatment wetlands

Kadlec and Wallace (2009) explain that modern treatment wetlands are man-made systems that have been designed to emphasize specific characteristics of wetland ecosystems for the purposes of improved treatment capacity. Treatment wetlands can be constructed in a variety of hydrologic modes treating various contaminants of concern (Kadlec and Wallace, 2009). The basic types of constructed wetland systems are shown in Figure 9.

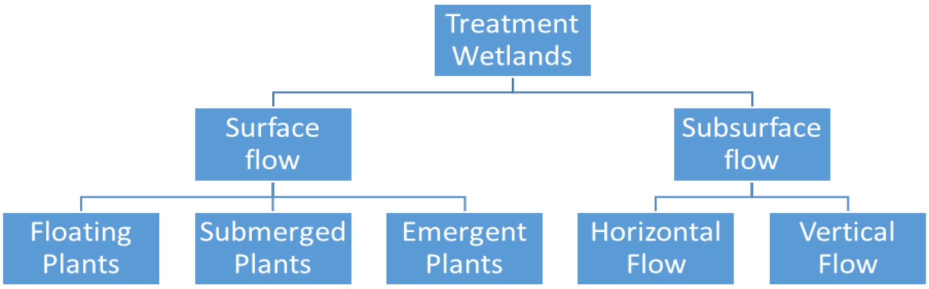

Figure 9: Treatment wetland types (adapted from Kadlec and Wallace, 2009)

Three types of wetlands are widely used at the current stage of technological development, according to Kadlec and Wallace (2009):

- Free water surface (FWS) wetlands: These constructed wetland treatment systems have areas of open water and are similar in appearance to natural marshes;
- Horizontal subsurface flow (HSSF) wetlands: These constructed wetland treatment systems typically employ a gravel bed planted with wetland vegetation. The water in the constructed wetland treatment system is kept below the surface of the bed and flows horizontally from the inlet to the outlet; and
- Vertical flow (VF) wetlands: These constructed wetland treatment systems distribute water across the surface of a sand or gravel bed planted with wetland vegetation, and wastewater is treated as it percolates through the plant root zone.

Constructed treatment wetlands can be used for the treatment of domestic wastewater treatment, animal wastewater treatment, mine water treatment, industrial wastewater treatment, leachate and remediation, urban storm water treatment and field runoff treatment (Kadlec and Wallace, 2009).

2.4.3.2. Floating treatment wetlands

Kezer-Vlek *et al* (2014), define floating treatment wetlands (Figure 10) as wetlands characterized by emergent macrophytes that grow on a floating mat that is placed on the surface of the water.

Figure 10: A floating treatment wetland developed and constructed by the researcher at the Modderfontein Nature Reserve, City of Johannesburg (Photo: Yolandi Schoeman, Modderfontein, 25 May 2015)

Keizer-Vlek *et al* (2014) further explain that emergent macrophytes in floating treatment wetlands are not anchored in the wetland sediment, but rather the roots extend into the water column where plants can take nutrients up directly, which is in contrast to traditional constructed wetland treatment systems.

The advantages of floating treatment wetlands are, according to Hubbard (2010) and Keizer-Vlek *et al* (2014), their ability to cope with fluctuations in water levels; their aesthetic value; their provision of habitat for invertebrates, fish and birds; the ability to reduce nutrient concentrations in wastewater; and the sense of green they create in urban environments.

Floating treatment wetlands are being applied in various sites worldwide (Hu *et al*, 2010). The main applications of floating treatment wetlands for water quality improvement include the treatment of storm water, sewage, pond water, urban lake water, dairy manure effluent and water supply reservoirs (Weragoda et al, 2012). A high number of studies have provided nutrient removal efficiencies for floating treatment wetlands (Revitt *et al*, 1997; Vymazal, 2007; De Stefani *et al*, 2011). For instance, it has been shown that the different biological and physico-chemical processes that play a role in nutrient removal using floating treatment wetlands are nitrification, denitrification and phosphorus adsorption. However, the effect of the vegetation on overall removal performance (including metals and non-metals) is poorly documented (Van de Moort *et al*, 2010; Chang *et al*, 2013).

2.5. Adoption of green infrastructure

2.5.1. Introduction to green infrastructure and ecological infrastructure

The 1999 report of “President’s Council on Sustainable Development” with the title “Towards a Sustainable America” introduced the term “green infrastructure” to the world (Benedict and McMahon, 2002; Mell, 2008). Green infrastructure is described in the report as a strategic tool that can be used to achieve sustainable community development (Barau, 2015). Green infrastructure is now a term used that collectively includes parks, private gardens, green bridges, scrublands, fish migration channels, drainage, waterways, high value farmland and forest areas, vertical greenery, street trees, green roofs, flood retention facilities as well as natural areas and features, and open spaces (Ahern, 2007; BISE, 2015; Mell *et al*, 2013; Schaffler and Swilling, 2013; Wong *et al*, 2010) – all of which demonstrate nature-based solutions and innovative planning approaches to multi-purpose and intelligent land-use (BISE, 2015).

A defining factor of a green infrastructure approach is the presence of ecological and natural assets that provide for multiple environmental, social and economic functions (Landscape Institute, 2009; Schaffler and Swilling, 2013). According to the European Commission, green infrastructure (Figure 11) can also be defined as natural and semi-natural strategically planned networks incorporating other physical features equipped to deliver a wide range of ecosystem services (BISE, 2015). Green infrastructure comprises blue (aquatic ecosystems) and green (terrestrial ecosystems) spaces, includes marine and coastal areas and represents urban and rural areas (BISE, 2015).

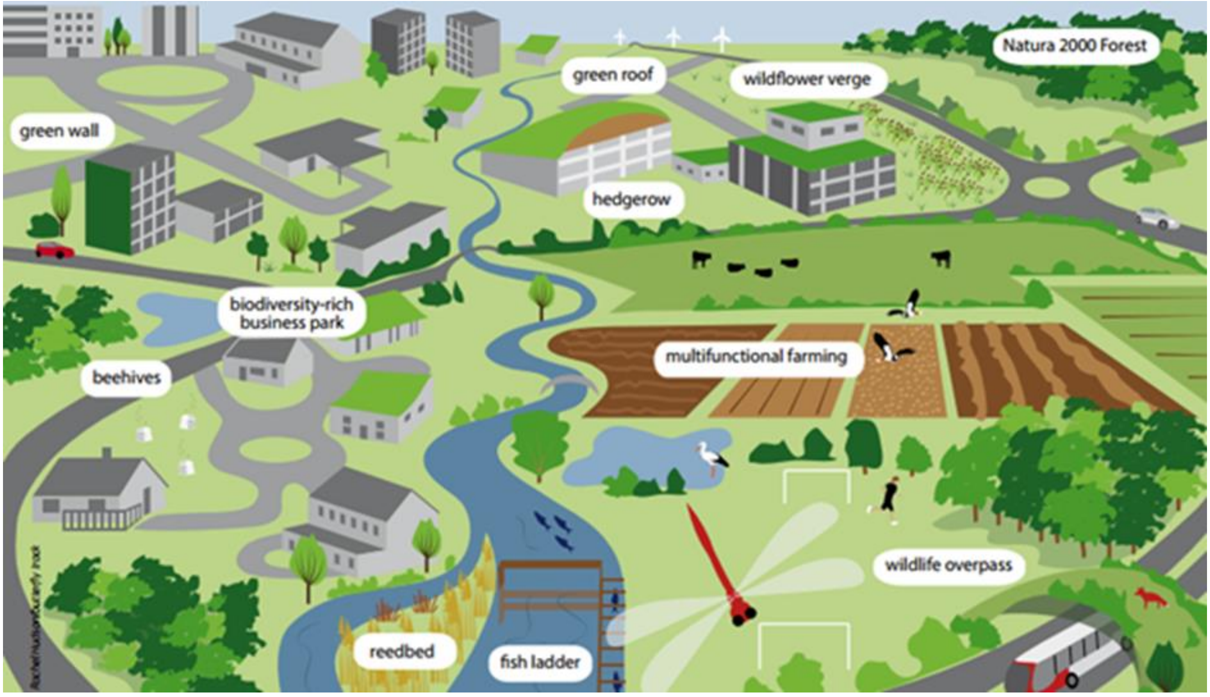

Figure 11: Illustrating various green infrastructure possibilities in an urban and rural setting (BISE, 2015)

Another reason green infrastructure has become popular lies in the application of green infrastructure from water purification to climate change mitigation and adaptation (Pakzad and Osmond, 2016). In addition, green infrastructure can also be characterized by potentially requiring lower maintenance, operational and capital costs coupled with fewer negative impacts on the environment. In addition, it is able to reduce carbon emissions when compared to grey infrastructure (Benedict and McMahon, 2006; Lafortezza *et al*, 2013; Pakzad and Osmond, 2016). Recently, green infrastructure has also grown into an urban sustainability policy and research theme (Barau, 2015).

The proposed targets and indicators of the United Nations Sustainable Development Goals (SDGs) have recognized the role of spatial configuration in achieving sustainability in the urban context together with emphasis on urban biodiversity composition, improved urban living and accessibility to green spaces (Barau, 2015; UN Development Solutions Network, 2014; UN Habitat, 2013). Regarding the latter, Thompson *et al* (2012) indicate that green spaces contribute significantly to enhancing human health and reducing stress when situated close to residential areas. Importantly, green infrastructure recognizes these socio-ecological aspects (Barau, 2015). Green infrastructure has the ability to contribute to socio-ecological resilience, which determines the ability of a complex system to re-organize and absorb disturbances in the face of pressures (Barthel, 2008; Ernstson, 2008; Folke *et al*, 2005).

Indeed, the basic organizational and physical structure that a society requires for its operation is infrastructure (Feng *et al*, 2016). Infrastructure provides the necessary facilities to address the gap between human functions and the economy (Feng *et al*, 2016; Patterson and Apostolakis, 2007; Sun *et al*, 2015). Infrastructure also interacts with ecosystems, and there is no city that can operate without having infrastructure (Feng *et al*, 2016). Traditional infrastructure (also referred to as grey infrastructure) includes highways and roads, systems transporting water, sewage and storm water (including treatment systems) and electrical grids (Feng *et al*, 2016).

However, the effects associated with grey infrastructure is habitat loss and landscape modification (Feng *et al*, 2016). Grey infrastructure development and establishment also pose significant threats to urban ecosystem sustainability and coherence (Cagno *et al*, 2011; Kjolle *et al*, 2012; Serrano *et al*, 2002). In addition, there are weaknesses associated with grey infrastructure (Kessler, 2011). Urban problems such as air pollution, traffic jams and flooding are characteristic of grey infrastructure, together with the associated inability to cope with factors such as climate change (Kessler, 2011). Owing to these problems with grey infrastructure, greater emphasis is being placed on creating infrastructure systems that are more resilient and inherently adaptable (Feng *et al*, 2016).

On one hand, traditionally grey infrastructure uses physical approaches to transport pollutions and wastes in cities to natural ecosystems, where it subsequently purifies the environment in urban areas (Feng *et al*, 2016). Grey infrastructure is also considered to be expensive, energy intensive and prone to obsolescence and deterioration, and it does not scale and is rigid with single functionality (Feng *et al*, 2016). On the other hand, green infrastructure is concerned with biological approaches (including green and blue spaces) in order to solve environmental problems and realize the integration of various components by means of combining greenways, natural reserves, wetlands and green spaces. It is regarded as being less expensive, requiring less on-going maintenance (Forest Research, 2010; Tzoulas *et al*, 2007) and being flexible with multiple functions (Feng *et al*, 2016).

According to Feng *et al* (2016), the integration of green infrastructure with grey is not sufficient, as this process overlooks the wider inclusion of grey infrastructure and only considers green infrastructures' connection with various components. Furthermore, Feng *et al* (2016) argue that such integration is also mainly at the structural level and that the coupling of ecological processes and ecosystem function is only an assumption.

In contrast, ecological infrastructure takes a composite view, integrating ecological planning, design, technological approaches and engineering in order to address and solve urban environmental problems, thereby reducing the impact urban development has on natural ecosystems (Feng *et al*, 2016). Ecological infrastructure also combines green and grey infrastructure at an ecosystem scale, thereby maximizing multiple system functions and emphasizing coordination of each component, and avoiding functionality of single components in isolation (Feng *et al*, 2016; Li *et al*, 2014).

Table 4 presents an overview of green infrastructure solutions in comparison to corresponding grey infrastructure solutions that are relevant to water resource management and applicable to this discussion (GreenCape, 2016). In Table 4, the role of constructed wetlands and wetlands restoration has been identified as being important in water quality regulation, water supply regulation, water purification and moderation of extreme events such as floods for the categories watershed, floorplan, urban and coastal (GreenCape, 2016).

Table 4: Green infrastructure solutions applicable to water resource management (GreenCape, 2016)

Water management issue (Primary service to be provided)	Green infrastructure solution	**Location**				Corresponding grey infrastructure solution (at primary service level)
		Watershed	Floorplan	Urban	Coastal	
Water supply regulation (including	Re/afforestation and forest conservation	X				Dams; groundwater pumping; water distribution systems

drought mitigation)						
	Reconnecting rivers to floodplains		X			
	Wetlands restoration/ conservation	X	X	X		
	Constructing wetlands	X	X	X		
	Water harvesting	X	X	X		
	Green spaces (bioretention and infiltration)			X		
	Permeable pavements			X		
Water quality regulation: water purification	Re-afforestation and forest conservation	X				Water Treatment Plant
	Riparian buffers		X			
	Reconnecting rovers to floodplains		X			
	Wetlands restoration/ conservation	X	X	X		
	Constructing wetlands	X	X	X		
	Green spaces (bioretention and infiltration)			X		
	Permeable pavements			X		

Water quality regulation: Erosion control	Re/afforestation and forest conservation	X				Reinforcement of slopes
	Riparian buffers		X			
	Reconnecting rivers to floodplains		X			
Water quality regulation: Biological control	Re/afforestation and forest conservation	X				Water treatment plant
	Riparian buffers	X	X	X		
	Reconnecting rivers to floodplains		X			
	Constructing wetlands	X	X	X		
Water quality regulation: Water temperature control	Re/afforestation and forest conservation	X				Dams
	Riparian buffers		X			
	Reconnecting rivers to floodplains		X			
	Wetlands restoration/ conservation	X	X	X		
	Constructing wetlands	X	X	X		
	Green spaces (bioretention and infiltration)					

Moderation of extreme events (floods): Riverine flood control	Re/afforestation and forest conservation	X				Dams and levees
	Riparian buffers		X			
	Reconnecting rivers to floodplains		X			
	Wetlands restoration/ conservation	X	X	X		
	Establishing flood bypasses	X	X	X		
Moderation of extreme events (floods): Urban storm water runoff	Green roofs			X		Urban storm water infrastructure
	Green spaces (bioretention and infiltration)			X		
	Water Harvesting	X	X	X		
	Permeable pavements			X		
Moderation of extreme events (floods): Coastal flood (storm) control	Restoring mangroves, marshes and dunes				X	Sea walls
	Protecting/ restoring reefs (coral/oyster)				X	

Floating treatment wetlands form part of the blue land of ecological infrastructure and green infrastructure that includes wetlands and rivers (Mitscha and Day, 2006). The links between rivers, dams and lakes can increase the communication between organisms and various materials in aquatic systems, promote the ability of water to self-purify, contribute to ecological restoration and digest pollution (Feng *et al*, 2016). Through these connections, urban wetlands can be protected, along with protecting aquatic biodiversity and water resources, which subsequently provide habitat for aquatic urban ecosystems and its restoration and remediation (Feng *et al*, 2016). When blocked connections are created between lakes, dams and rivers in urban areas, the result is reduction of biodiversity and wetlands functioning, creating conflicts between socioeconomic development and urban environmental protection (Feng *et al*, 2016).

Subsequently, through careful planning and a combination of ecological infrastructure, especially concerning wetlands of different types, water purification and conservation, water activation, beautification of the landscape and climate regulation can be achieved through the resulting ecosystem services and multiple functions provided by wetlands (Feng *et al*, 2016). In addition, water challenges such as water eutrophication, decreasing biodiversity and other relevant urban environmental problems can be solved (Feng *et al*, 2016). Through the integration of various components of urban ecological infrastructure, it is possible to repair the urban aquatic ecological environment, and the urban area or city is then metamorphosed into a "sponge" with capabilities that predominantly include water purification, penetration and retention (Wu, 2016).

2.5.2. Sustainable development and the diffusion of green infrastructure

2.5.2.1. Sustainable development challenges

The fact that societies have been affected by economic activities has caused an elevated interest in sustainability and related concepts (Hutchins and Sutherland, 2008). For instance, the "Brundtland Report" (also "Our Common Future" – WCED, 1987) marked a significant change in our attempts to connect bio-physical environmental, social and economic policy goals (Vallance *et al*, 2011) following the 1980s period when the conservation concept "sustainable development" was born (IUCN, 1980; Vinuales, 2013). Sustainable development was further recognized at the Earth Summit in 1992 (UN, 1992) as the leading concept that aims to protect the environment through global efforts (Vinuales, 2013). Since the publication of the "Brundtland Report", a profusion of literature devoted to the general topic of sustainable development became available, along with a blurring of focus, with topics such as urban sustainability, sustainable management, environmental sustainability, weak and strong sustainability, or purely sustainability being addressed, accompanied by debates occurring within and between each topic (Vallance *et al*, 2011). Other concepts and movements had also been developed over a period of time, including green economy and eco-development (Barbier, 2010; Glaeser, 1984; Pearce *et al*, 1989; UN, 1974); however, they were unsuccessful in gathering consensus amongst stakeholders, while sustainable development continued to drew a veil over the "environment-development" equation (Vinuales, 2013). Moreover, Vinuales (2013) argues that the concept of sustainable development does not provide an adequate umbrella for implementation, which is regarded as the main challenge that global environmental governance is facing.

Indeed, as implementation is becoming a matter of urgency, the ability of sustainable development to encompass different issues without clarifying interrelations is turning into its main weakness (Vinaules, 2013). Vinuales (2013) has therefore developed an alternative model (Figure 12) that addresses the following critical questions, namely "What should priorities under sustainable development be?" and "What would the relationship be between making progress regarding sustainable development priorities and the offerings of sustainable development?"

Vinuales' (2013) alternative sustainable development model consists primarily of four "knots" that are viewed as "acupunctural points" in the body of global environmental governance. These knots are participation, differentiation, decarbonization and innovation, and technology diffusion. Each knot included in the model is a frontline where considerations that compete and confront each other, and different calibrations need to be attempted according to the various areas of concern, i.e. fresh water contamination and efficiency, energy production, waste treatment, biological resources management, etc. (Vinuales, 2013).

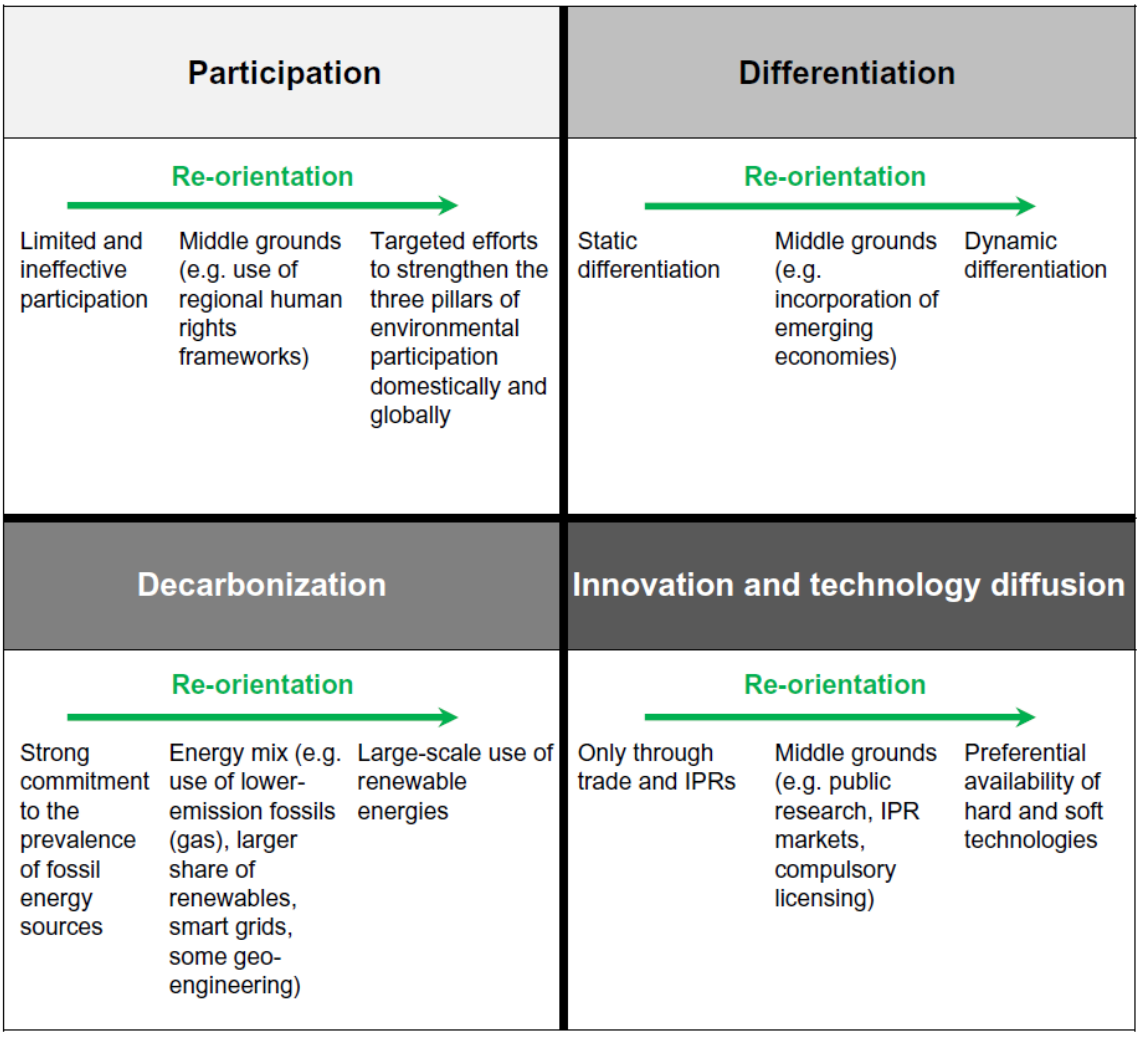

Figure 12: An alternative sustainable development model (Vinuales, 2013)

Within each knot are three columns that are intended solely to reflect the current situation regarding areas of concern (left column), followed by the most progressive scenario that is now being considered, to a variety of middle grounds and combinations as reflected by the middle column (Vinuales, 2013). All three columns under each knot need to be regarded as a continuum within which various solutions and specific frontlines can be opened (Vinuales, 2013). Each knot is briefly described in the section below.

Participation

Participation is the most fundamental knot of all (Vinuales, 2013). It is capable of exerting pressure, through creating social forces such as groups and individuals, or supporting economic operators and governments in changing their course of action (Andonova and Mitchell, 2010). The empowerment that participation brings is very important in creating the foundation to re-orientate an investment at industry and governmental level towards greener processes and products (Vinuales, 2013). This re-orientation can be achieved through awareness and education, as well as through competitive pressure from industries (Vinuales, 2013).

Differentiation

Differentiation includes the effectiveness of international law as well as the matter of fairness (Vinuales, 2013). In order to introduce some levels of differentiation among international obligations, different techniques have been developed (Magraw, 1989; Rajamani, 2006). The techniques include a combination of adjusted obligations and assistance (Vinuales, 2013).

Decarbonization

Energy also requires recalibration (Vinuales, 2013). The decarbonization knot faces an intimidating challenge: the renewed commitment to fossil fuels that has arisen from the considerable amount of resources invested in the last decade on the extraction and exploration activities associated with fossil energy resources (Maugeri, 2012). Decarbonization is regarded as a very important frontline, and needs to be treated as a priority in global environmental negotiations (Vinuales, 2013).

Innovation and technology diffusion

Progress in technology involves both innovation and diffusion of technology (Vinuales, 2013).

2.5.2.2. Sustainable development and communities

The concept of sustainability is mostly referred to in terms of the definition proposed by the World Commission on Environment and Development (WCED)(1987): “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The WCED relied the definition on two key concepts, namely “needs” and “meeting point” (Sianipar *et al*, 2013).

The first key concept, needs, refers to an overriding priority that must be provided to the essential needs of the poor communities of the world (Sianipar *et al*, 2013). The second key concept is the meeting point of the needs of present and future generations through technology and social organization to the ability of the environment to meet such needs (Sianipar *et al*, 2013). Other important aspects that need to be taken into account are social, environmental and economic values, which together are referred to as the "triple bottom line". Businesses (which includes community members as a main business party) have evolved and continue to evolve in their understanding of these values so as to address environmental sustainability, economic viability and social responsibility (Jamali, 2006). Sianipur and Adhiutama (2012) propose three perspectives in deciding on the most appropriate technology for the purposes of increasing acceptance of technology amongst communities.

However, globally, there is a tendency to see green issues as business discourse (Springett, 2003), and, owing to exploitation of businesses towards people and resources (Willers, 1994 and Escobar, 1995), this tendency has resulted in a failure in focus. A broader meaning of green has therefore been proposed from an engineering perspective (Sianipar *et al*, 2013). Sianipar *et al* (2013) argue that green as ultimate goal in environmental challenges and issues needs to be reached through a wider meaning of "technical perspective". Sianipar *et al* (2013) further emphasise that green can be reached when joint efforts in environmental sustainability are not based on fiction or slogans, but rather through technical efforts that are applied to measure environmental impacts through technology and technological assessments.

2.5.2.3. Governance for sustainable development

Sustainable development is often presented as a pathway to all that is desirable and good in a society (Van Zeijl-Rozema *et al*, 2008). However, in terms of guiding policy making, the rosy picture painted of sustainable development does not help (Holden and Linnerud, 2007).

Indeed, sustainable development is a complex concept, and deals with different temporal and spatial scales and with multiple stakeholders (Martens, 2006). In addition, there is a process of change, where the development goal is subject to change and not clearly outlined (Van Zeijl-Rozema *et al*, 2008). Subsequently, governance is regarded as a means to steer/direct the sustainable development process, but in itself is not a straightforward concept either (Van Zeijl-Rozema *et al*, 2008). Essentially, governance can be seen as a stakeholder involvement, a collection of rules and various processes used to achieve a common goal (Kemp and Martens, 2007).

Van Zeijl-Rozema *et al* (2008) propose a conceptual framework (Tables 5 and 6) that combines perspectives on sustainable development with the modes of governance, capturing boundaries and existing efforts and theories regarding governance for sustainable development and outcomes. This framework is addressed below.

Table 5: Characteristics of various governance types for sustainable development (Van Zeijl-Rozema *et al*, 2008)

Characteristics of Governance for Sustainable Development	Ecological-Hierarchical	Ecological-Deliberative	Well-being-Hierarchical	Well-being-Deliberative
Perspective on Sustainable Development	**Ecological**	**Ecological**	**Well-being**	**Well-being**
Focus	Environment	Environment	All three pillars (environment, economy and social)	All three pillars (environment, economy and social) receive great deal of attention
Use of Goals	Reliance on quantitative goals	Both qualitative and quantitative goals important	Attention to multitude of goals and their tradeoffs	Attention to multitude of goals and their tradeoffs
Supporting basis to legitimise goals	Scientific Evidence	Scientific Evidence plays an important role	Societal preferences on equal footing with scientific evidence	Societal preferences important; SD is a deeply normative issue; scientific evidence is uncertain and contested
Mode of Governance	**Hierarchical**	**Deliberative**	**Hierarchical**	**Deliberative**
Key decision-maker	Central government, president in authoritarian regimes	Multiple actors, including local government and NGOs	National politics and/or local government	Multiple actors, with a special role for civil society
Stakeholder relations	Vertical, top-down	Horizontal, bottom-up	Vertical, top-down	Horizontal, bottom-up, dynamically linked up with top-down
Favoured steering approach	Planning and control	Network management among key actors	Planning and control with attention to local circumstances, plus use of market-based instruments	Network management involving all stakeholders
Tensions	Focus of SD policy on certain parameters (such as CO_2) leads to transfer of problems and neglect of relevant parameters	Over-simplification of complex interactions between social systems and ecological systems. But this will be revealed in the process.	Actors may not agree with hierarchical goals, if they do not reflect local concerns	Emphasis of complexities might block implementation of policies (paralysis from analysis)
Tools for use[a]	Cost effectiveness analysis	Multi-criteria analysis such as weighted summation	Cost-Benefit Analysis for implementation	Integrated sustainability assessment; Participatory tools such as focus groups/ consensus conference for the goal-setting.
Examples	Kyoto protocol	IPCC/Millennium Ecosystem Assessment	Millennium goals	Dutch energy transition policy based on transition arenas for system innovation

Table 6: Expressions of governance for sustainable development- for various typologies (Van Zeijl-Rozema *et al*, 2008)

Expression of Governance for Sustainable Development	Ecological-Hierarchical	Ecological-Deliberative	Well-being-Hierarchical	Well-being-Deliberative
SD goal (summary)	SD goals are defined by leading authorative actor using scientific evidence. Specific goals are not an issue for societal discussion	SD goals (mostly about environmental issues) are defined by multiple actors, drawing on scientific evidence.	SD goals constitute temporary consensus of various societal preferences and are finally set by leading actor. Need for revision as society changes is understood and accepted	Multitude of SD goals are defined by multiple actors. There is agreement on their diversity and there is a need for refining and revising the understanding of the concept. Space for diverse ideas and strategies
Implementation strategy	Little discretion for implementers	Fair amount of discretion in implementation of SD policies, diversity is tolerated	Implementation of SD policies decided upon by leading actor, discretion in implementation large or small	High degree of discretion in implementation of SD policies, diversity is accepted
Commitment	Commitment to the rules set by leading actor, not to sustainable development	Commitment to SD at the implementation level	Commitment to SD but not always to the policies formulated from the top.	Commitment to SD throughout society, includes thinking about the concept as well as realising implementation
Acknowledgement of uncertainty	Uncertainty about scientific evidence and policy effects is downplayed	Uncertainty is acknowledged and policy concentrates on the best ways to achieve the goal	Uncertainty is concentrated on the concept of SD. One is willing to act in the face of uncertainty.	Uncertainty about the concept of SD and the best ways to achieve the goal is openly acknowledged. Policies are seen as fallible
Focus	Goal achievement	Goal achievement/ Implementation process	Goal-setting process/ Goal achievement	Goal-setting and implementation process
Role for technical fixes	Very important role for technical fixes which may be prescribed	Important role	Important, as well as behavioural change and system innovation	Only used in exceptional cases. Context-sensitive solutions are sought, including behavioural change and system innovation
Monitoring and evaluation questions	Has SD goal been achieved?	Has SD goal been achieved and what solutions have been developed?	Has SD goal been achieved? Has consensus goal changed and should implementation change?	Are we on the right track? What are the latest views on SD? What are possible ways to achieve SD?

The ecological sustainability – hierarchical type

Here, leading actors – often government – make the decisions (Van Zeijl-Rozema *et al*, 2008). Thus the implementation of sustainable development is decided upon by the leading actor in a straightforward manner, often with very little discretion and consideration for those that need to implement it (Van Zeijl-Rozema *et al*, 2008). The focus in this type is primarily on achievement and evaluation, and monitoring indicators are orientated around the output (Van Zeijl-Rozema *et al*, 2008). Potential dangers in this nitrating type of system include over-simplification, concentrating on remedying a few symptoms and ignoring inter-linkages that are very important in sustainable development (Van Zeijl-Rozema *et al*, 2008).

The ecological sustainability – deliberative type

The decisions on how best to achieve the sustainable development goals are made by representatives of state, market and the civil society, where the goal is formulated through scientific findings (Van Zeijl-Rozema *et al*, 2008). Consensus is reached quite easily, and the various actors are in agreement that development should take place within ecological limits (Van Zeijl-Rozema *et al*, 2008). The goals are consequently derived by negotiation and learning by doing, and a deliberative approach is followed (Van Zeijl-Rozema *et al*, 2008). The main focus lies on possible avenues towards achieving the set goals, with a high degree of discretion regarding the goal implementation (Van Zeijl-Rozema *et al*, 2008). Monitoring and evaluation focus on finding more out about good and possible solutions as well as on goal achievement (Van Zeijl-Rozema *et al*, 2008). Challenges with this type include the emphasis on ecology, which might be insufficient in understanding complexities regarding sustainable development. However, there is a strong focus on technology and the implementation process might help to reveal constraints (Van Zeijl-Rozema *et al*, 2008).

The well-being hierarchical type

As a result of societal preferences and their relationship to quality of life and well-being, the ultimate goal of sustainable development is often not well defined (Van Zeijl-Rozema *et al*, 2008). One goal is chosen, for the sake of implementation, through a process where the leading actor (often government) draws upon society to set goals (Van Zeijl-Rozema *et al*, 2008). The leading actor steers the road and coordinates the sustainable development goal achievement process once the goal is clarified (Van Zeijl-Rozema *et al*, 2008). Concepts that play an important role include technical fixes, system innovation and behavioural change (Van

Zeijl-Rozema *et al*, 2008). Challenges include commitment challenges for policies formulated at the top, unwilling societal actors to follow the chosen path and tension between the uncertainty in sustainable development priorities and the linear approach pursued by the leading actor (Van Zeijl-Rozema *et al*, 2008).

The well-being deliberative type

The priorities for sustainable development and the manner in which to pursue the goals (concerning well-being and quality of life) are deliberated upon by state representatives and market and civil society members (Van Zeijl-Rozema *et al*, 2008). Attention is paid to a multitude of trade-offs and soft goals between the horizontal relations among the government and other actors in society (Van Zeijl-Rozema *et al*, 2008). An unfolding societal process is dependent upon negotiation, and learning characterizes the process of defining goals, taking action for implementation, reframing the goals and adjusting the process accordingly (Van Zeijl-Rozema *et al*, 2008). The governance process towards sustainable development is open and deliberative, allowing for the articulation of what is wanted and what is desirable (Van Zeijl-Rozema *et al*, 2008). One notable aspect of this type is that commitment to sustainable development is found throughout the society and the process to achieve sustainable development is much more important than achieving the original pre-defined goal (Van Zeijl-Rozema *et al*, 2008). The monitoring and evaluation process focuses on the sustainable development process and on how to deal with new learnings and insights (Van Zeijl-Rozema *et al*, 2008). The constraints associated with this type are the uncertainty in processes and goals, which can create challenges in setting priorities, and further deciding upon implementation, hence society might be prevented from taking any actions owing to indecisiveness (Van Zeijl-Rozema *et al,* 2008). Nevertheless, sustainable development cannot be achieved without governance, owing to its normative nature that requires collective action (Van Zeijl-Rozema *et al*, 2008).

For the purposes of this research, emphasis will be placed on “bridge sustainability” in the context of the well-being deliberative type of sustainable development, which concerns changes in behaviour so as to achieve physical environmental goals. Bridge sustainability in the context of sustainable development actively and explicitly explores ways of promoting “eco-friendly” behaviour or stronger environmental ethics (Hobson, 2003; Linden and Carlsson-Kanyama, 2003; Bhatti and Church, 2004; Frame, 2004; Barr and Gilg, 2006; Boolaane, 2006; Lindenberg and Steg, 2007; Rutherford, 2007; Vlek and Steg, 2007). Various disciplines and fields are well-represented in bridge sustainability – such as psychology, human geography, socio-ecological studies and environmental sociology – with the ultimate goal of building better bridges, or connections, between people and the bio-physical environment (Foladori, 2005). The social element in this approach reflects attempts to harness human potential so as to generate improved environmental outcomes or, as Chiu (2003) describes it, identify “the social conditions necessary to support ecological sustainability”.

In closing, measuring sustainability and, in particular, quantifying the social dimension of sustainability are difficult tasks (Assefa and Frostell, 2007). The difficulty in quantifying the social dimension of sustainability is embedded in the need to identify a definition of social sustainability that is objective. Moreover, it is not possible to reach consensus on all the various components of social sustainability (Assefa and Frostell, 2007). The social sustainability dimension is therefore approached from an angle of social acceptance. Alcorn (2003) and Social Issues and Technology (2003) both identify social acceptance as key to much research concerned with social sustainability of technical systems (Assefa and Frostell, 2007).

2.5.3. The diffusion of green infrastructure

An introduction to diffusion

Diffusion is concerned with getting ideas adopted. As with new ideas, innovations can require a lengthy period of many years to be widely adopted, especially when compared to the time it takes for new ideas/innovations to become available (Rogers, 2003).

Diffusion can be defined as the process where an innovation or idea is communicated among members of a social system through various channels of communication (Rogers, 2003). Communication, embedded in the definition of diffusion, is a process whereby participants share and create information with one another so as to reach a common understanding (Rogers, 2003). The most important elements of diffusion, according to Rogers (2003), are innovation, channels of communication followed, time concerned and the social system.

The relative speed (or time taken) for a new idea or innovation to be adopted by members of a social system is termed the rate of adoption (Rogers, 2003). Various attributes perceived by the social system are important in explaining the rate of adoption of a new idea or innovation (Rogers, 2003). There are five main attributes: compatibility, relative advantage, complexity, trialability, compatibility and observability (Rogers, 1995). There are also four additional variables: adopter types, the nature of the communication channels diffusing innovation as various stages in the innovation-decision process, the social systems’ nature in which the innovation is diffusing, and the extent of the change agents' promotion efforts in diffusing the innovation, which ultimately affects an innovation's rate of diffusion and adoption (Figure 13). The five types of variables or perceived attributes of innovations have been extensively investigated and it has been found that approximately half of the variance in innovation rates of adoption can be explained by these attributes (Rogers, 2003).

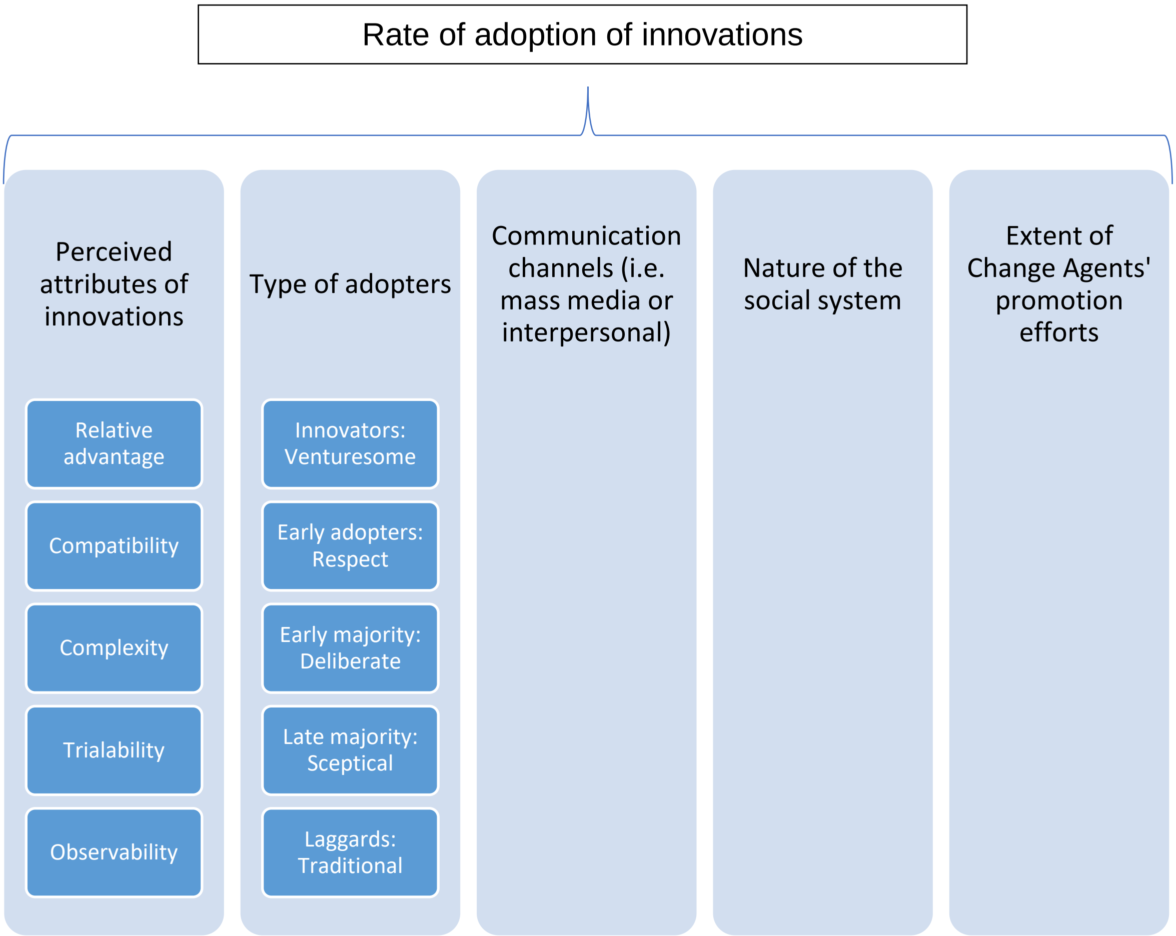

Figure 13: Variables determining the rate of adoption of innovations (Rogers, 2003)

Table 7 bellow summarizes the key aspects of adoption variables variable according to Rogers (2003).

Table 7: Key aspects of adoption variables (Rogers, 2003)

Variable	**Sub category**	**Key aspects**
	Relative advantage	- Degree to which an innovation is perceived and how it is better than a superseding idea.

Perceived attributes of innovations		- Can be expressed as economic profitability or social prestige. - The initial cost may impact its rate of adoption. - Over adoption can also take place and can be a result of prestige-conferring aspects. - Includes mainly a ratio of expected benefits and costs of adoption. - Preventive innovations refer to ideas individuals adopt in order to lower unwanted future events. - The rate of adoption can also be increased by means of offering incentives. - Mandates can exist for adoption, especially by governments.
	Compatibility	- Compatibility is concerned with the extent to which an innovation is perceived as being consistent with past experiences, values and the needs of potential adopters. - Can be compatible/incompatible with clients' needs, socio-cultural values and beliefs and previously introduced ideas. - New ideas will be evaluated in comparison to existing ideas/technologies and practice. - Innovations may be perceived collectively as an interrelated bundle of new innovations or ideas; this can trigger the adoption of other ideas. - The name of an innovation can affect its perceived compatibility and hence the rate of adoption. - Positioning an innovation is also important and an individual will behave in a similar manner towards other ideas that are perceived to be similar when applied to new ideas. Positioning of an innovation should focus on identifying the ideal niche. - Acceptance of research plays an important role in adoption of the new idea.

		- Indigenous knowledge needs to be considered when developing a new innovation or idea.
	Complexity	- Complexity refers to the level of difficulty at which an innovation is perceived to be understood and used.
	Trialability	- Trialability refers to the extent to which a new idea/innovation may be trialed or experimented with on a limited basis. - Innovations on installment plans are usually more adopted.
	Observability	- Observability refers to the extent to which results of new ideas/innovations are made visible to others.
Type of innovation decision	Innovators: Venturesome	- Adopters in this category have an obsession with innovators. - They are mainly cosmopolites. - They play a gate keeping role in the flow of new innovations and idea into a system.
	Early adopters: Respect	- In comparison to innovators, early adopters form a more integrated part of the local social systems. - Early adopters are mainly localites and are characterized by the highest degree of opinion leadership, and can therefore be used to trigger the critical mass when they adopt a new idea or innovation.
	Early majority: Deliberate	- This category adopts new ideas just before the average member of a system adopts it. - They are characterized frequent interaction with peers but seldom hold opinion leadership positions. - They represent an important link in the diffusion process given their unique location between the very early and relatively late adopters. - The innovation-decision period is longer than that of innovators and the early adopters.

	Late majority: Skeptical	- The late majority category of adopters adopts new ideas just after the average member of a system and they make out about one third of the members of a system. - Adoption of the late majority can be owing to an economic necessity and as a result of peer pressure increasing. - The pressure from peers plays an important role to motivate adoption in the late majority.
	Laggards: Traditional	- Laggards are the last adopters to adopt a new idea or innovation. - Laggards pose no opinion leadership and are the most localite of all other adopter categories. - For the laggards, decisions are made on point of reference of the past and hence what has been done previously. - Laggards interact with other individuals who also have relatively traditional values. - Apart from the laggards' innovation-decision process being lengthy, laggards also tend to be suspicious of innovations.
Communication channels	Critical mass strategies	- The target should be highly respected individuals in a system's hierarchy for initial adoption. - The perception of individuals concerning innovations can be shaped. - The new idea or innovation should be introduced to integral groups in a social system where the members are known to be more innovative. - What also needs to be considered is providing incentives for early adoption of the interactive innovation, at least until the critical mass is reached.
	Communication network	- A communication network is made up of interconnected individuals that are also linked by patterned flows of information. The subsequent links of an individual's network are important

		determinants of her or his adoption of new ideas or innovations. - Communication networks consist of communication structures, communication proximities and personal networks.
The change agent as an individual who influences clients' or customers' innovation-decisions in a direction desirable by a change agency of an innovation	The sequence of change agent roles	There are seven roles that can be identified in the process of a new idea or innovation for the change agent: - Develop a need for change; - Establish an information exchange relationship; - Diagnose problems; - Create an intent to change in the client or customer; - Translate an intent into an action; - Stabilize adoption and to prevent discontinuance; and - Achieve a terminal relationship.
	Factors in change agent success	There are certain change agents that are more successful than others. - A factor in a change agent's success is the amount of effort spent in communication. - The social position of a change agent is midway between the client system and the change agency, and subsequently is the change agent subject to role conflict. - Important for a change agent is also to diagnose the needs of clients. - The success of a change agent in securing the adoption of innovations by clients is positively related to empathy with clients
	Communication campaigns	Communication campaigns can be very effective if change agents conduct such campaigns according to appropriate communication strategies

	Homophily and change agent contact	- Homophily refers to the extent to which pairs of individuals who interact share similarities, and heterophily is the degree to which they differ. Change agents differ usually from clients in many aspects, and have the most contact with clients who are similar to themselves. - Lower-income clients need the assistance of change agents more than elite clients. - Change agents can also utilize an aide that is less than fully professional, as the case is for a change agent. - The success of change agents in securing an innovation to be adopted by a client is positively related to credibility in the eyes of a client. - Caution must be taken when an aide takes on identifying marks of a professional change agent as it can destroy the heterophily-bridging function for which aides are employed.
	The use of opinion leaders	- Opinion leadership refers to the extent to which an individual has the ability to influence the attitudes of other individuals or to steer behaviour in a desired way with a relatively high frequency. - The success of change agents in securing the adoption of innovations by customers or clients is positively related to the extent to which the change agent works through opinion leaders. - The role of demonstrations can also play an important role in the adoption of innovations. Demonstrations include experimental demonstrations that are conducted to evaluate the effectiveness of an innovation or new idea in a certain field or testing conditions and exemplary demonstrations. Exemplary demonstrations are conducted to facilitate diffusion of innovations to other units (Myers, 1978).

	Client's evaluative ability	- The unique inputs of change agents to the adoption of innovations are technical competence. - The success of change agents in securing the adoption of innovations by customers or clients is positively related to the ability of customers and clients to evaluate innovations.
	Centralized and decentralized diffusion systems	- Centralized diffusion systems are mainly based on a one-way, linear model of communication, whereas decentralized diffusion systems more closely follow a convergence model of communication, where participants in the process share and create information in order to reach a mutual understanding (Rogers and Kincais, 1981).

2.5.4. Diffusion of green infrastructure as eco-innovations

The term "eco-innovation" is defined by the Organization for Economic Co-operation and Development (OECD) as "the development of products (goods and services), processes, marketing methods, organizational structure, and new or improved institutional arrangements, which, intentionally or not, contribute to a reduction of environmental impact in comparison with alternative practices" (OECD, 2009). Eco-innovation is regarded as being multi- and trans-disciplinary, similarly to innovation, paving the way towards the use of different expressions related to similar approaches, such as environmental innovations, green innovations, sustainable innovations and eco-innovations (Boons and Ludeke-Freund, 2013; Bossle, 2015; Fagerberg, 2005; Santolaria *et al*, 2011)

Eco-innovation can contribute to positive trade-offs between environmental attributes and critical success factors such as design, style and performance (Bossle, 2015). Eco-innovations should also have a resultant positive impact on consumption and organizational practices, and comprise economic, social and environmental dimensions in the adoption and implementation process in order to ensure success in a sustainable development (Bossle, 2015; Hellstrom, 2007). Eco-innovations have also been documented in research as a way to improve environmental and/or social performance (Arnold and Hockerts, 2011; Carrillo-Hermosilla *et al*, 2010; Chang and Chen, 2013; Huang *et al*, 2009 and Verghese and Lewis, 2007). Essentially, innovation in green products is a way of integrating sustainability and innovation and is regarded as a potential key factor for achieving increased growth rates for companies and organizations (including parastatals) and resulting in a better life for society (Dangelico and Pujari, 2010).

There are various drivers and motivations for the adoption of eco-innovations, their sources and definitions (Bossle, 2015). Table 8 summarizes these various drivers (internal and external factors and control variables) and motivations regarding the adoption of eco-innovations by organizations and industries.

Table 8: Drivers and motivation for the adoption of eco-innovations

Factors	Definition	Sources
	External Factors	
Regulatory pressures	Determined by governments, and noncompliance with statutory regulations can result in unforeseen costs (Bossle, 2015)	Arnold and Hockerts, 2011; Azzone and Noci, 1998; Beise and Rennings, 2005; Bergquist and Soderholm, 2011; Berrone *et al*, 2013; Cainelli *et al*, 2012; Carrillo-Hermosilla *et a*l, 2010; Chappin *et al*, 2009; Chen *et al*, 2012; Demirel and Kesidou 2011; Green *et al*, 1994; Horbach 2008; Horbach *et al*, 2012; Huang *et al*, 2009; Kesidou and Demirel 2012; Huber 2008; Oltra and Jean 2009; Paraschiv *et al*, 2012; Weng and Lin 2011; Qi *et al*, 2010
Normative pressures	Normative pressures are related to the issue of legitimacy and how organizations compare themselves to competition and subsequently try to behave in accordance to norms and standards prevalent in the institutional field in which they function (Bossle, 2015). Normative pressures also include market demand by clients,	Beise and Rennings, 2005; Bergquist and Soderholm, 2011; Berrone *et al*, 2013; Chen *et al,* 2012; Gauthier and Woolridge, 2012; Huang *et al*, 2009; Kesidou and Demirel, 2012; Huber, 2008; Oltra and Jean,

	suppliers, societal demands and environmentalists (Bossle, 2015).	2009; Paraschiv *et al*, 2012; Wend and Lin, 2011
Cooperation	Cooperation refers to cooperation of organizations and institutions with suppliers, competitors, clients, universities, technological centres, consultants and research and development public and private laboratories (Bossle, 2015).	Bergquist and Soderholm, 2011; Buttol *et al*, 2012; Cainelli *et al*, 2012; Carrillo-Hermosilla *et al*, 2012; De Marchi, 2012; Geffen and Rothenberg, 2000; Green *et al*, 1994; Horbach, 2008; Huber, 2008; Verghese and Lewis, 2007
Expanding markets	Expanding markets act as an incentive for organizations and companies to invest in eco-innovation and relevant market shares (Bossle, 2015).	Green *et al*, 1994
Technology	Technology is characteristic of the technology environment as part of the organizational development and growth of industries and organizations (Bossle, 2015).	Oltra and Jean, 2009; Geffen and Rothenberg, 2010
The role of governments	Governments are required to develop new campaigns and initiatives aimed at increasing the level of environmental awareness associated with initiatives (Bossle, 2015).	Azzone and Noci, 1998
	Internal Factors	
Efficiency	Efficiencies refer to cost savings from environmental improvements, motivations required for equipment upgrades and research and development investments together with environmental management systems.	Brunnermeier and Cohen, 2003; Berrone *et al*, 2013; Chappin *et al*, 2009; De Marchi, 2012; Demirel and Kesidou, 2011; Green *et al*, 1994; Horbach, 2008; Horbach *et al*, 2012; Kesidou and Demirel, 2012; Rennings *et al*, 2006; Theyel, 2000; Tseng *et al*, 2013; Verghese and Lewis, 2007; Weng and Lin, 2011

Adoption of certifications	Certain certifications, such as ISO 14001, introduce the adoption of an environmental management systems and total quality management systems for ISO 9001 (Bossle, 2015).	Arnold and Hockerts, 2011; Azzone and Noci, 1998; Demirel and Kesidou, 2011
Environmental managerial concerns	Top executives in an organization or industry play a vital role in adopting eco-innovation and in the integration of innovation and sustainability into the strategy of the company (Bossle, 2015).	Arnold and Hockerts, 2011; Chang, 2011; Eiadat *et al,* 2008; Qi *et al*, 2010; Tseng *et al*, 2013.
Environmental leadership	Environmental leadership entails a dynamic process where one individual influences another to contribute to achieving environmental innovations and management (Bossle, 2015).	Arnold and Hockerts, 2011; Chen *et al*, 2012; Huang *et al*, 2009; Paraschiv *et al*, 2012.
Environmental culture	Environmental culture refers to a symbolic context of environmental innovations and management within which interpretations guide processes of members' sense making and behaviours (Bossle, 2015).	Chang *et al*, 2013; Chen *et al*, 2012; Paraschiv *et al*, 2012
Environmental capability	Environmental capability refers to the ability of organizations and industries to coordinate, integrate, reconfigure and build their competences and resources in order to accomplish their environmental innovations and management goals (Bossle, 2015).	Berrone *et al*, 2013; Chen, 2008; Chen *et al*, 2012
Human resources	Human resources include employee participation in the training and innovation so that companies and industries can employ and retain high quality staff (Bossle, 2015).	Arnold and Hockerts, 2011; Cainelli *et al*, 2012; Green *et al*, 1994; Paraschiv *et al*, 2012; Theyel, 2000; Weng and Lin, 2011
Performance	Performance includes measures taken for sales growth, return on investment and market share.	Eiadat *et al*, 2008; Tseng *et al*, 2013
	Control Variables	

Size	The size of the organization of industry refers to the structural characteristics that boost green innovations (Bossle, 2015).	Berrone et al, 2013; Chen, 2008; De Marchi, 2012; Demirel and Kesidou, 2011.
Public financing	Public financing plays an important role in in fostering eco-innovation introduction by subsidizing and training (Bossle, 2015).	Bergquist and Soderholm, 2011; De Marchi, 2012; Horbach, 2008; Weng and Lin, 2011
Sector	The sector in which organizations and industry find themselves influences their impact on the environment and the choice of what potential eco-innovations to adopt (Bossle, 2015).	Berrone *et al*, 2013; De Marchi, 2012; Horbach, 2008.

CHAPTER 3: CASE STUDY BACKGROUND

3.1. Case study introduction

The two case studies, on which this research was based, were floating treatment wetland installations in Modderfontein Nature Reserve and Rockville, Soweto (at Moroka Dam), both of which are situated in the City of Johannesburg, Gauteng, South Africa.

3.1.1. Modderfontein Nature Reserve

Modderfontein Nature Reserve is a 275-hectare private park and is the second largest private park in the Gauteng Province (Modderfontein Reserve, 2016). The Modderfontein Nature Reserve includes a number of dams and portions of the Modderfontein Spruit, and is characterized by hills and grasslands (Modderfontein Reserve, 2016) (refer to Figure 14). Modderfontein Nature Reserve is located north-east of Sandton in the City of Johannesburg, Gauteng, South Africa (Figure 15).

Figure 14: Modderfontein Nature Reserve Map (Modderfontein Reserve, 2016)

Figure 15: City of Johannesburg locality map (Johannesburg-Venues, 2016) and localities of installed floating treatment wetlands

Modderfontein Nature Reserve was initially the site by the Modderfontein Village, which was established in 1894 during the gold mining rush in South Africa (Modderfontein Reserve, 2016). Owing to the escalating gold mining activities in South Africa, there was a need to manufacture and subsequently sell dynamite, and this saw the establishment of the Modderfontein Dynamite Factory (originally constructed by Germans) (Modderfontein Reserve, 2016). The reserve was later established by AECI, which identified the need for a reserve and subsequently tasked Heartland to formalize the area (Modderfontein Reserve, 2016).

3.1.1.1. Floating treatment wetland installations in Modderfontein Nature Reserve

Two floating treatment wetlands (Figures 16 and 17), where developed and installed by the researcher during 2015. One floating treatment wetland was $10m^2$ and the other $30m^2$.

Figure 16: The first floating treatment wetland installed in Modderfontein Nature Reserve (Photo: Yolandi Schoeman, Modderfontein, 28 August 2015)

Both floating treatment wetlands were installed during Autumn/Winter 2015. Although the growth of the plants slowed down– because of the dormant winter growing season – full growth and recovery were observed during Spring 2015 and Summer 2016. Within a month of the islands being established, birdlife activity was observed to increase on the floating treatment wetlands. Additional nesting material had to be introduced on the first island to make provision for breeding activities. It was interesting to note that the roots of the plants used on the islands, which extended into the water, were not affected by fish activity in the dam. In conjunction with the introduction of treatment wetland islands in Modderfontein Nature Reserve, independent testing was done off-site on the phytoremediation properties of plants used. The tests indicated elevated removal of contaminants such as aluminium, iron and manganese from the water (amongst other contaminant removal) (GTRC, 2015).

Figure 17: Floating treatment wetland islands installed at Modderfontein Nature Reserve, 2015 (Photo: Yolandi Schoeman, Modderfontein, 04 February 2016)

3.1.2. Moroka Dam, Rockville, Soweto

Moroka Dam – previously known as Soweto Dam, the dam's name was later changed (from Soweto Dam) to Moroka Dam after Dr Moroka, who was a former president of the African National Congress (De Jager, 2012) – is located in the City of Johannesburg in Soweto and forms part of Thokoza Park (Figure 18). The dam was created in 1960, by means of an earth embankment under Vundla Drive, and was frequently used for swimming, picnics and as a meeting place by socialites of the area (De Jager, 2012). Following 1980, the dam and park area fell into deterioration owing to maintenance challenges and the subsequent moral decay as the area was taken over by criminal elements (De Jager, 2012). Today, however, Thokoza Park is a prime attraction in Rockville, Soweto, and is a well-used and maintained park that covers 4.5 hectares (Johannesburg City Parks and Zoo, 2016).

Figure 18: Map of Soweto and locality of installed floating treatment wetland

3.1.2.2. Floating treatment wetland installations at Moroka Dam

Two floating treatment wetland islands (Figures 19) were installed during March 2016 on Moroka Dam, Soweto. The size of each island was 20m^2 and contained 100 indigenous plants with known phytotechnological properties. The two islands were installed as part of National Water Week celebrations during March 2016 together with the City of Johannesburg, the Resolution Circle, University of Johannesburg and Johannesburg City Parks.

Following a visit to the two islands installed in May 2016, the researcher discovered a nest with nine eggs in it, and the root growth of some species of plants was extraordinary (Figure 20).

Figure 19: Installing two floating treatment wetlands on Moroka Dam, Rockville, Soweto (Photo: Yolandi Schoeman, Soweto, 17 March 2016)

Figure 20: Eggs discovered and impressive root growth (Photo: Yolandi Schoeman, Soweto, 17 March 2016)

3.2. City of Johannesburg

3.2.1. Climatology

Temperature

Current average temperatures (Figure 21) in the City of Johannesburg peak from 20^{0}C in January to a minimum of 10^{0}C in June, and then climb up to just below 20^{0}C in December (SoER, 2003; Engelbrecht, 2005). Important to note is the expected temperature increase for the City of Johannesburg for the period 2070-2100, ranging from 1^0 to 3^{0}C in summer and 1^0 to 2^0 in winter (Figure 21) (SoER, 2008).

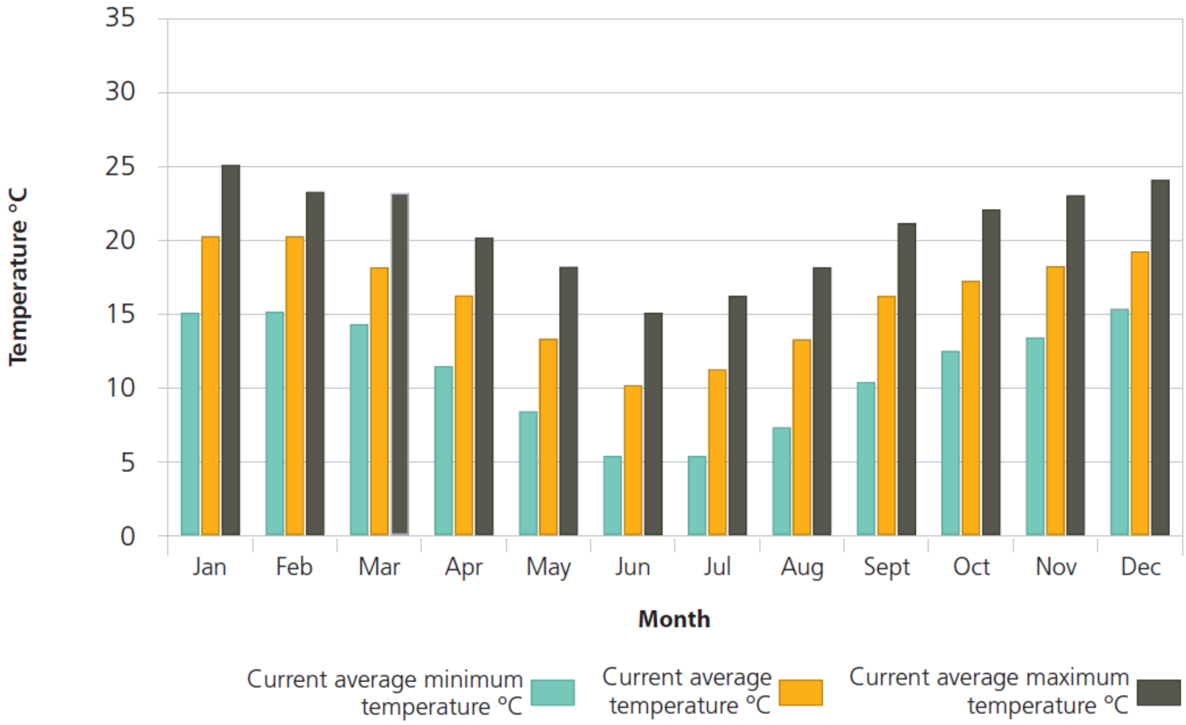

Figure 21: Current (1960 – 2000) and future (2070 – 2100) temperature trends (SoER, 2003; Engelbrecht, 2005)

Rainfall

Current average rainfall (Figure 22) for the City of Johannesburg ranges from 125mm during January, to 5mm during August, to 110mm in November (SoER, 2008).

Simulations on climate change predictions have been completed based on changing climatic conditions. It is expected that summer rainfall (December – February) will remain similar to the present day; however, small increases of 20% are expected to take place (Engelbrecht, 2005), or increases from 15 to 25mm (Hewitson and Crane, 2006). March to May (indicating early winter season) could continue the present trend of rainfall, with potential decreases in the range of 20 to 30% (Engelbrecht, 2005). It can be expected that from June to August (winter season), there will be either a continuum of current rainfall conditions (Engelbrecht, 2005), or a very slight increase expected in the mean monthly precipitation (between 5 and 10mm) (Hewitson and Crane, 2006). Considering the simulations for spring (September to November) with regard to rainfall, a different picture can be expected: 40 to 80% approximate decreases in rainfall (during September) to a possible increase to as much as 40% in November (Engelbrecht, 2005).

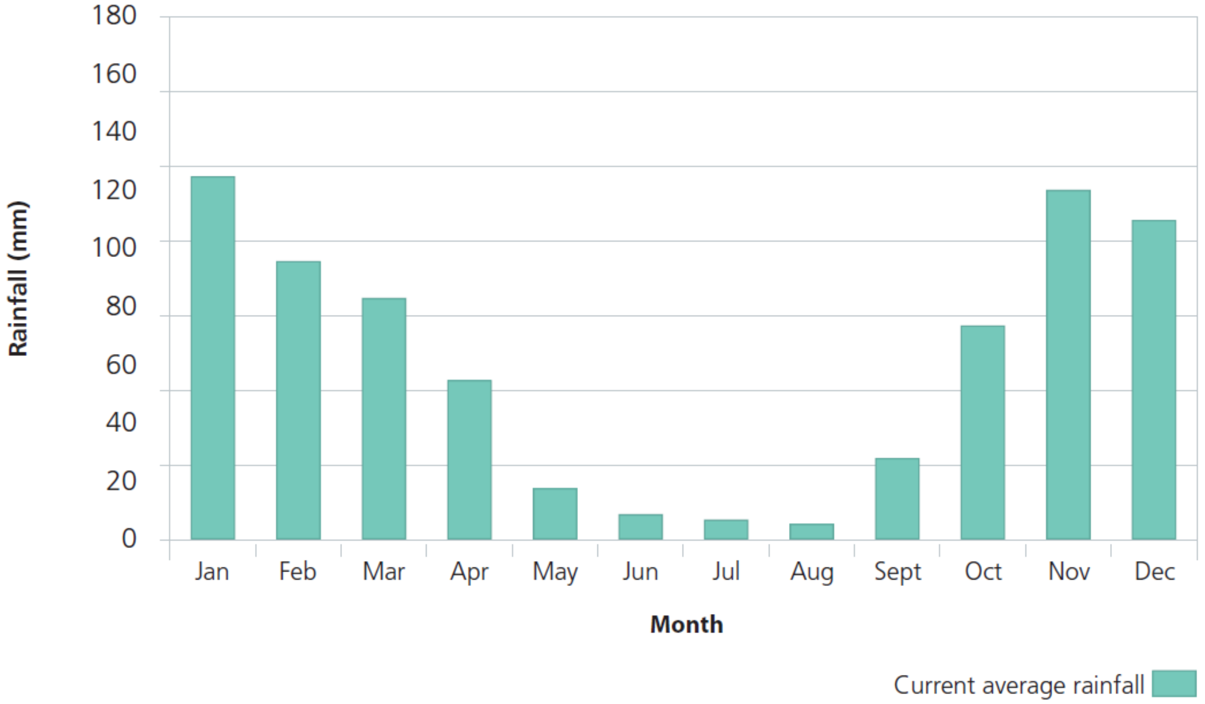

Figure 22: Current (1960 – 2000) rainfall trends (Engelbrecht, 2005; Hewitson and Crane, 2006)

Potential climate change impacts expected for water resources

The City of Johannesburg is already experiencing pressure on its water resources because of population growth, water pollution and urbanization (SoER, 2008). Poor wastewater management in informal areas also exerts pressure on the city's water resources together with ineffective waste management that further causes an increase in polluted storm water run-off (SoEr, 2008). What is inevitable is an increase in the price of water, wastewater disposal problems and the presence of waterborne diseases because of the changes in demand, quality and supply of water during drought periods, extreme events and flooding occurrences (SoER, 2008). In addition, an elevated impact is also to be expected on aquatic ecosystems and human health due to leaks, blockages and sanitation services capacity constraints that will further contribute to surface water pollution (SoER, 2008).

3.2.2. State of green infrastructure

Green infrastructure can be seen as a way to support and sustain society through natural and man-made ecological features that are components of an infrastructural fabric (Schaffler, 2013). Green infrastructure has thus emerged as a means of attaching values to green assets serving as infrastructure (Schaffler, 2013). Through green infrastructure planning, ecosystem services are enhanced and created, and can assist society in functioning in the face of ecological, climatic and infrastructural challenges (Schaffler, 2013). Ecosystem services that are of benefit to humans include air purification, reduction of erosion, disaster risk mitigation and prevention, water flow regulation, and provision of green space for growing food, a relaxing environment, wildlife habitat and ecosystems that support biodiversity (Schaffler, 2013).

Green infrastructure in the City of Johannesburg refers to an interconnected set of man-made and natural ecological systems that include green spaces and other landscape features (Schaffler, 2013). Specifically, it refers to indigenous and planted trees, parks, wetlands, green open spaces, parks, original woodlands and grasslands and possible street-level design and building interventions that incorporate vegetation, such as green roofs and vertical gardens (Schaffler, 2013). All the green infrastructure assets form an interrelated network that provides strategic functions and services similar to “hard” or grey infrastructure (Schaffler, 2013).

It remains a challenge for the City of Johannesburg infrastructure to cater for a growing population and economy (Seedat, 2013). It is also difficult to meet the expanding demand for urban services given the resource constraints experienced in the context of historically dysfunctional, inequitable and sprawling urban settlement patterns (Seedat, 2013). The challenge is further exacerbated by ever growing volumes of industrial and domestic waste and an increase in water, air and land pollution (Seedat, 2013).

In Table 9 below, the City of Johannesburg is compared to other municipalities in the Gauteng province regarding current infrastructure.

Table 9: Number of square kilometres of each land cover class in specific municipal areas in Gauteng (GTI, 2012)

Land cover class	**Westonaria**	**Johannesburg**	**Tshwane**	**Total Gauteng**
Buildings	1	23	17	60
Building (School)	0	3	2	10
Building (Campuses)	0	0	0	1
Sport Stadiums	0	0	0	0
School Grounds	0	18	17	64
Sports and Recreation	0	7	5	22
Golf Courses	1	9	9	33
Industrial	1	21	17	84
Heavy Industrial	0	1	2	11
Residential (Cluster)	0	30	17	62
Residential (Residential and planned)	3	113	115	356
Township (Formal)	1	66	38	209
Township (Informal)	1	12	56	94
Small Holdings	19	89	362	902
Roads	8	132	149	516
Rail	0	1	3	11
Thicket, Bushland and Bush Clumps	8	2	842	1071
Forest (Indigenous)	2	43	206	370
Trees (Non-Natural and Planted)	14	226	188	779

Grassland (Natural and Planted)	354	508	2693	7811
Wetlands	28	51	202	716
Degraded Natural Vegetation	2	5	38	91
Cultivated Commercial (Irrigated)	9	9	64	236
Cultivated Commercial (Dryland/Rainfed)	145	50	865	3314
Mines and Quarries	19	34	46	261
Open (Little or No Vegetation, Parking Lots, Bare Sand)	12	173	196	720
Water	1	7	37	150
Bare Rock and Soil	9	11	105	217
New Development	0	1	4	10
Total	640	1645	6298	18182

Natural vegetation

The natural vegetation coverage in the Gauteng Province corresponds to the grassland biome, which is the second largest biome in South Africa, covering the central interior of the country (Schaffler, 2013). Temperate inland grasslands and Highveld grasslands are naturally occurring, along with various other indigenous vegetation types such as thicket, indigenous forests, shrub land and bush clumps (Figure 23).

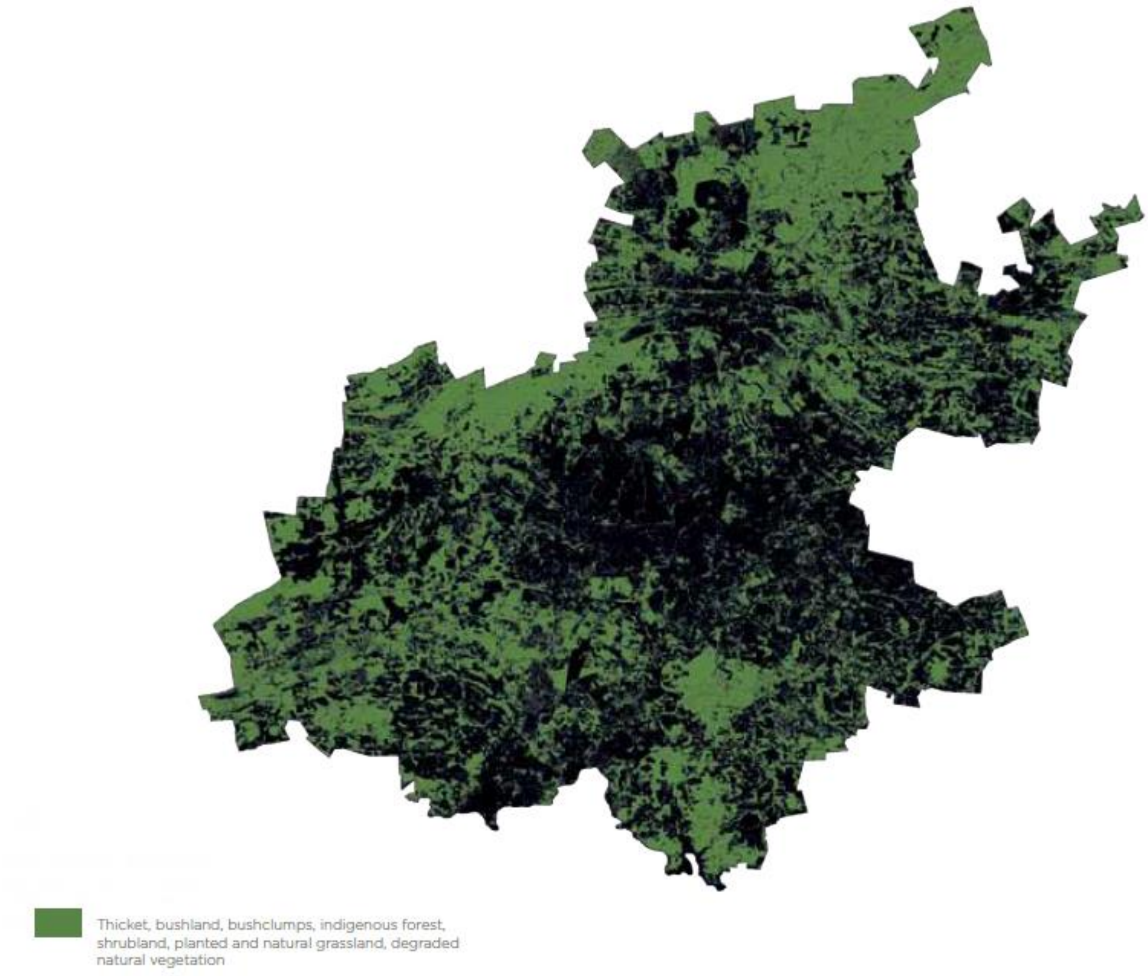

Figure 23: Natural vegetation coverage in the Gauteng Province (Schaffler, 2013)

The City of Johannesburg's land coverage for thicket, bushland and bush clumps amounts to 0.19% when compared to the total coverage in the Gauteng Province (Schaffler, 2013). Indigenous forest land cover amounts to 12%, grassland (natural and planted) amounts to 7% and the total tree (planted and natural) land cover coverage amounts to 29%.

Hydrological networks

Broader ecological processes are supported by hydrological networks that play a determining and supporting role in their functioning, benefiting both the environment and humans (Schaffler, 2013). Various hydrological features make up an integrated hydrological network (Schaffler, 2013). The integrated hydrological network of the Gauteng Province is represented in Figure 24. Hydrological features here include regional non-perennial and perennial rivers, manmade water infrastructure (including dams, reservoirs and other water bodies) and RAMSAR sites (such as the Blesbokspruit in the eastern part of Gauteng Province) (Schaffler, 2013).

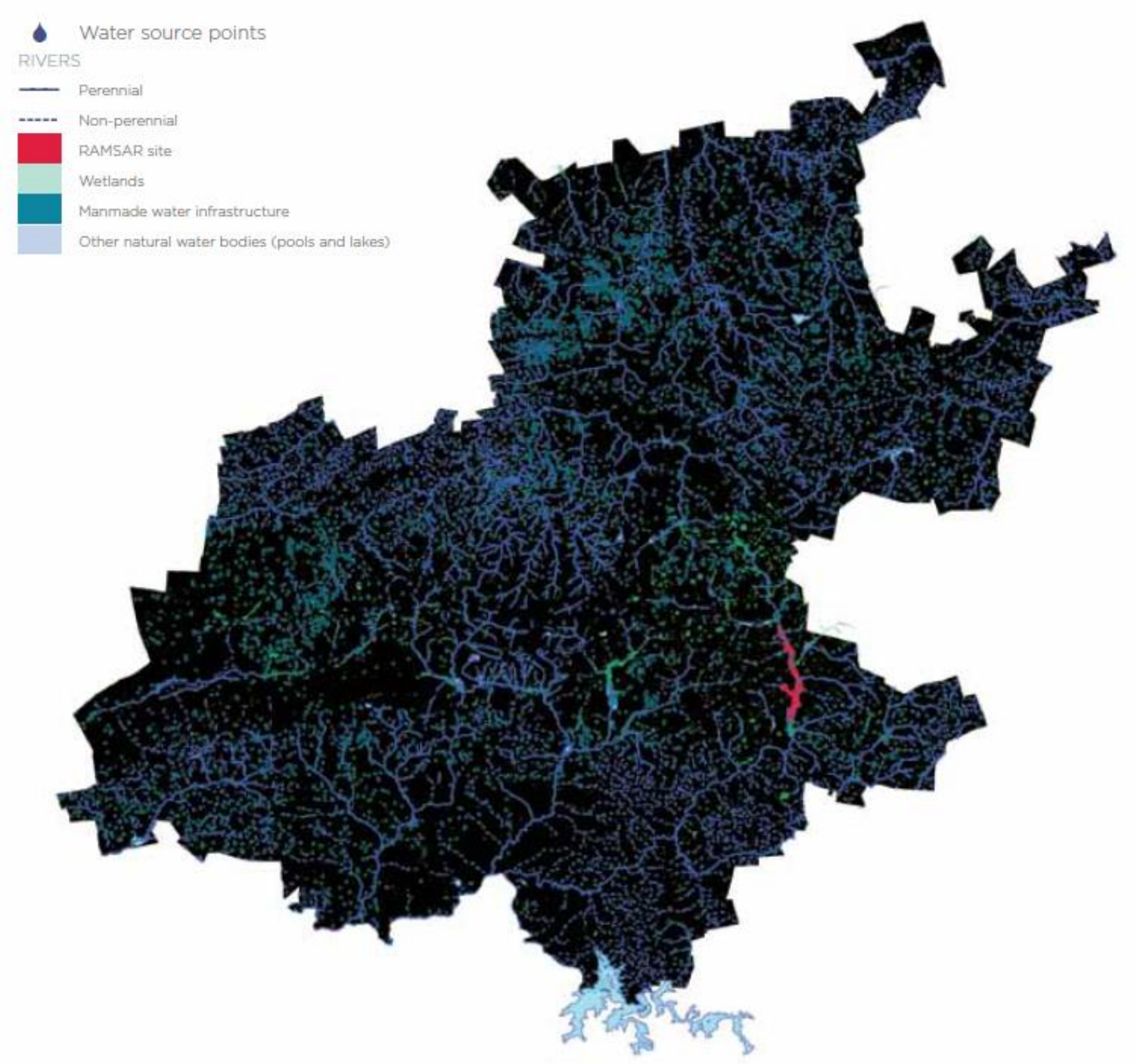

Figure 24: The hydrological network in the Gauteng Province (Schaffler, 2013)

Despite the view that water policies in South Africa are regarded to be some of the most progressive in the world, the hydrological network in the Gauteng Province is subjected to various challenges brought about by poor management of man-made and natural hydrological systems, together with poor enforcement and implementation of water legislation (Schaffler, 2013). Of all the challenges that currently affect the Gauteng Province, water quality and supply are amongst the acute (Schaffler, 2013).

In addition, the main development nodes of Gauteng Province are located a significant distance away from sustainable and large water sources, a situation that is aggravated by the blanketing of its hydrological networks with characteristically built forms, consequently altering natural flow regimes (Schaffler, 2013). Furthermore, water quality and water availability are compromised in this province by short-sighted development activities, cynical abuse of water legislation and the degradation of water bodies including wetlands and aquatic ecosystems (Schaffler, 2013). Examples of activities that contribute to water quality and availability challenges include acid mine drainage polluting various water bodies and wastewater contamination through poorly managed man-made water infrastructure (Schaffler, 2013). Ecosystem services (including the functioning of hydrological systems) are thereby significantly altered and impacted upon when considering the environmental problems affecting downstream water users (Schaffler, 2013).

Green infrastructure can play a crucial role in remediating and addressing faltering ecosystem services (Schaffler, 2013). Certain plants and tree species have phytoremediating properties that can aid in addressing soil and water contamination by removing toxic substances in a natural way (Schaffler, 2013).

City of Johannesburg: plans, visions and capabilities for green infrastructure

The profile of the City of Johannesburg is both interesting and controversial (Schaffler, 2013). The Witwatersrand initially had no gardens, no parks, no trees and savannah grassland; some native woodland areas and scattered bushveld were characteristic of the natural landscape (CoJ, 2012; CoJ JCP, 2012; Schaffler, 2013).

Today, the City of Johannesburg is home to an extraordinary ecological asset, the world's largest urban forest, which has grown to 10 million trees interspersed with public and private green space areas (CoJ, 2008).

Indeed, there is a significant proportion of planted green space in the City of Johannesburg when compared to natural green space, as illustrated by Figure 25, thus although there is an overall high share of green space, a significant portion is not necessarily naturally occurring (Schaffler, 2013).

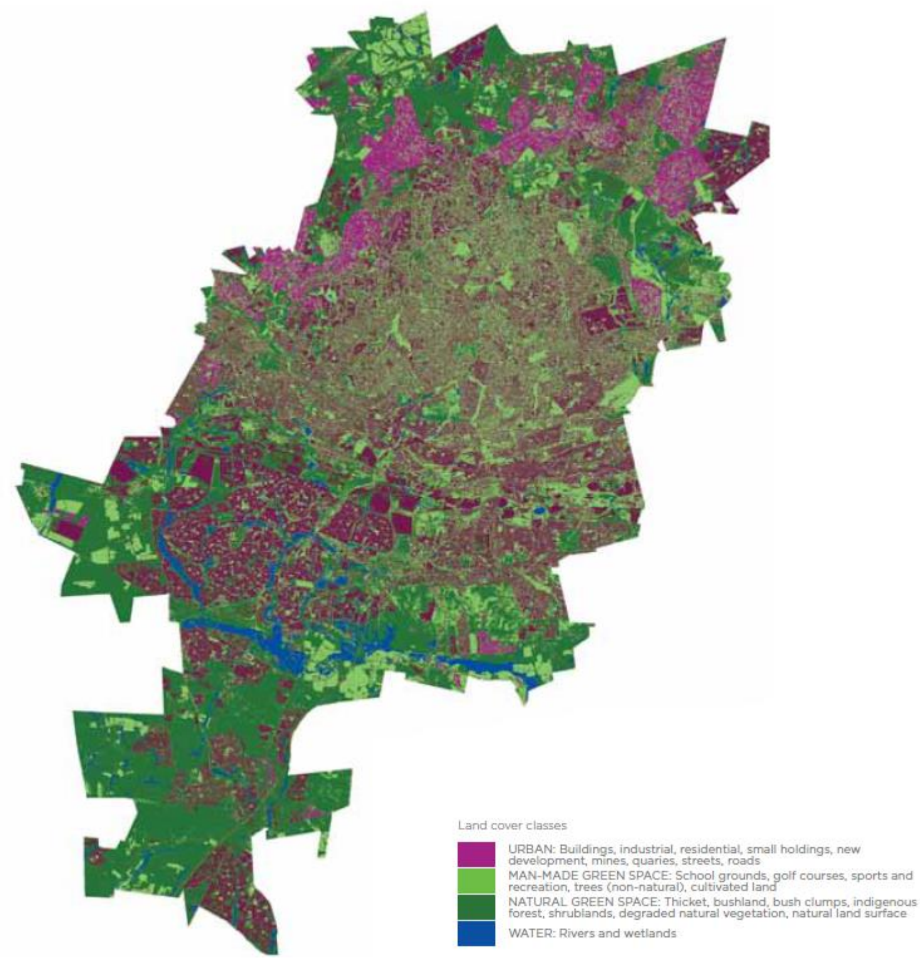

Figure 25: Overview of land cover classes in the City of Johannesburg (Schaffler, 2013)

In reviewing the literature, it is clear that the efforts of the City of Johannesburg to conserve green spaces and biodiversity is underpinned by an explicitly equity rationale, with access appearing as a key determinant and precondition for green space planning (CoJ JCP, 2012). However, the processes and decision-making structures seem to be key challenges for the City of Johannesburg, together with an additional challenge of overlapping and/or mixing of responsibilities for the drafting of policies (Schaffler, 2013).

Schaffler (2013) argues that the City of Johannesburg does not adequately emphasise the purpose of green infrastructure to address current sustainability challenges, in that greening activities and initiatives are often seen as a means to address and facilitate recreational opportunities and assist in redressing ecological disparities. Further, “greening” seems to serve social development objectives more than ecological-economical objectives, and it is not clear from literature whether the City of Johannesburg is considering ecological functions of greening projects that can benefit the broader landscape (Schaffler, 2013). Indeed, although there are conservation strategies where investments are made that embrace the role of indigenous vegetation together with the maintenance of ecological processes, they do not form part of broader infrastructure planning strategies but rather of conservation strategies (Schaffler, 2013).

The current perceptions of ecological assets and subsequently green infrastructure are also mixed (Schaffler, 2013). Progressive officials that promote green infrastructure as an alternative strategy are often challenged by a set of perceptions, standard daily operations and planning cultures that stunt innovation in the green infrastructure space (Schaffler, 2013). Officials and managers of the City of Johannesburg experience obstacles when they attempt to demonstrate the benefits associated with green infrastructure solutions, especially when they are faced with everyday operations that promote concrete canals, gabions and steel reinforcing with the objective of dealing with “urban flooding” (Schaffler, 2013).

These daily operations, together with cultural and cognitive reluctance to abandon business as usual, create a situation in which the officials of the City of Johannesburg become sceptical and reluctant to entertain alternative infrastructure options, with various officials indicating without detailed evidence that “green infrastructure methods are expensive” (CoJ JRA Official, pers. comm., 2012). Below are excerpts supporting this current cultural and cognitive reluctance to abandon business as usual:

“ …on the other hand, the problem is that you have engineers who, in most cases, do not want to change and adapt to new ways of thinking….” (CoJ Official, pers. comm., 2012). “Most traditional engineers think if you use, for example, street swales or buffer strips for drainage, you then have a situation where you constantly have to maintain these and as a result incur more cost you would have avoided if you provided concrete paving” (CoJ Official, pers. comm., 2012). “…even the notion of implementing green roofs or gardens raises a lot of concerns. For those trees to grow, tons of soil will have to be loaded on the building roofs that were not initially designed for such mass. With rainfall, this mass will even be doubled. Now you can imagine the effect this will have on the building. So, to have such initiatives will require that more money is spent to ensure that we do not have buildings collapsing in the next few years" (CoJ JRA Official, pers. comm., 2012). "…our role is to ensure that the surface of the road gets dry as quickly as possible after rainfall. Now, I am not sure if having green servitudes will appropriately serve this purpose " (CoJ JRA Official, pers. comm., 2012)

CHAPTER 4: METHODOLOGY

4.1. Introduction

This chapter describes the methodology used in the study. This study is designed as a qualitative research project with a qualitative research approach. Davis (2014) explains that qualitative research presents interpretive data, and typically consists of data that is difficult to quantify, such as interview transcripts and field notes of non-verbal communication, drawings or film (Van Griensven *et al*, 2014). Qualitative research also concerns itself with meanings, social context and personal experiences (Snape and Spencer, 2003). It is typically inductive, where the theory derives from the data rather than being predetermined and verified by the researcher (Van Griensven *et al*, 2014). It is also possible to make a quantitative analysis of qualitative information, for instance by counting how often a particular word is used in an interview or identifying its proximity to other key words (Van Griensven *et al*, 2014). However, qualitative researchers suggest that this process cannot be done without a significant loss of meaning and depth contained in the data (Van Griensven *et al*, 2014). As such, researchers instead prefer to immerse themselves in their data in order to gain an intimate understanding of what their participants say, do or experience (Van Griensven *et al*, 2014). Thus, the main rationale for applying the qualitative research approach in the research is to obtain an in depth understanding of what certain stakeholders say, do or experience in terms of social sustainability of floating treatment wetland systems.

In summary, the qualitative component of the research that will be utilized by the researcher will consist of questionnaires and in-depth interviews (together with the use of forum discussions) with selected stakeholder groups for the purpose of investigating the social sustainability of floating treatment wetlands. It is envisaged that this study will contribute to a deeper understanding of the concept of social acceptance as well as assist in identifying constraints and solutions that will impact upon further development and implementation of the floating treatment wetlands.

4.2. Philosophical foundations

A qualitative research method was used in this study owing to the interest the researcher has in the depth of the human experience (Strydom and Bezuidenhout, 2014). The study used interpretivist/constructivist procedures, where the theoretical lens the diffusion of innovation theory was used as the overarching perspective within the research design, which relied upon qualitative data collection methods. The researcher selected this approach because theories on the sustainability of floating treatment wetlands are scarce, and there exists a need for these theories to be developed, as well as a need for new thoughts around the topic and, consequently, new patterns of argumentation (Strydom and Bezuidenhout, 2014).

Together with the use of interpretivist / constructivist procedures, the use of a case study in the Modderfontein Nature Reserve formed the foundation of the study together with a case study in Soweto, Rockville. An attempt was made to understand the diffusion process of floating treatment wetland technology in an urban setting. Thus, focus group meetings were held at the Modderfontein Nature Reserve, where two floating treatment wetlands were installed by the researcher. The study then made use of further field research methods, including an additional focus group meeting and interviews investigating the diffusion process of floating treatment wetland technology, involving other selected stakeholders involved with water quality enhancement and management.

The fundamental aims of this investigation were to create awareness of floating treatment wetlands as a biotechnology; to investigate levels of acceptance of floating treatment wetlands, identifying the barriers to acceptance, understanding the sustainability components and needs; and ultimately developing a conceptual model of a floating treatment wetland system specifically adapted for South Africa to be used as a tool for water quality enhancement. This tool may be utilized by water managers, municipalities, consultants and other professionals concerned with challenges in water quality and the development and implementation of floating treatment wetlands.

4.3. Objectives of the research

The broad objective of this research was to investigate the social sustainability (through the process of diffusion) of floating treatment wetlands in South Africa as a tool in water quality enhancement in the context of integrated watershed management. The social sustainability was investigated by testing the acceptance of such systems, their applicability to various water challenges and assessing the social, economic and environmental components.

4.3.1. Specific objectives

The following were the specific objectives of this research:

(a) To identify the factors contributing to the diffusion of floating treatment wetland technology amongst various stakeholders;

(b) To identify the process of diffusion to be followed that will contribute to the widespread acceptance of floating treatment wetland technology as a tool in water quality enhancement; and

(c) To investigate the sustainable development components of floating treatment wetland technology in South Africa by selected and strategic stakeholder groups.

4.4. Research design

4.4.1. Definition of qualitative research

Creswell (2003) defines the qualitative research approach as one where the researcher makes knowledge claims that are mainly based on perspectives that are constructivist, meaning making knowledge claims on multiple meanings based on individual experiences. Multiple meanings can also be historically and socially constructed with the ultimate intent of developing a pattern or theory (Creswell, 2003). Creswell (2014) further defines qualitative research as an approach where the meaning individuals attach to some human or social problem is explored and understood. In this approach, a process must be followed that can include emerging procedures and questions, data collection, data analysis and data interpretations of the collected data (Creswell, 2014).

The qualitative approach can also include participatory/advocacy perspectives, including issue-, change-, political- or collaborative-oriented perspectives, and can simultaneously consider constructivist perspectives (Creswell, 2003). Strategies of inquiry utilized by the qualitative approach include narratives, ethnographies, phenomenologies, case studies or grounded theory studies (Creswell, 2003). The primary intent of the qualitative research approach is the collection of open ended and emerging data (Creswell, 2003).

Creswell (2003) identifies several practices that the researcher uses during the qualitative research approach. The researcher:

- Collects participant meanings;
- Brings personal values into the study;
- Validates the accuracy of findings;
- Positions him- or herself;
- Interprets the data;
- Creates an agenda for reform or change; and
- Collaborates with the participants.

Bogdan and Bilken (1992) divide qualitative research into two main categories, namely participant observation and in-depth interviewing. With regards to participant observation, Bogdan and Bilken (1992) refer to data that is gathered in an environment that promotes natural behaviour. In depth interviewing, in contrast, includes open ended questions that are used by the researcher to obtain as much detail as possible concerning the research (Bogdan and Bilken, 1992).

In addition to their categorization of qualitative research, the Bogdan and Bilken (1992) identify five prominent features of qualitative research. These features are:

- Naturalistic: Researchers aim to find themselves into a certain environment, where they bring with them take note-making equipment to observe and understand the aspect they are researching.
- Descriptive data: In qualitative research, numbers are not as important as pictures and words, and often includes descriptive data in the form of quotations by participants for illustration and to substantiate particular findings.
- Concern with process: For researchers conducting qualitative research, the process concerns researchers more than the outcomes.
- Inductive: During the research analysis process, qualitative researchers analyze data inductively and do not aim to find data to disapprove or approve a particular hypothesis that was drafted before the research commenced.
- Meaning: The perspectives of participants that participate in the qualitative research are important, and researchers can present their data to participants in the form of transcripts and recorded material. What can also become an important component of qualitative research is the interaction between the participants or informants and the researcher.

Creswell (2014) discusses further characteristics of qualitative research that can convince many stakeholders of its legitimacy as qualitative design. Creswell’s observations are supported by Creswell (2013), Hatch (2002) and Marshall and Rossman (2011).

These characteristics include:

- A natural setting: Researchers that use qualitative research approaches tend to collect data, where participants in the research experience a certain problem or issue. The natural setting provides for face-to-face interaction and observation of behaviour within the participants’ context.

- Researcher as key instrument: Qualitative researchers collect data through observing behaviour, interviews with participants and examining documents.
- Multiple sources of data: Multiple forms of data are used by qualitative researchers, such as observations, documents, audiovisual information and interviews. Reliance is not place on one single source of data.
- Inductive and deductive data analysis: Qualitative researchers organize the data into abstract units of information by means of building categories, patterns and themes from the bottom up. A comprehensive set of themes need to be set up in the inductive process. By means of the deductive process, qualitative researchers need look back at their data and determine if enough supporting evidence has been obtained for themes developed, or if more evidence is required.
- Participants' meanings: The participants' meanings attached to a certain problem or issue is the focal point of qualitative research, not the meaning that researchers bring to the research.
- Emergent design: For qualitative research, the research changes often throughout the process, from the initial research plan, to the data collection, to the analysis of data. The research will ultimately be adapted according to the issues or problems presented by the participants.
- Reflexivity: The background of the researcher can also shape the study.
- Holistic account: Through qualitative research, a complex picture of the problem can be developed by, for example, reporting various perspectives, identifying factors that are involved in a particular situation and sketching the larger picture as it emerges.

Table 10 below summarizes the main components of qualitative research according to Bogdan and Bilken (1992) and can be regarded as a checklist of components to which this study confirms to.

The characteristics of qualitative research presented by Creswell (2014) and the features described by Bogdan and Bilken (1992) are apparent in the research design of the study. The data collection in part took place in the form of multiple data collections in the natural setting of key participants to observe behavior, and was supported by qualitative telephonic interviews. Both interviews and focus group meetings included open ended questions that were few in number. The researcher also used qualitative audio and visual materials in focus group meetings and interviews.

Table 10: A summary of the main components of qualitative research according to Bogdan and Bilken (1992)

Qualitative research aspects	**Description**
Goals	Sensitizing concepts development
	Multiple realities described
	Grounded theory
	Understanding development
Design	General, flexible, evolving
	Guessing as to how to proceed
Written research proposals	Brief
	Speculative
	Suggesting areas research may be relevant to
	In many cases written after some data has been collected
	The literature review is not substantive
	General statement of approach
Data	Descriptive
	Personal documents
	Field notes
	Photographs
	People's own words
	Artifacts and other official documents
Sample	Small
	Non-representative
	Theoretical sampling
	Snow ball sampling
	Purposeful
Techniques or Methods	Observation
	Participant observation
	Reviewing various documents
	Open ended interviewing
	First person accounts
Relationship with Subjects	Empathy
	Empathy on trust

	Egalitarian
	Subject as friend
	Intense contact

4.4.2. Use of theory and paradigms

In many research approaches, theories can be used by researchers to explore questions in a particular study, serving as a lens that shapes the research (Creswell, 2014). In qualitative research in particular, theory can be used to explain attitudes and behaviours in a broad manner, supported further by hypotheses and variables (Creswell, 2014). Another application of theory in qualitative research is the use of a theoretical lens or perspective in research that is qualitative (Creswell, 2014).

The theoretical lens presents an interpretivist/constructivist paradigm in shaping types of questions asked to the participants, subsequently informing data collection and analysis (Creswell, 2014). The interpretivist/constructivist paradigm aims to understand “the world of human experience” (Cohen and Manion, 1994), which suggests that “reality is socially constructed” (Mertens, 2005). The researcher relies upon the “participants’ view of the situation being studied” (Creswell, 2003), and therefore recognizes his or her own experiences and background with regard to the impact on the research (Mackenzie and Knipe, 2006).

This study uses the theory of “diffusion of innovation”, which is described and explored by Rogers (2003) as a theoretical lens (Craig, 2012) through which to study the research questions and address the objectives of the study. Diffusion of innovation helps the researcher identify what issues are important and need to be examined as part of the diffusion process; the participants that have to be involved; how the researcher should position herself; how the final data needs to be written up; and the recommendations and model proposed for improving the social sustainability of floating treatment wetland islands. Figure 26 illustrates how the theory of diffusion of innovation was be applied as the theoretical lens for the research study.

4.5. Sampling Methodology

4.5.1. Study site

The study site needs to be purposefully selected in terms of which will best assist the researcher in understanding the problem and its research question (Creswell, 2014). The main study site (Modderfontein Nature Reserve) was selected in 2015, and two floating treatment wetland islands were installed on Fish Eagle Dam by the researcher.

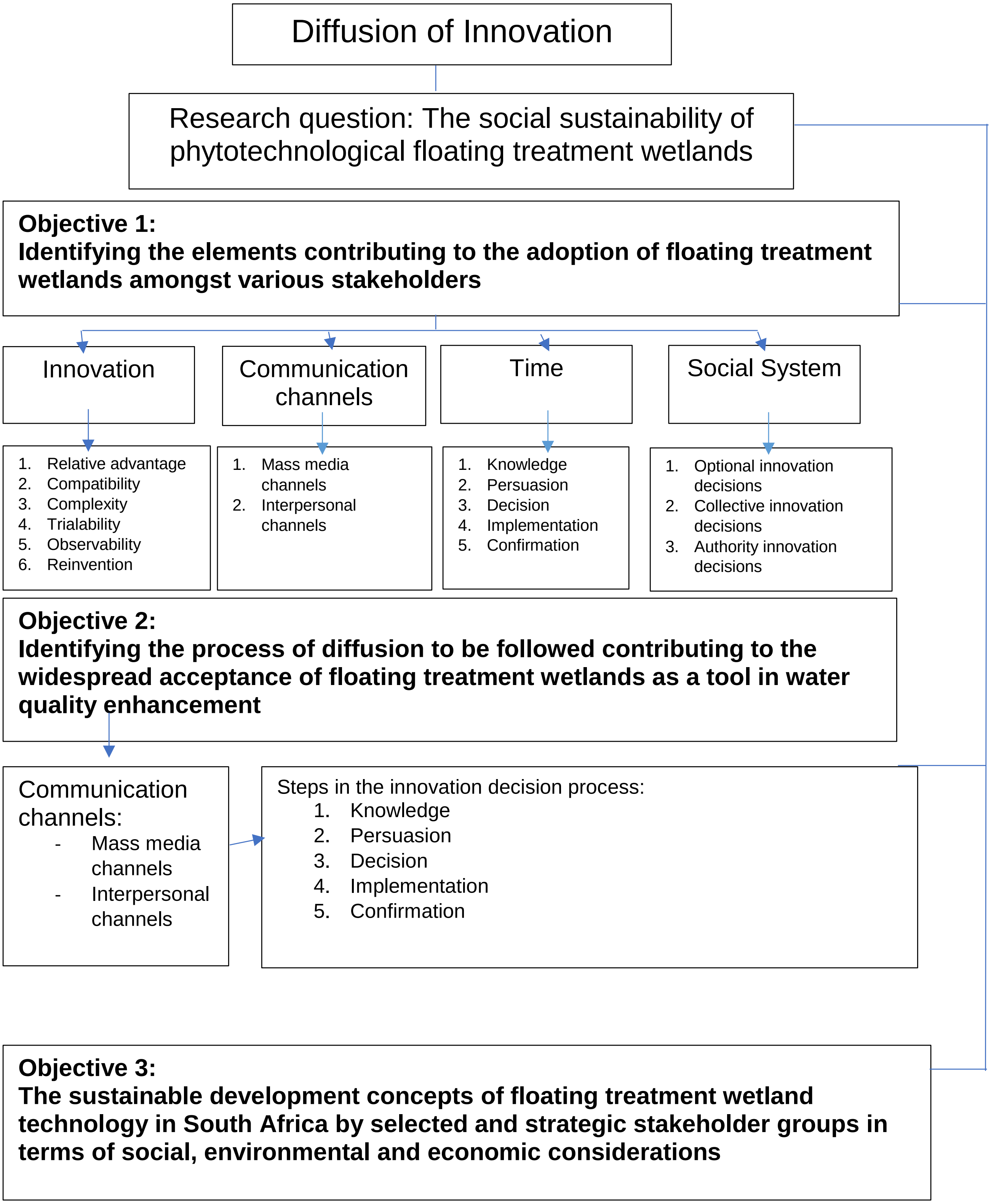

Figure 26: Diffusion of innovation as theoretical lens (adapted from Rogers, 2003 and Craig, 2012), the elements and rate of diffusion

The main study site was selected based on ease of access and safety, and for the purposes of continuous observation and research. The Modderfontein Nature Reserve also has pollution challenges, and as public park also serves as an awareness location for urban conservation efforts and initiatives.

The researcher conducted a preliminary site visit to Modderfontein Nature Reserve on 22 April 2015 and met up with the Endangered Wildlife Trust team to discuss the planned floating treatment wetland installations and obtain permission for the subsequent installations. During interactions with the Endangered Wildlife Trust team, the researcher used her observations to begin the process of developing questions for the interviews and focus group meetings that was mainly based on the Modderfontein study site.

4.5.2. Focus group meetings

The process of qualitative data inquiry includes identifying four aspects that need to be researched as part of the qualitative inquiry (Miles and Hubermann, 1994). These four aspects are: the setting (where the research will take place), the actors (the participants that will be interviewed and observed), the events (includes the actions of the actors that will be interviewed and observed) and the process (includes the progress of events that will be portrayed by the actors within the study context).

The selection process was based on the non-probability sampling technique. Creswell (2009) advises non-probability sampling for research cases where the researcher has no knowledge of the population cross-section in terms of the study. Creswell (2009) further proposes that quota sampling be used where the researcher aims to fill certain categories for a representation of various participant types, which will contribute to obtaining an overview of the research question.

4.5.2.1. Modderfontein Conservation Society focus group meeting

The Endangered Wildlife Trust assisted the researcher in organizing the focus group Meeting (consisting out of 14 members) that involved the Modderfontein Conservation Society. The Modderfontein Conservation Society assists the Modderfontein Nature Reserve in executing and achieving its conservation mandate and goals. The Modderfontein Conservation Society is an existing society and there were no criteria applicable for the compilation of the focus group.

The interviews were based on the Modderfontein floating treatment wetland installation site in the Modderfontein Nature Reserve, City of Johannesburg.

4.5.2.2. Wetland and environmental professionals focus group meeting

The Wetland and environmental professionals focus group meeting (consisting out of 16 professionals) included participants from a wetlands course where the researcher presented. The course minimum requirements included criteria such as background education, interests and field of employment, which contributed to the participant selection for the focus group meeting. It can be confirmed that this type of selection helped to achieve a breadth of coverage that is inclusive and wide (Denscombe, 2007).

The interviews were based on the Modderfontein floating treatment wetland installation site in the Modderfontein Nature Reserve, City of Johannesburg.

4.5.2.3. Interviews

Creswell (2012) indicates that interviews are a qualitative data collection type that can be face-to-face, in-person, by telephone or via e-mail. The researcher used telephonic and e-mail interviews to investigate the research question as part of the qualitative data collection process. The participants were purposefully selected (Denscombe, 2007), i.e. the researcher already had knowledge of the selected participants. The participants in the interviews were selected in this manner because they were likely to produce valuable data regarding the water governance and integrated water resource management sphere, and the researcher had a specific purpose in mind, together with specific research questions and topics (Denscombe, 2007).

An additional interview group was set up (consisting out of more than 30 participants) via the internet and was based on non-probability sampling, where an invitation was circulated over the social media platform “LinkedIn” to participate in the research. This method proved to be successful as the participants that participated represented various age groups, included both male and female participants, and represented a wide interest field in the environmental, business and engineering sectors.

The interviews were based on the Modderfontein floating treatment wetland installation site in the Modderfontein Nature Reserve, City of Johannesburg.

4.5.2.4. Other site observations and interviews

During March 2016, two floating treatment wetlands were installed in Rockville, Soweto, City of Johannesburg. During the installations, the researcher observed community behaviour and also had short discussions with interested community members.

4.6. Ethical considerations

The study site in Modderfontein was chosen owing to the researcher's previous experience with the study area and the earlier discussions with the Endangered Wildlife Trust, which included network building with current staff at the Trust who assisted in setting up the Modderfontein Conservation Society focus group meeting. The Environmental and Wetland Professionals focus group included individuals who participated in a wetland training course in which the researcher was a presenter. Participation in the focus group meeting was voluntarily, and all participants indicated that they wished to participate to gain more insight into floating treatment wetlands and the social sustainability thereof.

Interview participants (three participants) were purposefully selected and participated voluntary. A background information document was first sent via email to the participants, which indicated both the background to the study and that participation was voluntary. Acknowledgement in writing was received from the participants, confirming their participation.

The participation in the on-line internet-based interview was also on voluntary basis, and participants all indicated that they wanted to obtain further information following the conclusion of the study.

The data collection did not infringe on any of the participants' rights and did not cause any discomfort to the participants. The only inconvenience all participants experienced was the time they allowed for participation in the study. Participation by all was voluntary, and it was explained that should any participants want to withdraw at any time, they were welcome to do so without prejudice.

Before any data collection could commence, the researcher had to obtain ethics clearance from the Monash University Human Research Ethics Committee (MUHREC). Following submission to MUHREC, the research was classified as being a low-risk study as the questions posed together with the sampling methodology to be followed did not pose a risk of causing any emotional distress to any participants, and personal information would not be revealed. Ethics clearance was thus received from MUHREC on 18 January 2016 (refer to Appendix A).

As part of the ethics approval process, the researcher had to elaborate on the way that data would be recorded at forums or interviews. The researcher also had to provide a written explanatory statement (Appendix B), which the participants were to keep, and consent forms (Appendix C), which were both given to all participants before the data collection process commenced. The explanatory statement introduced the study to the participants and provided an introduction to the researcher. It also explained why each participant was chosen, and indicated what the purpose of the study was. The benefits associated with participating in the study were explained, and the statement also confirmed that the study would not cause any discomfort to participants. Information concerning confidentiality, voluntary participation and storage of data was provided. The consent form accompanied the explanatory statement, and required the participants to provide written confirmation of participation, thereby acknowledging the content of the explanatory statement.

4.7. Validity and reliability of data

In qualitative data research, validity of findings needs to take place throughout the research process (Figure 27) (Creswell, 2009). Validity in qualitative research is concerned with checks the researcher must carry out on the accuracy of findings by means of employing certain procedures (Creswell, 2009). Validity is a strength of qualitative research as it is based on determining if the findings are accurate as investigated by the researcher and from the researcher's, participants' and readers' points of view (Creswell and Miller, 2000). Terms that are used to ensure validity in qualitative research are trustworthiness, credibility and authenticity (Creswell and Miller, 2000; Lincoln and Guba, 2000).

In ensuring internal validity and rigor in the research, the following verification strategies (Table 11) were employed in all phases of the study (Guba and Lincoln, 1981; Guba and Lincoln, 1982; Lincoln and Guba, 1985; Creswell and Miller, 2000; Morse *et al*, 2002):

- Data triangulation: Data for the study was collected through various sources, including observations, interviews, document analysis and focus group meetings (Creswell, 2014).
- Member checking: Participants served as a check throughout the data analysis process in instances where confirmation was required (Creswell, 2014).

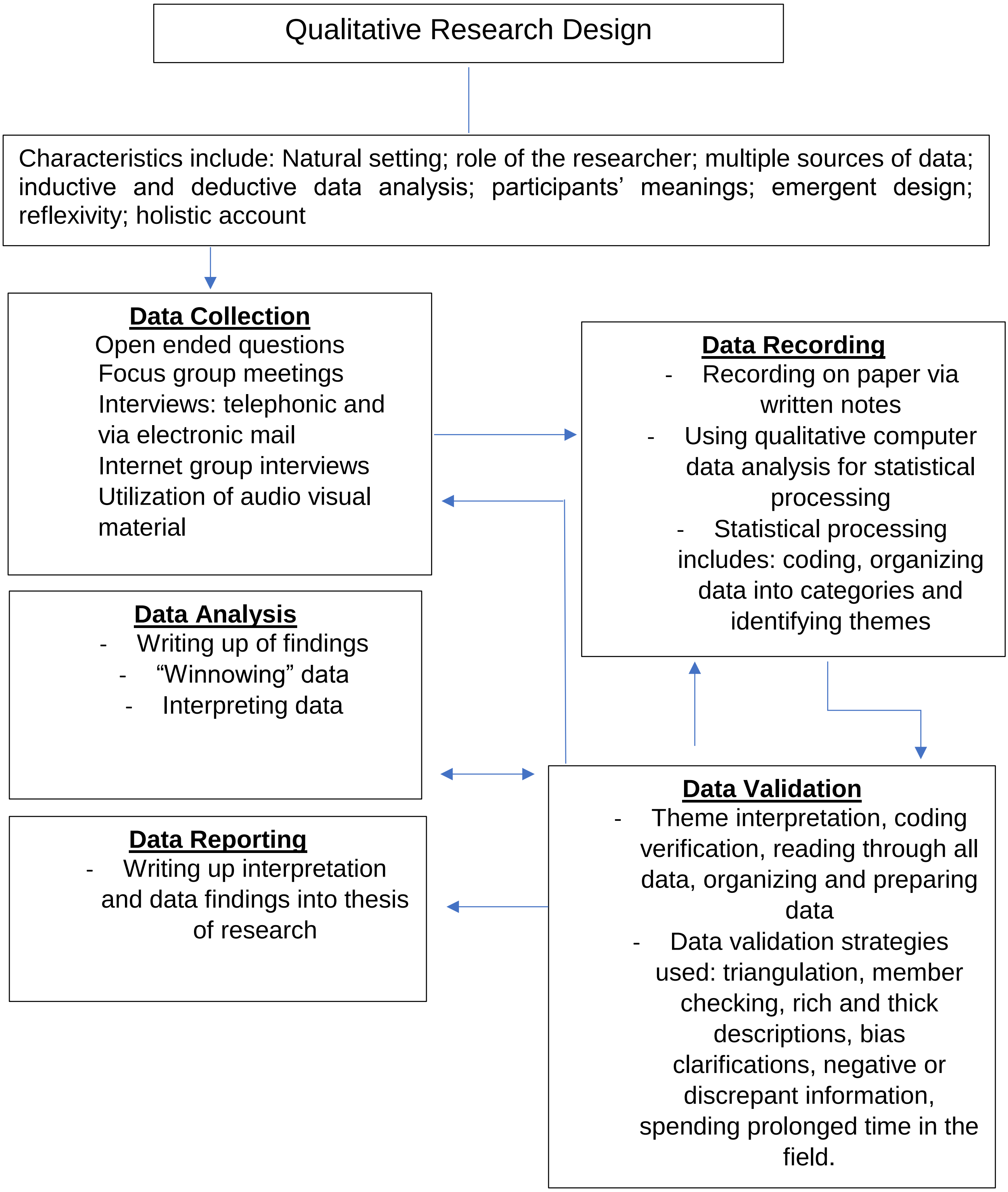

Figure 27: Qualitative research design (adapted from Creswell, 2014)

Table 11: Validity procedure within qualitative lens and paradigm assumptions (Creswell and Miller, 2000)

Paradigm assumption/lens	**Post positivist or systematic paradigm**	**Constructivist paradigm**	**Critical paradigm**

Lens of the researcher	Triangulation	Disconfirming evidence	Researcher reflexivity
Lens of study participants	Member checking	Prolonged engagement in the field	Collaboration
Lens of people external to the study (reviewers, readers)	The audit trial	Thick, rich description	Peer debriefing

Reliability of approaches in qualitative research can be ensured by documenting the procedures of case studies, as well as many of the steps of these procedures as possible (Yin, 2009). Thereafter, setting up a detailed database and study protocol can also assist in future researchers following suit (Creswell, 2014). Gibbs (2007) suggests several other qualitative reliability procedures that can be followed by researchers, and the following were included in this study: checking transcripts for obvious mistakes and checking for drift in codes definitions. The researcher aimed to keep the coding consistency at least at 80% to ensure good qualitative reliability (Miles and Huberman, 1994).

- Long term and repeated observations (prolonged time in the field): long term observations began with the installation of floating treatment wetland islands in Rockville, Soweto and ongoing maintenance visits to the Modderfontein Nature Reserve site. Repeated visits were conducted over at least a four-month period for the purposes of regular observation (Creswell, 2014).
- Thick, rich description: The aim of thick and rich descriptions is to provide a reliable overview of shared experiences, especially for interviews and focus group meetings not taking place at the site where the floating treatment wetland islands are installed (Creswell, 2014).
- Presentation of discrepant, contradictory or negative information running counter to themes: Contrary information that exists owing to real life situations offers different perspectives, adding to the overall credibility of a researched problem (Creswell, 2014).
- Clarification of researcher bias: The researcher bias was articulated at beginning of the study under the heading “The Researcher’s Role” (Creswell, 2014).
- Participatory modes of research: The participants were involved in month study phases, including design to checking interpretations and conclusions (Creswell, 2014).

4.8. Method of data collection

The study used interpretivist/constructivist procedures, where the theoretical lens of diffusion of innovation theory (Craig, 2012) was used as the overarching perspective within the research design, which relied upon qualitative data collection methods (Mackenzie and Knipe, 2006). The research represents an attempt to confirm certain characteristics about human beings located in the environments in which they evolve and live (Biesta and Burbules, 2003). The theoretical lens guides the type of questions asked (in conjunction with the diffusion of innovation theory), and data collection can be collected either concurrently or sequentially (Johnson and Onwuegbuzie, 2004).

4.8.1. Modderfontein Conservation Society focus group

Contact was made with the Endangered Wildlife Trust's training representative, who recommended conducting a focus group meeting with the Modderfontein Conservation Society, owing to the involvement of the society in supporting the EWT's conservation goals and initiatives. The sampling method used for the focus group was based on the non-probability sampling method. Before the meeting, the researcher compiled a list of questions.

The data collection process, as indicated by Figure 26, followed a qualitative data research design process. Data was collected by using open ended questions in the forum discussion with the Modderfontein Conservation Society. The meeting took place in the training centre of the EWT in Modderfontein, City of Johannesburg. Open ended questions were mainly asked to allow participants to share their views, opinions and comments on sustainability-related aspects of floating treatment wetland islands.

Before the question and engagement session commenced, the researcher presented audio visual material to the focus group meeting, including videos of the floating treatment wetland installations done by the researcher. The videos also included visual descriptions of what floating treatment wetland islands comprise.

The following open-ended question was asked for the purposes of understanding how the focus group meeting participants defined integrated watershed management and what their perceptions were concerning the term:

a. How would you define the term integrated watershed management?

The next open-ended questions were aimed at discovering components of diffusion of innovation as described in Chapter Two. The questions focused on the current level of awareness in urban water quality management and sustainable urban drainage systems, and were as follows:

b. What are the current challenges experienced in urban water quality management?
c. What measures or tools are applied to deal with urban water quality issues?
d. In your opinion, how effective are current implemented sustainable urban drainage systems?

Open ended questions were also asked concerning sustainable development, in particular social sustainability. The researcher asked the questions to understand the views and perceptions of the participants on the pillars of sustainability with regard to floating treatment wetlands. The questions were:

e. In your opinion, what are the social aspects and concerns associated with floating treatment wetlands?
f. In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands?
g. In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?

The next open-ended questions centred around design aspects of the floating treatment wetlands, and were as follows:

h. What is your opinion of using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plants outperform indigenous plants in the uptake of contaminants?
i. What modification suggestions do you have for floating treatment wetlands in the urban context?
j. Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool (Yes/No)?

A final open-ended question was included to encourage further discussion with participants and to raise any further comments following the focus group interview:

k. What is your general opinion of floating treatment wetlands?

At the end of each question, the researcher repeated the ideas generated by that question to the focus group participants. Following the closing of the meeting, the researcher encouraged the participants to contact the researcher should they want to continue any of the discussions.

4.8.2. Environmental and wetland specialist focus group meeting

A workshop was organized where various environmental and wetland specialists could register to attend. The researcher presented on wetland restoration and rehabilitation. As part of the workshop presentation, the researcher incorporated a focus group meeting discussion on the social sustainability of floating treatment wetland systems. The purpose here to facilitate a focus group meeting with environmental and wetland specialists in which the researcher could obtain the views and perceptions of professionals already working in the environmental and wetland space in an effort to understand their experience of floating treatment wetlands, especially in a social sustainability context.

The data collection process, as indicated by Figure 26, followed a qualitative data research design process. Data was collected by using open ended questions in the forum discussion with the specialist group. The meeting took place outside Hartbeespoortdam at a training facility. Open ended questions were mainly asked to allow participants to share their views, opinions and comments on sustainability-related aspects of floating treatment wetland islands.

Before the question and engagement session commenced, the researcher presented audio visual material to the focus group meeting, including videos of floating treatment wetland installations done by the researcher, as well as a visual description of what floating treatment wetland islands comprise.

The following open-ended questions were asked to understand how the focus group meeting participants define integrated watershed management and what their perceptions are concerning the term:

a. How would you define the term integrated watershed management?

The next open-ended questions were aimed at discovering components of diffusion of innovation, as described in Chapter Two. The questions asked revolved around the current level of awareness in urban water quality management and sustainable urban drainage systems, and were as follow:

b. What are the current challenges experienced in urban water quality management?
c. What measures or tools are applied to deal with urban water quality issues?
d. In your opinion, how effective are current implemented sustainable urban drainage systems?

Open ended questions were also asked concerning sustainable development and, in particular, social sustainability. The researcher asked the questions in order to understand the views and perceptions of the participants on the pillars of sustainability with regard to floating treatment wetlands. The questions asked were:

e. In your opinion, what are the social aspects and concerns associated with floating treatment wetlands?
f. In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands?
g. In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?

The next open-ended questions to the focus group were centred around design aspects of the floating treatment wetlands:

h. What is your opinion of using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plants outperform indigenous plants in the uptake of contaminants?
i. What modification suggestions do you have for floating treatment wetlands in the urban context?
j. Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool (Yes/No)?

A final open-ended question was included to encourage further discussion with participants and to raise any further comments following the focus group interview:

k. What is your general opinion of floating treatment wetlands?

At the end of each question, the researcher repeated the ideas generated by that question to the focus group participants. Following the closing of the meeting, the researcher encouraged the participants to contact her should they want to continue any of the discussions.

4.8.3. Interviews

The researcher used telephonic and e-mail interviews to investigate the research question as part of the qualitative data collection type used for the research. The participants were purposefully selected (Denscombe, 2007), and the researcher already had knowledge of the selected participants. The participants in the interviews were selected in this manner because they were likely to produce valuable data given their experience in the water governance and integrated water resource management sphere, as the researcher had a specific purpose in mind with regarding the research questions and topics (Denscombe, 2007).

The interviews (telephonic, electronic mail and internet based) were based on the Modderfontein floating treatment wetland installation site in the Modderfontein Nature Reserve, City of Johannesburg.

4.8.3.1. Telephonic and e-mail interviews

The following open-ended questions were asked to understand how the focus group meeting participants define integrated watershed management and what their perceptions are concerning the term:

a. How would you define the term integrated watershed management?

The next open-ended questions were aimed at discovering components of diffusion of innovation, as described in Chapter Two. The questions asked revolved around the current level of awareness in urban water quality management and sustainable urban drainage systems, and were as follows:

b. What are the current challenges experienced in urban water quality management?
c. What measures or tools are applied to deal with urban water quality issues?
d. In your opinion, how effective are current implemented sustainable urban drainage systems?

Open ended questions were also asked concerning sustainable development and, in particular, social sustainability. The researcher asked the questions in order to understand the views and perceptions of the participants on the pillars of sustainability with regard to floating treatment wetlands. The questions asked were:

e. In your opinion, what are the social aspects and concerns associated with floating treatment wetlands?
f. In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands?
g. In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?

The next open-ended questions to the focus group were centred around design aspects of the floating treatment wetlands:

h. What is your opinion of using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plants outperform indigenous plants in the uptake of contaminants?
i. What modification suggestions do you have for floating treatment wetlands in the urban context?
j. Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool (Yes/No)?

A final open-ended question was included to encourage further discussion with participants and to raise any further comments following the focus group interview:

k. What is your general opinion of floating treatment wetlands?

At the end of each question, the researcher repeated the ideas generated by that question to the focus group participants. Following the closing of the meeting, the researcher encouraged the participants to contact her should they want to continue any of the discussions.

4.8.3.2. Internet group discussion

An additional interview group was set up via the internet that was based on non-probability sampling, where an invitation to participate in the research was circulated over the social media platform "LinkedIn". This method proven to be successful as the participants that participated represented various age groups, included both male and female participants, and represented a wide interest field in the environmental, business and engineering sectors. Participation was announced through the researcher's profile on LinkedIn, posting on the various LinkedIn groups to which the researcher subscribed and through making an announcement via the administrator of the South African Wildlife Management Association to all members on the database.

The group represented participants from government organizations, tertiary educational institutions, business or industry sectors, non-governmental organizations and the community or public sphere.

The following open-ended questions were asked to understand how the focus group meeting participants define integrated watershed management and what their perceptions are concerning the term:

- How would you define the term integrated watershed management?

The next open-ended questions asked were aimed at discovering components of diffusion of innovation, as described in Chapter Two. The questions asked revolved around the current level of awareness in urban water quality management and sustainable urban drainage systems, and were as follows:

- What are the current challenges experienced in urban water quality management?
- What measures or tools are applied to deal with urban water quality issues?
- In your opinion, how effective are current implemented sustainable urban drainage systems?

Open ended questions were also asked concerning sustainable development and, in particular, social sustainability. The researcher asked the questions in order to understand the views and perceptions of the participants on the pillars of sustainability with regard to floating treatment wetlands. The questions asked were:

- In your opinion, what are the social aspects and concerns associated with floating treatment wetlands?
- In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands?
- In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?

The next open-ended questions to the focus group were centred around design aspects of the floating treatment wetlands:

- What is your opinion of using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plants outperform indigenous plants in the uptake of contaminants?
- What modification suggestions do you have for floating treatment wetlands in the urban context?
- Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool (Yes/No)?

A final open-ended question was included to encourage further discussion with participants and to raise any further comments following the focus group interview:

- What is your general opinion of floating treatment wetlands?

Following completion of the open-ended questions by the participants, a summary of the ideas received were circulated to all participants for further input and commenting.

4.8.3.3. Field visits, observations and interviews

The researcher returned to the Modderfontein Nature Reserve for maintenance activities during 2016. Two floating treatment islands were also installed in Rockville, Soweto during March 2016. A subsequent maintenance visit took place in May 2016. These site visits allowed for prolonged time spent on site to further observe and have informal interviews with interested community members. The researcher explained to each interested community member what a floating treatment wetland is and how it functions. That explanation further promoted discussion and comments from community members.

CHAPTER 5: RESEARCH RESULTS AND DISCUSSION

5.1. Introduction

The broad objective of this research was to investigate diffusion of floating treatment wetland technology in South Africa as a tool in water quality enhancement in the context of integrated watershed management. The diffusion of this technology was investigated by testing the elements of diffusion, namely innovation, communication channels, time and the social system. This chapter contains the results of the focus group meetings, surveys and interviews pertaining to the diffusion of phytotechnological floating treatment wetland technology in integrated watershed management in the City of Johannesburg, South Africa.

In addition, through focus group meetings, interviews and surveys, the researcher aimed to:

(a) Identify the specific elements of diffusion as applicable to floating water treatment technology;

(b) Identify the process of diffusion to be followed that contributes to the widespread acceptance of floating treatment wetland technology as a tool in water quality enhancement; and

(c) Identify the sustainability aspects associated with floating wetland technology that also influence the diffusion of this technology and the associated rate of adoption.

5.2. Overview of results from the participatory process

5.2.1. Elements of diffusion

The following section presents the results from the data collection in terms of elements that contribute to the diffusion of floating treatment wetlands technology, as presented in Figure 26. These elements include innovation, communication channels, time and social system, and are discussed in detail below

5.2.1.1. Innovation

Floating treatment wetlands can be regarded as an innovation in the sense that they are perceived as new by an individual in the form of an idea or project. Even if an invention has been invented a couple of years ago, if individuals perceive it as new, then it may still be an innovation to such individuals. The relative advantage of floating treatment wetlands has been identified by participants as being new, cost effective (when compared to conventional waste water treatment systems) and efficient, together with being aesthetically pleasing, promoting water purification, providing habitat for biodiversity and increasing biodiversity.

The advantages of floating treatment wetlands have been described as promoting cleaner water whilst limiting disease and removing pollutants from water bodies. In the open forum discussions, participants indicated that it is important that communities be made aware of floating wetlands development and implementation, so that they not only participate in the introductions, but also participate in long term floating treatment wetland establishment programmes, where there is a possibility to gain skills and develop downstream businesses.

Participants indicated that awareness programmes and capacity building need to be introduced before floating treatment wetlands are installed in areas so that communities understand how the islands function and the benefits associated with such islands, and perceived complexity does not negatively impact island introductions. Awareness campaigns beforehand will also instill a sense of belonging amongst community members where installations are planned, and further campaigns will also cultivate respect from community members, which would hopefully result in their assistance with maintenance and subsequent introduction programmes. Awareness is thus an important factor that can influence the adoption of floating treatment wetlands.

The trialability of the floating treatment wetlands has been confirmed, as the researcher developed and installed more than $40m^2$ of islands in the City of Johannesburg. The trials also confirmed that the islands can be custom shaped and sized. The participants indicated, following the trials, that the shape needs to be designed in such a manner so that it resembles natural lines and fits into the natural surroundings. Furthermore, participants indicated that the system should be of low maintenance and the material of which the islands consist must not have a negative impact on the surrounding environment. They also noted that subsurface funneling can be introduced, and the islands can also provide interesting options for agriculture. The participants expressed overall satisfaction with the current designs and indicated that municipalities need to roll out islands in areas currently subjected to water contamination, especially in informal areas where water quality is a big concern. One participant indicated that the Department of Water and Sanitation needs to make island introductions compulsory, and that floating treatment wetlands' specifications are also currently included for water treatment plant lagoons.

Concerning observability, participants indicated that the floating treatment wetlands are aesthetically pleasing and that they can even increase property values. Other participants indicated that with such islands having a positive impact on water quality, they may even allow for fishing, farming and harvesting of material in wetland islands. Regarding observability, participants noted that the islands can potentially result in a overall better environment and better water for communities, resulting in visibly beneficial outcomes that can facilitate and expedite the diffusion of floating treatment wetlands.

The researcher has demonstrated that floating treatment wetlands can be custom shaped and sized, contributing to innovation, which allows for such islands to be diffused more rapidly and structurally. The importance of custom shaping and sizing for various ecosystems was emphasized by participants for the use of islands in various types of water environments. By informing individuals about the consequences (advantages and disadvantages associated with the floating treatment wetlands), the uncertainty of adopting the innovation can also be reduced.

5.2.1.2. Communication channels

Communication channels in another factor that contributes to the adoption of an innovation, and refers to process whereby information is created and shared amongst participants so as to reach a state of mutual understanding. This communication process between sources takes place through channels. Essentially, a communication channel refers to the way in which information is transferred between individuals.

The participants indicated that communication is a vital aspect of floating treatment wetland programmes. Important components and communication-related aspects, as identified by participants, include the following:

- Communication channel proposed: Public/community presentations by means of open days, workshops and informal meetings, and on-site educational posters and signage.
- Before island introductions, floating treatment wetland introductions need to be presented to the relevant public or community. During presentation, it is important that benefits are underlined, together with costing of islands and knowledge conveyance, particularly with regard to system functioning.
- Communication channel proposed: Background investigation and developing a strategy through pre-consultation on site sessions with stakeholders, in-field discussions, radio discussions, newspaper articles and on-site demonstrations
- Social leadership, associated costs, perceived effectiveness, and accurate knowledge of the functionality and reasons for floating treatment wetland programmes can influence the diffusion of such islands, and thus are important components that need to be taken into consideration when communication strategies are developed.

- The lack of knowledge, ignorance, taboos and disrespect of nature and others are important aspects to take into account when communication strategies are developed and can be addressed by means of the proposed channel.
- The level of awareness, community structure and attitude of the community in which introductions are planned need to be determined before community engagement commences as this will provide valuable insight as to how the community needs to be approached, the details that need to be included in the introduction and the nature of communication channels used.
- Communities need to be properly briefed about the thinking behind floating treatment wetlands and why they are being introduced in that area. The communities need to feel as if they have been consulted and properly involved when outsiders try to impose solutions in their area. This strategy provides an opportunity for community members to become actively involved in island introduction programmes and possibly also promote job creation and other opportunities such as skills development.
- Mass media channels such as public media (newspaper, radio, posters and on-site signage) can be used during the knowledge stage so that the communication media will be effective in reducing any uncertainty concerning floating treatment wetlands and more able to provide specific information on how the floating treatment wetlands function.
- Interpersonal channels such as methods including a two-way communication between individuals are more able to address strong attitudes, and are more important in the persuasion stage where a positive opinion about the floating treatment wetlands needs to be promoted and a favorable intention to adopt the innovation developed.

5.2.1.3. Time

An innovation such as the floating treatment wetlands is adopted over time. Time is an important component of the adoption process. It was confirmed during the open forum discussions and interviews as well as the adopter categories that the innovation-diffusion process and the rate of adoption all included a time dimension. The time an individual/stakeholder takes to adopt an innovation, consequently taking place over a period of time, is influenced by knowledge, persuasion, decision, implementation and confirmation, which are the steps in the innovation-decision process for floating treatment wetlands.

- Knowledge: Awareness and training was identified by participants to be an important component for social acceptance and hence, social adoption.

- Persuasion: The open forum discussions and interviews indicated that there is a joint favorable attitude towards floating treatment wetland islands from all participants, especially considering the environmental, social and economic benefits associated with such islands
- Decision: The decision to adopt or reject the floating treatment wetlands is mainly influenced by economics, social acceptance, maintenance requirements, feasibility, performance and long-term sustainability, as identified by the participants.
- Implementation: Once floating treatment wetlands are implemented, factors were identified by the participants that can lead to a reinvention of the floating treatment wetlands islands, namely: performance, plant mixes used, maintenance required, impact on the ecosystem and downstream opportunities created. These factors can mainly lead to design modifications.
- Confirmation: Confirmation will take place once the floating treatment wetlands have addressed the constraint or challenge for which it was deployed (with or without design modifications). Confirmation can then lead to additional installations and widespread adoption of the floating treatment wetland islands.

5.2.1.4. Social system

The boundaries of diffusion are determined by the social system (Rogers, 2003). The diffusion of floating treatment wetlands is influenced by opinion leaders and change agents. The nature of the social system thus is important to consider when floating treatment wetland islands are to be installed, as this will provide direction regarding the consultation and communication approaches. We can distinguish between five components of the social system that influence the diffusion of floating treatment wetlands, each of which are addressed below.

1. Social structure and diffusion

The social structure applicable to the diffusion of floating treatment wetlands in the City of Johannesburg includes statutory departments such as the Department of Water and Sanitation, Johannesburg City Parks, Johannesburg Water and Department of Environmental Affairs, which play an important role in conserving biodiversity and dealing with environmental matters. Within the statutory departments there are also a hierarchy of applicable responsibilities. Important for diffusion is the awareness levels of officials of statutory departments regarding green or ecological infrastructure. An important observation made by the researcher during telephonic discussions with officials is that currently the awareness levels of the importance and benefits associated with ecological infrastructure such as floating treatment wetlands is low. This lack of awareness contributes to challenges being experienced when programmes are to be implemented, especially concerning floating treatment wetlands, which further contributes to challenges with community introduction and liaison.

Further observations were made that community members are much more open to solutions that can address their challenges immediately. Community members are also more supportive of solutions that can be of economic benefit to them. Although there is also a community structure applicable when consultations commence prior to introduction programmes, the researcher found that – especially in the Rockville, Soweto community – the community welcomed on-site field demonstrations and consultation sessions, and were very open to accepting solutions that are environmentally sound, make economic sense and are socially acceptable.

2. System norms and diffusion

The norms of members in a social system are behaviour patterns that are established and can subsequently be used as a guide for the members of a social system.

Members of statutory departments need to comply with various statutory norms, guidelines and laws when executing their daily duties. If there are no guidelines available on ecological infrastructure such as floating treatment wetland applications, it can be expected that the level of awareness and subsequent rate of diffusion in statutory departments will be low. However, conventional environmental engineering guidelines and resources are easily available and hence the awareness level of environmental engineering applications is high.

Community members in the City of Johannesburg also have particular behaviour patterns. Currently, many communities, as is the case with Rockville, Soweto, live in areas where challenges are experienced concerning water security. Surface water bodies are heavily impacted by anthropogenic activity and are subsequently in states ranging from eutrophic to hypertrophic. The behaviour from community members is directed towards seeking solutions to better quality water.

The norms of a system can also be a barrier to change, i.e. if there is inadequate awareness in communities, there is a risk that floating treatment wetland technology will be misunderstood and hence rejected by the community owing to cultural or social beliefs.

3. Opinion leaders and change agents

It can happen in certain situations in a social system where a specific member is innovative causing the individual to be perceived as deviating from the social system, and subsequently gaining a low credibility status by fellow average members of the same social system. This innovative member's role in diffusion is very limited and other members of the community – and social system – function thus as opinion leaders. Opinion leaders in a social system provide valuable advice and information about other individuals. They are part of the system that can assist the diffusion process and are characteristic influential persons that can contribute in spreading new ideas. Examples of opinion leaders in communities include ward councilors, community leaders and women entrepreneurs. Change agents – professional individuals – represent change agencies external to the social system, and seek to obtain new ideas adoption that can also slow the process of diffusion down. Such change agents use opinion leaders as their spokespersons in activities associated with diffusion.

Once a floating treatment wetland technology project is identified for a specific area, the community structure and social system needs to be thoroughly investigated so that the in-house change agents and opinion leaders are identified. This approach will hopefully result in a diffusion process that has influence and increased success rate of being accepted by individuals in a social system, especially within communities.

4. Types of innovation decisions

In a social system such as a community, an innovation can either be rejected or adopted by members of the social system. The adoption or rejection can also be made by the entire social system or a specific system.

Types of identified innovation decisions associated with the social system as an element in diffusion include:

- Optional innovation-decisions: The choice to adopt the floating treatment wetland islands by individuals such as farm owners and business owners where the decision is independent of the decisions of other social system members;
- Collective innovation-decisions: The choice to adopt the floating treatment wetlands islands are in this case made collectively by consensus among the social system members that are indicative of communities in community initiatives where islands are to be installed. Collective innovation-decisions are also applicable in housing or residential estates when floating treatment wetland islands are to be installed; and

- Authority innovation-decisions: The choice to adopt the floating treatment wetlands can be prescribed by statutory bodies such as the Department of Water and Sanitation and provincial conservation statutory bodies such as the Mpumalanga Parks and Tourism Agency. Statutory bodies possess power, status and technical expertise and can therefore prescribe adoption requirements.

In the City of Johannesburg in South Africa, the fastest rate of adoption stems from the decisions and projects of authorities such as the Department of Water and Sanitation, City of Johannesburg and City Parks. However, if at the outset of project development members of a system are not adequately consulted, such member of a system can circumvent and create challenges for the authority during project implementation.

Furthermore, the type of innovation-decision of a social system in a particular area can change or be changed over time. However, social participation needs to continue, irrespective of the innovation-decision type and power of influence of a social system.

5. Consequences of innovations

Through the process of adopting or rejecting an innovation, an individual or social system can experience certain consequences. The consequences can include:

- Desirable versus undesirable consequences, depending on the effects of an innovation becoming functional or dysfunctional. Desirable consequences of implemented floating treatment wetland technology can include promoting sustainable livelihoods, promoting overall well-being and water security for social members, increasing biodiversity and ecosystem health, promoting aquatic health and providing economic opportunities and a source of income to communities and social structures. The desirable consequences enhance livelihoods and further promote or sustain diffusion of the innovation. Undesirable consequences can include vandalism that leads to floating treatment wetland technology destruction or damage and maintenance constraints should maintenance become neglected. These constraints can lead to non-acceptance or reluctance to accept the innovation.
- Direct versus indirect consequences, which is a second-order result or an immediate response to an innovation to an individual or a social system. Direct consequences include both positive and negative consequences that directly impacts on individuals

of a social system or on the entire cohort of the social system. Indirect consequences can include consequences such as where water quality enhancement (following the acceptance of the innovation) leads to flourishing fish life. This indirect consequence is that of food security.

- Anticipated versus unanticipated consequences, which depend on whether changes are intended or recognized by members of the social system or individuals. It might be the case where the majority of members of a social system accept the innovation and indirectly cause the minority to accept the innovation following benefits derived from the implemented innovation.

5.2.2. Process of diffusion for floating treatment wetland islands

The process of diffusion for floating treatment wetlands takes place over a time continuum, and over five stages, with either mass media or interpersonal communication channels. Figure 28 indicates the process of diffusion to be followed as identified by participants in the open forum discussions and interviews following the investigation of the diffusion of floating treatment wetland technology. Figure 28 captures the process of diffusion as identified following the stakeholder participation sessions.

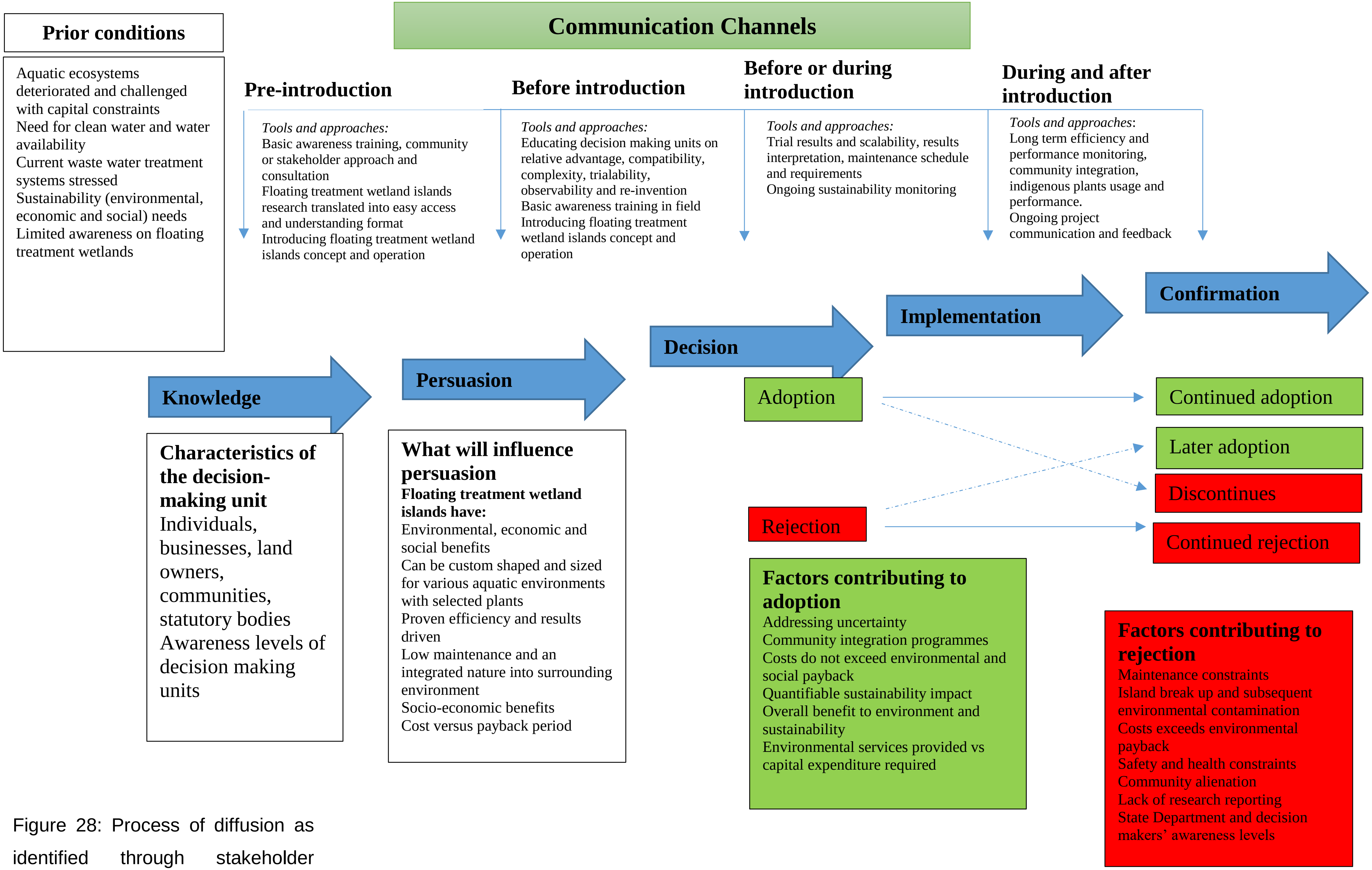

Figure 28: Process of diffusion as identified through stakeholder consultation

5.2.3. The sustainable development components of floating treatment wetland technology

Sustainable development comprises three spheres, namely environmental, social and economic. These factors have been identified by participants as influencing aspects of sustainable development and subsequently the diffusion of the floating treatment wetlands as an innovation. Each factor is addressed below.

Environmental factors

Most participants indicated that the types of plants used on the floating treatment wetland islands and their invasive nature (for indigenous and non-indigenous species) need to be carefully considered, so as not create an additional burden on the existing environment. It was also noted that the use of floating treatment wetlands in natural environments for the purposes of remediation and rehabilitation activities need to be considered. Participants also indicated that the root system of plants used do not need pruning, and have a beneficial impact on fish in the ecosystem as well.

Participants also indicated that for any application there is a limit to its performance and that limit needs to be clearly defined for ecosystems in which this technology is introduced. Amount of maintenance and aftercare were also identified as being components to clearly define upfront before introductions, to make sure adequate resources are available so as to achieve maximum performance of the floating treatment wetland islands. The floating treatment wetland islands were identified as being a low risk to the surrounding environment, which also promotes the adoption of the islands. Participants indicated that the islands can have a positive impact in promoting biodiversity and habitat for species, providing carbon credits, and being able to be integrated into hydroponics and agriculture.

To summarize, before the floating treatment wetlands are introduced, the environment into which it is to be introduced needs to be clearly understood so that the design and functionality of the islands can complement and improve the current state of the environment.

Social factors

The need to integrate the community, with subsequent socio-economic benefits, into floating wetland island introductions was identified as one of the main social factors that can impact on island introductions. When community members have a sense of belonging and being part of the journey before introductions, they are more likely to feel a sense of ownership and cooperation, which will benefit the long-term sustainability of island introductions. It was also identified by participants that when islands are introduced into aquatic ecosystems and performance is related to water quality improvement, they will then have a direct impact on community livelihood and overall health. Subsequent opportunities for social interaction can also be created by introducing skills development programmes and promoting food production and employment opportunities, coupled with downstream entrepreneurship.

A barrier identified by participants includes the scenario in which certain people may prefer open water and have the opinion that floating treatment wetlands are unattractive. In this case a lot of emphasis needs to be placed on awareness and education prior to any introductions. Participants also emphasized that informing and educating people and communicating the value of the islands are central to the success of long term introduction, in the sense that ecological infrastructure provides ecosystem benefits to the society. Recreational activities on water impoundments and in aquatic ecosystems need to be carefully evaluated to ensure that additional safety risks are not introduced upon island introductions. Participants indicated that theft can be a problem, together with children and community members that access the islands, who can create subsequent island damage and present drowning risks.

Economic factors

The self-sustaining nature of floating treatment wetlands was identified as an important factor for island introductions by participants. Participants also indicated that the cost benefit to natural areas where wetland degradation is of concern and also needs to be considered. The participants acknowledged that it will cost money to introduce floating wetland islands, but also noted that island introductions will provide benefits. In addition, active management will be required to maintain the islands, but has an added benefit that communities can be integrated into introduction programmes with associated socio-development benefits and community upliftment. Participants indicated that a commercial value needs to be integrated into the islands, so that islands can become a central feature of an aquatic ecosystem with many other spinoffs such as education centers, nurseries and other commercial initiatives. Essentially, floating treatment wetland islands must not function in isolation when introduced into aquatic ecosystems. Participants also indicated that the vegetation to be used on floating treatment wetland islands might be too expensive for small community projects when they cannot source the vegetation locally, which would result in expensive sourcing of required vegetation. To measure performance and sustainability, participants suggested that proper evaluation of the social sustainability, measuring the social standing and weight in comparison to some trade-off scenarios between having an island installed and improving the environment. Furthermore, the option to introduce floating treatment wetland islands should be driven by what one prioritizes, and what one prioritizes depends on social status, hence understanding the economic, social and environmental nature of the environment into which islands are to be introduced.

5.2.4. General field observations

During the floating wetland island installation in March 2016 in Rockville, Soweto, at Moroka Dam, field observations where made pertaining to community behavior, and short discussions also took place with community members that visited the area during that time.

From the start of the installation there was interest by the community. The floating treatment wetlands were installed during National Water Week in South Africa and, fortunately for the drought conditions experienced at that time in the area, widespread rainfall was experienced. Community members eagerly assisted in the installation and showed extreme interest in the installation (Figure 29).

Figure 29: Some community members assisting the installation team (Photo: Yolandi Schoeman, Soweto, 17 March 2016)

Short discussions with community members indicated that solutions are required for the polluted environment in which they are situated. During the installation, a large amount of storm water entered the dam during rainfall on the day, carrying with it a significant amount of solid waste. During good weather, the colour of the water close to the edges is green and characteristic of a nutrient-rich impoundment (Figure 30).

Figure 30: A photo indicating the state of the water quality in Moroka Dam, Soweto (Photo: Yolandi Schoeman, Soweto, 17 March 2016)

The community members welcomed the installation and showed amazement after being made aware of the function of the floating treatment wetlands, and requested more to be installed.

5.3. Diffusion of floating treatment wetland technology as a tool in sustainable urban water quality management

Considerations from the data collection process were used to complete this section, which details the conceptual floating wetland treatment model for urban introduction.

5.3.1. Considerations from public engagement

The following general comments and suggestions emerged from the focus group discussions and on-line questionnaire, and need to be considered during the planning phases of a floating treatment wetland technology introduction project:

- Vegetation of floating treatment wetlands should mainly consist of wetland plants, preferably with known contaminant uptake potential, that are indigenous or region-specific. Species such as *Typha capensis* and *Cyperus alternifolius* are excellent choices with which to begin. However, there are many varieties and species with known phytotechnological properties that will be useful in floating treatment wetland introduction programmes. Region-specific indigenous plants are well adapted to local conditions, therefore indigenous plants in one region in South Africa might not perform as well as in other regions.

- Non-indigenous plants can be used on floating treatment wetlands only if supported by credible research sources and proof that there is no substitute amongst indigenous plants. Species such as *Vetiver zizanoides* that are proven to be sterile should also be considered for use in floating treatment wetland projects.
- The construction material of floating treatment wetlands should not have an adverse impact on the surrounding environment. The material of the base need to be UV resistant and able to remain stable in a variety of aquatic environments so as to prevent degradation and break-up, which can cause additional environmental challenges.
- The mechanics of floating treatment wetland need to make provision for wildlife, recreational use and flood interaction. The floating mechanisms need to incorporate breeding bird colonies where needed and additional nesting material should be introduced onto the islands so that water birds do not cause damage to the islands in "harvesting" for nesting material. The attachment mechanisms of the floating treatment wetlands also need to be sturdy and safe, owing to the possible occurrence of water recreation on the water body. In the latter scenario, it is recommended that floating treatment wetlands be established closer to the shore to prevent possible hazards to recreational users such a jet skis and boating.
- The socio-economic benefits associated with floating treatment wetlands can be expanded to include and make sustainable widespread job creation, downstream opportunities and business development. The natural products market alone in Africa is a business exceeding 30 million rand (Mungai, 2014) and, as well as removing contaminants from water, some plants also have medicinal, oil and cosmeceutical properties.
- Floating treatment wetlands need be integrated into the environment in a social, environmental and economic way so as not to be isolated systems. The planning for placing floating treatment wetlands is very important and needs to ensure that the wetlands make economic sense, and are environmentally sound and socially acceptable. The floating treatment wetlands should not be isolated systems cut off from the rest of the environment and communities. Rather, they should promote biodiversity protection and, where possible, the floating treatment wetland islands should have economic and socio-economic potential.

- Agricultural integration of floating treatment wetlands is also an option, specifically semi-hydroponics, with associated social, environmental and economic benefits.
- Floating treatment wetlands can be used to complement existing water treatment management initiatives. They can be integrated into constructed wetlands to increase nutrient uptake from oxidation ponds and can also be integrated into conventional sewage treatment works to further remove contaminants from the treatment process.
- The use of floating treatment wetlands to promote and support natural systems rehabilitation and remediation must also be considered. Floating treatment wetland technology can be used in a “dry” and “wet” stage to assist with the establishment of vegetation, mitigate soil erosion and promote biodiversity and rehabilitation objectives in aquatic and terrestrial rehabilitation initiative and programmes.
- Education and awareness drives regarding introducing and implementing floating treatment wetland systems will impact social acceptance of such systems. Education and awareness thus need to take place in the earliest possible stages of floating treatment wetlands technology planning.
- Floating treatment wetlands can be used as measures to promote water quality and access to water in the form of a non-threatening technology. It is also low technology, which makes it easier to introduce and train members of a social system to manage floating treatment wetlands. Floating treatment wetland technology is a low cost and low maintenance solution to assist with water security and quality management.
- Floating treatment wetlands can be used as a tool to promote a cleaner, more natural and biodiverse environment whilst simultaneously creating wildlife habitat.
- Social leadership and community attitudes are also important considerations when installations and developments are being planned. Through early community consultation and participation, social leadership and a positive community attitude are nurtured.
- Cost, time, proven results and accessibility need to be considered before installation commences, and must be part of the communication strategy.
- Floating treatment wetlands have high value and this value needs to be communicated to the public and members of the social system, and emphasized in the overall introduction and sustainability strategy of floating treatment wetlands.
- Communication is an important component. The benefits of the systems need to be communicated so that communities can respect and maintain them. Communication can take the form of community workshops and open days, or even on-site correspondence and radio updates.

- Communities need to be integrated into floating treatment wetland initiatives so as to nurture a sense of responsibility for and inclusion in the initiative. Members of the social system where floating treatment wetlands are to be introduced need to form part of the introduction programme from the onset.
- Periodic monitoring and maintenance should form part of floating treatment wetland introductions as well as communication of performance. Communication need to take place according to a well-defined strategy that includes members of the social system and governance structures.
- A decommissioning protocol needs to form part of floating treatment wetland initiatives.
- A full site assessment need to take place before introduction of floating treatment wetlands in order to investigate environmental, social and economic aspects that can influence and subsequently be impacted upon, including overall sustainability and ongoing social acceptance of floating treatment wetlands in an area.
- A metric to measure the social standing of floating treatment wetlands needs to be developed, which can then be weighed against some trade-off scenario between having a flotation device and improving the environment in a way that will also benefit introduction motivations and project feasibilities.
- It is important to consider the current social status of the communities in which islands are to be introduced, as what one prioritizes depends on one's social status (i.e. Maslow's hierarchy of needs), which will influence social acceptance.
- Floating treatment wetlands can be used as a tool in sustainable urban drainage systems.

Floating treatment wetland technology has been widely accepted in the City of Johannesburg by both members of the social system and by various governance structures. An immediate need has been identified to install low maintenance, low cost and low-tech solutions to address some of the City of Johannesburg's water security challenges experienced with freshwater sources.

5.3.2. Considerations from organizational and regulatory engagement

The interviews with representatives from two different regulatory organizations responsible for water security in the City of Johannesburg were also used in the development of the conceptual floating treatment wetland technology model. The main points were:

- Maintenance is required to ensure the effectiveness of the installations. There is also a degree of maintenance required to ensure the floating treatment wetland functions optimally. Community members can be trained to perform the periodic maintenance on floating treatment wetlands.
- Floating treatment wetlands can be used as a secondary treatment tool for water treatment facilities. They can be incorporated into urban constructed wetlands and green infrastructure to assist with flood mitigation and additional removal of contaminants from the system.
- Floating treatment wetlands pose a low ecological risk as they do not contain harmful chemicals or dosing activities, and are constructed out of material that is environmentally stable.
- Vegetation of floating treatment wetlands should mainly consist of wetland plants, preferably with known contaminant uptake potential, that are indigenous or region-specific.
- Non-indigenous plants can be used on floating treatment wetlands only if supported by credible research sources and if there is no suitable substitute amongst indigenous plants.
- Floating treatment wetland designs should be adapted to allow for easy monitoring, and designs should accomplish a long-term goal of sustainable implementation.
- The Department of Water Affairs and Sanitation should make floating treatment wetlands compulsory for various applications. There is already an existing drive to utilize this technology as a tool in sustainable urban drainage design and to incorporate it into existing conventional waste water treatment plants and green infrastructure in the urban context.
- Informing and educating people on the value of floating treatment wetlands is important for the social acceptance of these systems, and should be incorporated early on in the planning stages of introductions.
- There is great value in investing in ecological infrastructure solutions, and such solutions should be promoted as they promote urban water security.
- There are many economic benefits associated with implementation programmes of floating treatment wetlands such as job creation, promotion of the establishment of local business and other economic opportunities.
- It is important to understand that there are limits associated with what floating treatment wetlands can achieve, such as water contamination levels, contaminants that need to be removed, accessibility of sites and overall performance in certain heavily contaminated waterbodies.

- Floating treatment wetlands have much environmental, economic and social value and application potential.
- Floating treatment wetlands can be used in conjunction with other tools in water quality management and mitigation.
- Floating treatment wetlands can be used as a tool in sustainable urban drainage systems.

It was shown that floating treatment wetland technology is widely accepted in the City of Johannesburg amongst governance stakeholders. Using floating treatment wetland technology for appropriate environments can produce economic, social and environmental benefits, not only to members of the social system but also to governance stakeholders. Lastly, it can promote overall water security.

5.3.3. Research conclusion

Floating treatment wetland technology needs to be communicated over a period of time through certain communication channels amongst individuals and members of a social system. Through diffusion, a message is spread about the innovation of floating treatment wetlands, which are perceived to be new and have value. The main elements of diffusion, namely innovation, communication channels, time and social systems, need to be carefully researched before introductions commence so that the environment is understood in which diffusion needs to take place, in order to ensure that the floating treatment wetlands are accepted. Social system and individual participation has been found to be critical in technology acceptance, together with providing factual evidence to both social systems and governance structures. Sustainable development remains at the top of the agenda for water security and social upliftment, as is technology that is environmentally sound, socially acceptable and makes economic sense, tailored for specific areas in which introductions are to take place.

CHAPTER 6: REVISITING THE CONCEPTUAL MODEL FOR FLOATING TREATMENT WETLAND TECHNOLOGY AND CONCLUSION

6.1. Introduction to the conceptual model

This chapter presents the conceptual model (depicted in Figure 31) that was developed following the open forum discussions and interviews conducted with stakeholders. It includes the four most important factors that contribute to the diffusion of the floating treatment wetland technology, namely innovation, time, communication channels and social system. The factors have been broken down further to include other components that contribute to the diffusion process, which will be discussed below.

6.2. Conceptual model

6.2.1. Innovation

Innovation is an element that contributes to the diffusion of floating treatment wetland technology. In Figure 31, it is shown that environmental factors, social factors and floating treatment wetland construction were identified as key technical and environmental considerations that can influence the diffusion of an innovation that supports the relative advantage of floating treatment wetland technology, especially when implementing floating treatment wetlands islands for similar reasons as implementing grey infrastructure.

Environmental elements that need to be understood and carefully researched prior to implementation include the current state of the environment, vegetation and biodiversity, water quality, bird life surrounding the water body and the environmental footprint that the floating treatment wetland is envisaged to have. Social elements include communities surrounding or within 1km of the water body, which can possibly assist in the installation and skills development, the economic status quo of the aforementioned communities, the nature of commercial activities within 20km of the water body that can possibly be a catalyst for downstream business created from floating treatment wetlands, current community structure and channels, the nature of current recreation activities and safety and vandalism considerations.

Floating treatment wetlands need to be integrated into the landscape, and consist of materials that have a long-life span and are designed to need little maintenance. There also needs to be an offset for harvested plants, and the islands need to be integrated with biodiversity and community goals. The islands need to be robust enough to survive flood conditions. On-site plant propagation activities will also contribute to the sustainability of floating treatment wetlands.

6.2.2. Time

Time is an important component of the adoption process of floating treatment wetland technology. It was confirmed during the open forum discussions and interviews that knowledge, persuasion, decision, implementation and confirmation are the steps in the innovation-decision process for floating treatment wetlands that ultimately promote the acceptance of an innovation over a certain period.

Knowledge of floating treatment wetland technology can be promoted by specific and targeted awareness and training initiatives such as workshops, information sessions, community integration consultations and programmes to inform the community and other stakeholders of floating treatment wetlands, share research outcomes and indicate how such islands can benefit certain areas where challenges are experienced. Attitudes need to be influenced through awareness programmes and communicating in a manner that community members and other stakeholders can understand what is being communicated as well as the impact of a change proposed, in order to ultimately promote persuasion. Communication pertaining to facts from research activities and trials conducted needs to be included in all communication channels.

The decisions taken by stakeholders to either adopt or reject floating treatment wetland technology are influenced by economics, social needs and benefits, maintenance requirements, visible positive impacts, project feasibility, performance of the islands and the long-term sustainability of such islands. Successful implementation is determined by the overall impact floating treatment wetland technology has on the ecosystem, the types and mixes of plants used, community integration, maintenance programmes, monitoring programmes and the nature and channels of reporting and feedback obtained as well as adaptive management. Ultimate confirmation and the decision to re-introduce or to introduce in other areas is influenced by whether the constraint or challenge has been addressed upon first implementation, and whether success has been achieved regarding community integration and skills development.

CONCEPTUAL MODEL FOR FLOATING TREATMENT WETLAND TECHNOLOGY

Innovation – Technical and environmental considerations for diffusion

Environmental
- Current state of environment
- Vegetation and biodiversity state of the environment
- Water quality of receiving environment
- Bird life surrounding the water body
- Footprint on surrounding environment

Social
- Communities surrounding or within 1km of water body
- Skills development and economic needs
- Nature of commercial activities within 20km of water body
- Community structure and channels
- Current recreation activities
- Safety and vandalism considerations

Floating wetland islands construction
- Long term sustainability of materials used
- Integrate into landscape
- Integrate biodiversity and community into design
- Design for little maintenance
- Offset for harvested plants
- Flood and current controls
- On site plant propagation

Time – diffusion process components

Knowledge: awareness and training identified as key components for social acceptance, including workshops, training and information sessions, community integration consultation and programmes

Persuasion: attitudes need to be influenced to ultimately promotes persuasion through: awareness programmes, community benefits communicated in understandable language, communicating facts based on research and in field demonstrations and application

Decision: decisions to adopt or reject is influenced by: economics, social needs and benefits, maintenance requirements, visible positive impacts, project feasibility, performance, long term sustainability

Implementation: Successful implementation is determined by: floating wetlands vs ecosystem fit, types of plants used, plant mixes, community integration, maintenance programmes, monitoring programmes, nature of reporting, feedback obtained and integrated

Confirmation: confirmation and re-introductions take place once: constraint / challenge has been addressed or proof that it is being addressed with favourable monitoring results, success from community integration and skills development

Communication channels – promoting diffusion through developed (social) sustainability indicators to monitor and measure and report

Ecological
- Climate and microclimate modifications
- Air quality improvements
- Carbon sequestration
- Hydrological regulations
- Erosion control
- Nutrient cycling
- Biodiversity protection and enhancement

Health
- Improving physical, mental and social wellbeing

Socio-cultural
- Food production
- Recreation opportunities
- Provision of outdoor sites for education and research
- Sense of belonging
- Ecological infrastructure
- Enhancement attractiveness of cities

Economic
- Increased property values
- Greater economic activity
- Healthcare cost savings
- Economic benefits of provision of services
- Value of avoided CO^2 emissions or carbon sequestration
- Value of air pollutant removal
- Value of cleaner water to community and ecosystem services
- Value of avoided grey infrastructure design
- Value of reduces flood damage

Social system (cont'd)

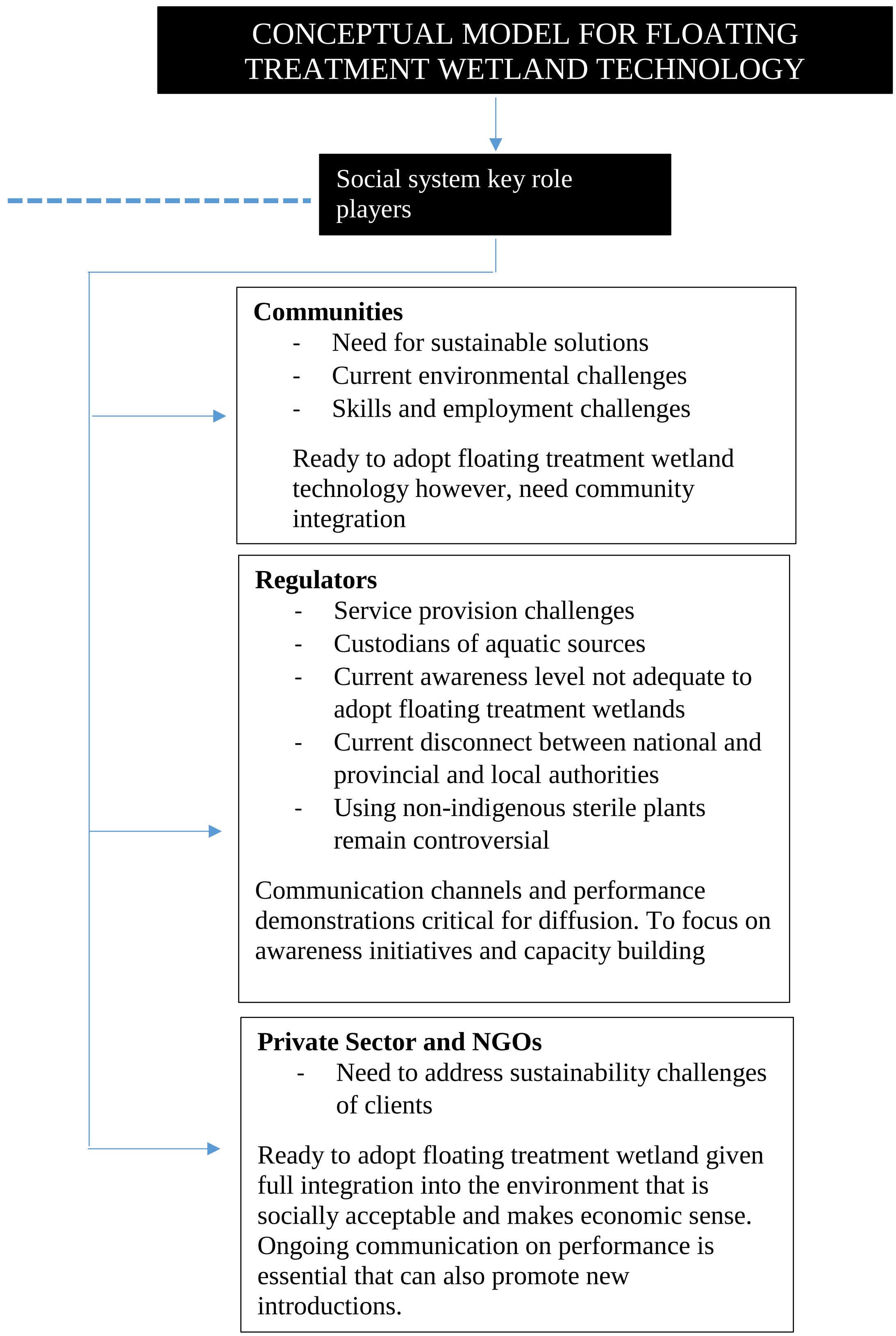

Figure 31: Conceptual model for floating treatment wetland islands diffusion

6.2.3. Communication channels

Communication channels form part of the factors that contribute to the diffusion of an innovation, and refer to the way in which information is transferred between individuals.

Identified by participants in the open forum discussions and interviews is a need to provide feedback on measured indicators that provide information on the sustainability, performance and success of implementation and the impact it has made on the social sustainability environment. The criteria suggested that form part of the conceptual model to be included in monitoring, reporting and feedback programmes are ecological, health, socio-cultural and economic indicators.

6.2.4. Social system

The boundaries of diffusion are determined by the social system and, subsequently, the diffusion of floating treatment wetlands is influenced by opinion leaders and change agents. The nature of the social system is important to consider when floating treatment wetland islands are to be installed, as the nature of the social system will provide direction regarding the consultation and communication approach. Social system stakeholders in the implementation and introduction of floating treatment wetland technology into the urban context include communities that reside in the environment into which floating treatment wetland islands are planned, regulators that have the responsibility to implement services and address water quality challenges, the private sector (consultants, business owners) and representatives of non-governmental organizations that have direct and indirect interests in floating treatment wetland introductions.

6.3. Research and policy recommendations

6.3.1. Research recommendations

Further research is required to investigate the diffusion of eco-technology (and in particular floating treatment wetlands) in other parts of South Africa and to compare the findings to the findings of a research study as this one undertaken. The researcher has the hypothesis that the diffusion process to adopt floating treatment wetlands as an eco-technology will differ from province to province that is influenced by the state of the environment of such areas and the needs of communities that reside in the said environments, however additional research is required to investigate this. Further research is also required to investigate the phytotechnological properties of the indigenous aquatic vegetation of South Africa for simultaneous cosmeceutical and other market value and application that can also be useful when community programmes and economic opportunities are created during eco-technology introductions. The researcher also suggests further research to be done on floating treatment wetland technology, in particularly, concerning the potential to treat water bodies in a state of eutrophication and hypertrophication. There is also an important research need to investigate the current awareness level concerning eco-technology and its application amongst major environmental regulatory departments (such as the Department of Water and Sanitation and the Department of Environmental Affairs) that will also inform the path to policy development and implementation.

6.3.2. Policy recommendations

Sustainable development priorities are developed and driven by state representatives with input from market and civil society members in particularly for the City of Johannesburg. National Guidelines, formal National Regulations and specific policy concerning eco-technology and the applicable diffusion process are currently not available in South Africa apart from guidelines and policy regarding the public process to be followed that is associated mainly with the environmental authorization process for various developments.

Localised South African guidelines have been published for the City of Cape Town. The City of Tshwane has also published their own policy documents whilst the City of Johannesburg is in the final stages of releasing their own. But none of the aforementioned guidelines specifically addresses eco-technology and the diffusion thereof, nor the diffusion process of floating treatment wetlands. The researcher identified a need for guidelines and subsequent policy documents (national, provincial and local) to be developed pertaining to current available and potential applicable eco-technology solutions to address various water security challenges and the diffusion process to be followed prior, during and after technology introductions between all stakeholders, including regulatory departments.

6.4. Conclusion

The purpose of this research study was to investigate the diffusion (and identify the sustainable development components) of phytotechnological floating treatment wetland technology in South Africa as a tool in water quality enhancement, whilst improving ecosystem services, in the context of integrated watershed management in the City of Johannesburg, South Africa. Open forum discussions and interviews where applied to investigate the diffusion of floating treatment wetland technology and through the research floating treatment wetland technology where accepted and promoted by stakeholders participating.

The factors that contribute to floating treatment wetland technology diffusion were also investigated together with identifying the process of diffusion to be followed that can positively contribute to the widespread acceptance of floating treatment wetlands as a tool in water quality enhancement. Further, the sustainable development components of floating treatment wetland technology in the City of Johannesburg, South Africa was investigated through open forum discussions and interviews and consequently indicators where proposed to monitor performance and to use such indicators in communication channels to the social system.

The researcher concludes that floating treatment wetlands can be applied sustainably and effectively as an ecotechnology tool in the urban context. Floating treatment wetlands can contribute to enhance water quality and can be sustainably utilised further as a tool in integrated watershed management, water security and in urban green infrastructure and resilience projects.

Floating treatment wetland technology is also accepted as a tool in water quality improvement and as a tool in SUDS in South Africa. As a tool in SUDS, floating treatment wetland technology contributes to allow for water quality management, water quality treatment, enhanced amenity and the subsequent maintenance of biodiversity, mitigating many environmental and storm water challenges particularly in an urban context and ultimately contributing to urban resilience. Floating treatment wetlands can further provide ecological infrastructure, erosion control, enhance biodiversity, provide employment and skills development opportunities to communities, can contribute to water security and promote water quality of a water body.

However, special attention needs to be provided to understanding the environment (economically, socially and environmentally) prior to physical introductions. What can also contribute to the sustainability of introductions are integrating the community into activities relating to floating treatment wetland introductions. Further research is recommended on introductions in the rest of South Africa and also beyond South Africa together with further research in phytotechnological plants or vegetation that also has medicinal and cosmeceutical properties.

Further, the nature of monitoring activities and reporting mechanisms also need to be taken into consideration to provide adequate and fact-based information about system performances based on indicators that can accurately provide feedback on overall performance. Efficient communication and monitoring activities can not only contribute to sustainable performance of current introductions, but can also promote new introductions when the support is obtained by various stakeholders.

It was found that using sterile, non-indigenous plants in floating treatment wetlands was contentious. Moreover, although communities, the private sector and non-governmental organisations representatives confirmed the positive adoption of floating treatment wetlands, a disconnect between national and provincial/local state departments was noticed: national state departments seemed positive about floating treatment wetlands but certain provincial and local state departments were lacking in appropriate awareness on the functioning of floating treatment wetlands. This finding confirms that prior to introductions, an assessment needs to be conducted on the level of awareness of stakeholders, which can negatively or positively impact on these introductions.

Finally, no policy constraints were found, and floating treatment wetlands promote the guidelines for sustainable urban drainage design as supported by the Department of Water and Sanitation in South Africa. However, a need was identified to develop guidelines and policy documents that identify available eco-technology solutions and the diffusion process to be followed that will also contribute in addressing the current awareness level amongst all stakeholders.

REREFENCES CITED

Ahern, J. (2007) Green infrastructure for cities: the spatial dimension. In V. Novotny and P. Brown (Eds), Cities of the future towards integrated sustainable water and landscape management. London, UK: IWA Publishing.

Alcorn, P.A. (2003) Social issues in technology – a format for investigation. Forth edition. New Jersey: Prentice Hall.

Andonova, L. and Mitchell, R. (2010) The rescaling of global environmental politics. Annual Review of Environment and Resources. Volume 35, p 255.

Armitage, N., Vice, M., Fisher-Jeffes, L., Winter, K., Spiegel, A. and Dunstan, J. (2013) Alternative Technology for Stormwater Management: The South African guidelines for sustainable drainage systems. WRC Report No TT 558/13, May.

Arnold, M.G. and Hockerts, K. (2011) The greening Dutchman: Philips' process of green flagging to drive sustainability innovations. Bus. Strategy Environ. Volume 20, pp 394-407.

Assefa, G. and Frostell, B. (2007) Social sustainability and social acceptance in technology assessment: a case study of energy technologies. Technology in Society. Volume 29, pp 63-78.

Azzone, G. and Noci, G. (1998) Seeing ecology and "green" innovations as a source of change. Journal of Organisational Management. Volume 11 (2), pp 94-111.

Barau, A.S. (2015) Perceptions and contributions of households towards sustainable urban green infrastructure in Malaysia. Habitat International. Volume 47, pp 285-297.

Barbier, E. (2010) A global green new deal: rethinking the economic recovery. Cambridge: Cambridge University Press.

Barr, S. and Gilg, A. (2006) Sustainable lifestyles: framing environmental action in and around the home. Geoforum. Volume 37 (6), pp 906-920.

Barthel, S. (2008) Recalling urban nature – linking city people to ecosystem services. Sweden, Stockholm University (Dissertation).

Beise, M. and Rennings, K. (2005) Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations. Ecological Economics. Volume 52 (1), pp 5-17.

Benedict, M.A. and McMahon, E.T. (2002) Green infrastructure: smart conservation for the 21st century. Washington, DC: Sprawl Watch Clearing House.

Benedict, M.A. and McMahon, E.T. (2006) Green infrastructure: linking landscapes and communities. Washington, DC: Island Press.

Bergquist, A.K. and Soderholm, K. (2011) Green innovation systems in Swedish industry, 1960-1989. Bus. Hist. Rev. Volume 85 (4), pp 677-698.

Berrone, P., Fosfuri, A., Gelabert, L. and Gomez-Mejia, L.R. (2013) Necessity as the mother of "green" inventions: institutional pressures and environmental innovations. Strategic Management Journal. Volume 34, pp 891-909.

Bhatti, M. and Church, A. (2004) Home, the culture of nature and meanings of gardens in late modernity. Housing Studies. Volume 19 (1), pp 37-51.

Biesta, G.J.J. and Burbules, N.C. (2003) Pragmatism and educational research. Langam, MD: Rowman and Littlefield.

Bogdan, R.C. and Bilken, S.K. (1992) Qualitative research for education: An introduction to theories and models. Available at www.researchgate.net/publications/242375185_Qualitative_Research_for_Education. (Accessed: 25 May 2016).

Boolaane, B. (2006) Constraints to promoting people centred approaches in recycling. Habitat International. Volume 30 (4), pp 731-740.

Boons, F. and Ludeke-Freund, F. (2013) Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. Journal of Cleaner Production. Volume 45 (2), pp 278-293.

Bossle, M.B., De Barcellos, M.D. and Vieira, L.M. (2015) The drivers for adoption of eco-innovation. Journal of Cleaner Production. In press, pp 1-12.

Brinson, M.M. (1993) A hydrogeomorphic classification for wetlands. Technical Report WRP – DE- 4, US Army Engineer Waterways Experiment Station, Vicksburg.

Buttol, P., Buonamici, R., Naldesi, L., Rinaldi, C., Zamagni, A. and Masoni, P. (2012) Integrating services and tools in an ICT platform to support eco-innovation in SMEs. Clean Technol. Environ. Policy. Volume 14 (2), pp 211-221.

Cagno, E., Ambroggi, D.M., Grande, O. and Trucco, P. (2011) Risk analysis of underground infrastructures in urban areas. Reliab. Eng. Syst, Saf. Volume 96, pp 139-148.

Cainelli, G., Mazzanti, M. and Montresor, S. (2012) Environmental innovations, local networks and internazionalisation. Industry Innovation. Volume 19 (8), pp 697-734.

Carillo-Hermosilla, J., Del Rio, P. and Konnola, T. (2010) Diversity of eco-innovations: reflections from selected case studies. Journal of Cleaner Production. Volume 18(10), pp 1073-1083.

Chang, C.H. (2011) The influence of corporate environmental ethics on competitive advantage: the mediation role of green innovation. Journal of Business Ethics. Volume 104 (3), pp 361-370.

Chang, C.H. and Chen, Y.S. (2013) Green organizational identity and green innovation. Management Decisions. Volume 51 (5), pp 1056-1070.

Chang, N.B., Xuan, Z., Marimon, Z., Islam, K. and Wanielista, M.P. (2013) Exploring hydrobiogeochemical processes of floating treatment wetlands in a subtropical stormwater wet detention pond. Ecological Engineering. Volume 54, pp 66-67.

Chappin, M.M., Vermeulen, W.J., Meeus, M.T. and Hekkert, M.P. (2009) Enhancing our understanding of the role of environmental policy in environmental innovation: adoption explained by the accumulation of policy instruments and agent-based factors. Environmental Science Policy. Volume 12 (7), pp 934-947.

Chen, Y.S. (2008) The driver of green innovation and green image – green core competence. Journal of Business Ethics. Volume 81 (3), pp 531-543.

Chen, Y.S., Chang, C.W. and Wu, F.S. (2012) Origins of green innovations: the differences between proactive and reactive green innovations. Management Decisions. Volume 50 (3), pp 368-398.

City of Johannesburg (CoJ) (2008) State of the Environment Report. Available at www.joburg-archive.co.za/2003/budget/idp/annex3.pdf (Accessed: 13 June 2010).

City of Johannesburg (CoJ) (2012) Greening Soweto: transforming dustbowls and landfill sites to award-winning parks and eco-services. Available at www.jhbcityparks.com/pdfs/greening_soweto12.pdf (Accessed: 27 June 2013).

City of Johannesburg (CoJ) (2012) Public spaces. Available at www.joburg.org.za/index.php?option=com_content&task=view&id=1734&Itemid=49 (Accessed: 27 June 2013).

City of Johannesburg (CoJ) (2012) Eagle, J. (Personal communication) (28 November).

City of Johannesburg (CoJ): Johannesburg City Parks (JCP)(2012) Letsoko & Njingolo (Personal communication) (28 November).

City of Johannesburg (CoJ): Johannesburg Roads Agency (JRA) (2012) JRA Official (Personal communication) (21 November).

Cohen, L. and Manion, L. (1994) Research methods in education. Fourth Edition. London: Routledge.

Craig, L. (2012) The viability of biofiltration stormwater management systems in informal settlements in South Africa. MPhil Thesis, Monash South Africa.

Creswell, J.W. (2003) Research design: qualitative, quantitative and mixed methods approaches. Second edition. Sage Publications.

Creswell, J.W. (2009) Research design: qualitative, quantitative and mixed methods approaches. Third edition. Sage Publications.

Creswell, J.W. (2014) Research design: qualitative, quantitative and mixed methods approaches. Fourth edition. Sage Publications.

Creswell, J.W. and Miller, D.L. (2000) Determining validity in qualitative inquiry. Theory into practice. Ohio State University: College of Education. Volume 39 (3), pp 124-130.

CSIR (2010) A CSIR perspective on water in South Africa -2010. CSIR Report No. CSIR/NRE/PW/IR/2011/0012/A. Pretoria.

Dangelico, R.M. and Pujari, D. (2010) Mainstreaming green product innovation: why and how companies integrate environmental sustainability. Journal of Business Ethics. Volume 95, pp 471-486.

De Marchi, V. (2012) Environmental innovation and R&D cooperation: empirical evidence from Spanish manufacturing firms. Res. Policy. Volume 41, pp 614-623.

De Jager, R. (2012) Moroka Park Precinct, Ntuli street, Soweto. University of Pretoria. Available at: http://able.wiki.up.ac.za/index.php/Moroka_Park_Precinct,_Ntuli_street,_Soweto (Accessed: 29 September 2017).

De Stefani, G., Tocchetto, D., Salvato, M. and Borin, M. (2011) Performance of a floating treatment wetland for in-stream water amelioration in North East Italy,. Hydrobiologia. Volume 674, pp 157-167.

Demirel, P. and Kesidou, E. (2011) Stimulating different types of eco-innovation in the UK: government policies and firm motivations. Ecological Economics. Volume 70, pp 1546-1557.

Department of Water and Sanitation (DWS) (2013a) National water resources strategy: June 2013 (second edition). DWS, Pretoria, South African Government.

Department of Water and Sanitation (DWS) (2013b) Strategic overview of the water sector in South Africa. DWS, Pretoria, South African Government.

Department of Water and Sanitation (DWS) (2014) Strategic plan for the fiscal years 2015/16 to 2019/20. DWS, Pretoria, South African Government.

Department of Water and Sanitation (DWS) (2015) Briefing of the Portfolio Committee on Water and Sanitation: progress report on the process of allocation of water use licenses in different sectors to advance the developmental needs of South Africa, 5 August 2015. DWS, Pretoria, South African Government.

Denscombe, M. (2007) The good research guide: for small-scale social research projects. Third edition. Open University Press.

Donnelly, L. (2012) South Africa's water crises just got expensive. Mail and Guardian online. Available at http://mg.co.za/article/2012-04-16-sas-water-crises-just-got-expensive (Accessed: 06 June 2015).

DWA (Department of Water Affairs) 2014. The annual national state of water resources report – October 2012 to September 2013. DWA, Pretoria.

DWAF (Department of Water Affairs and Forestry) 2004. National water resource strategy. First edition. September 2004. Department of Water Affairs and Forestry: Pretoria, South Africa.

DWAF (Department of Water Affairs and Forestry) 2008. Guide to the National Water Act. Department of Water Affairs and Forestry: Pretoria, South Africa.

Eiadat, Y., Kelly, A., Roche, F. and Eyadat, H. (2008) Green and competitive? An empirical test of the mediating role of environmental innovation strategy. Journal of World Business. Volume 43, pp 131-145.

Engelbrecht, F. (2005) Simulations of climate and climate change over southern and tropical Africa with the Conformal-Cubic Atmospheric Model. In R.E. Schulze (Ed.), Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Water Research Commission. WRC Report 1430/1/05, pp 57-74.

Fagerberg, J. (2005) Innovation: a guide to the literature. In: J. Fagerberg, D. Mowery and R. Nelson (Eds), The Oxford Handbook of Innovation. Oxford: Oxford University Press.

Feng, L., Xusheng, L., Zhang, X., Zhao, D., Liu, X., Zhou, C. and Wang, R. (2016) Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban systems. Journal of Cleaner Production, pp 1-7.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C.S. (2005) Regime shift, resilience and biodiversity in ecosystem management. Annual Review of Environment and Resources. Volume 35, pp 557- 581.

Forest Research (2010) Benefits of green infrastructure. Forest Research, Farham. Report by the Forest Research.

Fountoulakis, M., Terzakis, S., Chatzinotas, A., Brix, H., Kalogerakis, N. and Manios, T. (2009) Pilot-scale comparison of constructed wetlands operated under high hydraulic loading rates and attached biofilm reactors for domestic wastewater treatment. Sci. Total Environ. Volume 407 (8), pp 2996-3003.

Frame, B. (2004) The big clean up: social marketing for the Auckland region. Local Environment. Volume 9 (6), pp 507-526.

Gauthier, J. and Wooldridge, B. (2012) Influences on sustainable innovation adoption: evidence from leadership in energy and environmental design. Business Strategy Environment. Volume 21 (2), pp 98-110.

Geffen, C.A. and Rothenberg, S. (2000) Suppliers an environmental innovation: the automotive paint process. Int. J. Prod. Manag. Volume 20 (2), pp 166-186.

GeoTerraImage (GTI) (2012) 2,5m Urban Land Cover map. GTI.

Gibbs, G.R. (2007) Analyzing qualitative data. In: U. Flick (Ed.), The Sage Qualitative Research Kit. Thousand Oaks, CA: Sage.

Glaeser, B. (1984) Ecodevelopment: Concepts, Projects, Strategies. Pergamon Press.

Google Earth (2015) Satellite imagery obtained from www. https://www.google.com/earth. Accessed: 17 July 2015.

Green, K., Mcmeekin, A. and Irwin, A. (1994) Technological trajectories and R&D for environmental innovation in UK firms. Futures. Volume 26 (10), pp 1047-1059.

GreenCape (2016) Water: 2016 Market Intelligence Report. GreenCape, Cape Town.

Greenhouse Trial and Research Centre (GTRC) (2015) Evaluating the efficacy of different water plants to reclaim polluted water resources. December 2015. Report to Yolandi Schoeman.

Guba, E.G. and Lincoln, Y.S. (1981) Effective evaluation: improving the usefulness of evaluation results through responsive and naturalistic approaches. San Francisco, CA: Jossey: Bass.

Guba, E.G. and Lincoln, Y.S. (1982) Epistemological and methodological bases of naturalistic inquiry. Educational Communication and Technological Journal. Volume 30 (4), pp 233-252.

Heathcote, I.W. (2009) Integrated Watershed Management: Principles and Practice. Wiley.

Hellstrom, T. (2007) Dimensions of environmentally sustainable innovation: the structure of eco-innovation concepts. Sustainable Development. Volume 15 (3), pp 148-159.

Hewitson, B.C. and Crane, R.G. (2006) Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa, International Journal of Climatology. Volume 26, pp 1315-1337.

Hobson, K. (2003) Thinking habits into action: the role of knowledge and process in questioning household consumption practices. Local Environment. Volume 8 (1), pp 95-112.

Holden, E. and Linnerud, K. (2007) The sustainable development area: satisfying basic needs and safeguarding ecological sustainability. Sustainable Development. Volume 15, pp 174-187.

Horbach, J. (2008) Determinants of environmental innovation – new evidence from German panel data sources. Res. Policy. Volume 37, pp 163-173.

Horbach, J. Rammer, C. and Rennings, K. (2012) Determinants of eco-innovations by type of environmental impact – the role of regulatory push/pull, technology push and market pull. Ecological Economics. Volume 78, pp 112-122.

Hu, G.J., Zhou, M., Hou, H.B., Zhu, X. and Zhang, W.H. (2010) An ecological floating bed made from dredged lake sludge for purification of eutrophic water. Ecological Engineering. Volume 36, pp 1448-1458.

Huang, Y.C., Ding, H.B. and Kao, M.R. (2009) Salient stakeholder voices: family business and green innovation adoption. J. Manag. Organ. Volume 15, pp 309-326.

Hubbard, R.K. (2010) Floating vegetated mats for improving surface water quality. In: V. Shah (Ed.), Emerging Environmental Technologies, Volume II. Netherlands: Springer.

Huber, J. (2008) Technological environmental innovations (TEIs) in a chain-analytical and life-cycle-analytical perspective. Journal of Cleaner Production. Volume 16, pp 1980-1986.

Hutchins, M.J. and Sutherland, J.W. (2008) An exploration of measures of social sustainability and their application to supply chain decisions. Journal of Cleaner Production. Volume 16, pp 1688-1698.

ITRC (Interstate Technology and Regulatory Council). 2009 PHYTO-3 Phytotechnology Technical and Regulatory Guidance and Decision Trees, Revised. Washington, DC: Interstate Technology and Regulatory Council, Phytotechnologies Team.

Jamali, D. (2006) Insights into triple bottom line integration from a learning organisation perspective. Business Process Management Journal. Volume 12 (6), pp 809-21.

IUCN (International Union for the Conservation of Nature and Natural Resources) (1980) World Conservation Strategy: Living Resource Conservation for Sustainable Development. IUCN, UNEP and WWF.

Johannesburg-venues (2016) Johannesburg Map. Available at www.johannesburg-venues.co.za Accessed: 10 April 2016.

Johannesburg City Parks and Zoo (2016) Thokoza Park. Available at www.jhbcityparks.com Accessed: 22 April 2016.

Johnson, R.B. and Onwuegbuzie, A.J. (2004) Mixed methods research: A research paradigm whose time has come. Educational Researcher. Volume 33 (7), pp 14-26.

Johnson, R., Onwuegbuzie, A. and Turner, L. (2007) Toward a definition of mixed methods research. Journal of Mixed Methods Research. Volume 1 (2), pp 112-133.

Karakaya, E., Hidalgo, A. and Nuur, C. (2014) Diffusion of eco-innovation: a review. Renew Sust. Energy Rev. Volume 33, pp 392-399.

Keizer-Vlek, H.E., Verdonschot, P.F.M., Verdonschot, R.C.M. and Dekkers, D. (2014) The contribution of plant uptake to nutrient removal by floating treatment wetlands. Ecological Engineering. Volume 73, pp 684-690.

Kemp, R. and Martens, P. (2007) Sustainable development: how to manage something that is subjective and can never be achieved? Sustainability: Science, Practice and Policy. Volume 3, pp 1-10.

Kennen, K. and Kirkwood, N. (2015) Phyto: principles and resources for site remediation and landscape design. Routledge.

Kesidou, E. and Demirel, P. (2012) On the drivers of eco-innovations: empirical evidence from the UK. Res. Policy. Volume 41, pp 862-870.

Kessler, R. (2011) Storm water strategies: cities prepare aging infrastructure for climate change. Environ. Health Prospect. Volume 119, pp 514-519.

Kjolle, G.H., Utne, I.B. and Gjerde, O. (2012) Risk analysis of critical infrastructures emphasising electricity supply and interdependencies. Reliab.. Eng. Syst. Saf. Volume 105, pp 80-89.

Koudstaal, R, Rijsberman, F.R and Savenije, H. (1992) Water and sustainable development. Natural Resources Forum. Volume 16(4) pp 277-290.

Lafortezza, R., Davies, C., Sanesi, G. and Konijnendijk, CC. (2013) Green infrastructure as a tool to support spatial planning in European urban regions. iForest. Volume 6, pp 102-108.

Landscape Institute (2009) Green infrastructure; connected and multifunctional landscapes. The Landscape Institute, London, April.

Lee, T. (1992) Water management since the adoption of the Mar del Plata Action Plan: lessons for the 1990s. Natural Resources Forum. 16 (3), pp 202-211.

Li, F., Wang, R.S. and Zhao, D. (2014) Urban ecological infrastructure based on ecosystem services: status, problems and perspectives. Acta Ecol. Sin. Volume 34, pp 190-200.

Lincoln, Y.S. and Guba, E.G. (1985) Naturalistic Inquiry. Beverly Hills, CA: Sage.

Linden, A. and Carlsson-Kanyama, A. (2003) Environmentally friendly disposal behaviour and local support systems: lessons from a metropolitan area. Local Environment. Volume 8 (3), pp 291-301.

Lindenberg, A. and Steg, L. (2007) Normative, gain and hedonic goal frames guiding environmental behaviour. Journal of Social Issues. Volume 63 (1), pp 117-137.

Lu, H., Ku, C. and Chang, Y. (2015) Water quality improvement with artificial floating islands. Ecological Engineering. Volume 74, pp 371-375.

Mackenzie, N. and Knipe, S. (2006) Research dilemmas: paradigms, methods and methodology. Issues in Educational Research. Volume 16, pp 1-11.

Magraw, D.B. (1989) Legal treatment of developing countries: differential, contextual and absolute norms. Colorado Journal of International Environmental Law and Policy. Volume 1.

Martens, P. (2006) Sustainability: Science or fiction? Sustainability: Science, Practice and Policy. Volume 2, pp 1-5.

Maugeri, L. (2012) Oil: the next revolution. Belfer Center for Science and International Affairs, Harvard Kennedy School.

Mell, I.C. (2008) Green infrastructure: concepts and planning. FORUM. Volume 8, pp 69-80.

Mertens, D.M. (2005) Research Methods in Education and Psychology: Integrating Diversity with Quantitative and Qualitative Approaches. Second Edition. Thousand Oaks: Sage.

Miles, M.B. and Hibermann, A.M. (1994) Qualitative Data Analysis: A Sourcebook of New Methods. Second Edition, Sage Publishers.

Modderfontein Nature Reserve (2016) Nature on your doorstep. Available at www.modderfonteinreserve.co.za (Accessed: 19 April 2016).

Morse, J.M., Barrett, M., Mayan, M., Olson, M. and Spiers, J. (2002) Verification strategies for establishing reliability and validity in qualitative research. International Journal of Qualitative Methods. Volume 1(2), pp 13-22.

Mungai, C. (2014) Cosmetics and beauty in Africa: Boom in traditional products, and how skin bleaching is unexpectedly driving innovation. Mail and Guardian Africa, 13 October 2014. Available at: http://mgafrica.com/article/2014-10-11-cosmetics-and-beauty-in-africa-a-growing-market-a-surge-in-traditional-products-and-how-skin-bleaching-is-unexpectedly-driving-innovation (Accessed: 28 September 2017).

Myers, S. (1978) The demonstration project as a procedure for accelerating the application of the New Technology. Report, Institute of Public Administration, Washington, D.C.

Mill, I.C., Henneberry, J., Hehl-Lange, S. and Keskin, B. (2013) Promoting urban greening: valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban Forestry and Urban Greening. Volume 12(3), pp 296-306.

Mitsch, W.J. and Gosselink, J.G. (2015) Wetlands. Fifth edition. New Jersey: John Wiley and Sons, Inc.

NWA (1998) National Water Act, Act no 36 of 1998. Republic of South Africa, Pretoria.

OECD (2009) Sustainable manufacturing and eco-innovation: towards a green economy. Policy Brief, June 2009. Available at www.oecd.org/sti/42944011.pdf Accessed: 20 November 2010.

Ollis, D., Snaddon, K., Job, N. and Mbona, N. (2013) Classification system for wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems. SANBI Biodiversity Series 22.

Oltra, V. and Jean, M.S. (2009) Sectoral systems of environmental innovation: an application to the French automative industry. Technol. Forecast. Soc. Change. Volume 76, pp 567-583.

Pakzad, P. and Osmond, P. (2016) Developing a sustainability indicator set for measuring green infrastructure performance. Urban Planning and Architecture Design for Sustainable Development (UPADSD), 14-16 October 2015. Procedia – Social and Behavioural Sciences. Volume 216, pp 68-79.

Paraschiv, D.M., Nemoianu, E.L., Langa, C. and Szabo, T. (2012) Eco-innovation, responsible leadership and organisational change for corporate sustainability. Rev. Amfiteatru Econ. Volume 14 (32), pp 327-342.

Patterson, S.A. and Apostolakis, G.E. (2007) Identification of critical locations across multiple infrastructures for terrorist actions. Reliab. Eng. Syst. Volume 92, pp 1183-1203.

Pearce, D.W., Markandya, A. and Barbier, E.B. (1989) Blueprint for a green economy. Earthscan.

Qi, G.Y., Shen, L.Y., Zeng, S.X. and Jorge Ochoa, J. (2010) The drivers for contractors' green innovation: an industry perspective. Journal of Cleaner Production. Volume 18, pp 1358-1365.

Rajamani, L. (2006) Differential treatment in international environmental law. Oxford: Oxford University Press.

Rennings, K., Ziegler, A., Ankeleb, K. and Hoffman, E. (2006) The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance. Ecological Economics. Volume 57, pp 45-59.

Revitt, D.M., Shutes, R.B.E., Llewellyn, N.R. and Worrall, P. (1997) Experimental reed bed systems for the treatment of airport runoff. Water Science Technologies. Volume 36 (8-9), pp 385-390.

Reynolds, C.M. (2012) Presentation to Harvard University GSD 9108, Phyto Research Seminar: Remediation and Rebuilding Technologies in the Landscape. March, 2012.

Rock, S. (2000) Lecture delivered at the Phytoremediation, State of the Science Conference, Boston, MA, May 2000.

Rogers, E.M. (1995) Diffusion of Innovations. Fourth Edition. Free Press.

Rogers, E.M. (2003) Diffusion of Innovations. Fifth Edition. Free Press.

Rogers, E.M. and Kincaid, D.L. (1981) Communication Networks: Toward a New Paradigm for Research. New York: Free Press.

Rutherford, S. (2007) Green governmentality: insights and opportunities in the study of nature's rule. Progress in Human Geography. Volume 31 (3), pp 291-307.

SA-Venues (2016) Soweto Map. Available at www.savenues.co.za Accessed: 19 April 2016.

Saeed, T., Al-Muyeed, A., Afrin, R., Rahman, H. and Sun, G. (2014) Pollutant removal from municipal wastewater employing baffled subsurface flow and integrated surface flow-floating treatment wetlands. Journal of Environmental Sciences. 26, pp 726-736.

Santolaria, M., Oliver-Sola, J., Gasol, C.M., Morales-Pinzon, T. and Rieradevall, J. (2011) Eco-design in innovation driven companies: perception, predictions and the main drivers of integration. The Spanish example. Journal of Cleaner Production. Volume 19, pp 1315-1323.

Schaffler, A. (2013) State of the Green Infrastructure in the Gauteng City-Region. Gauteng City-Region Observatory.

Schaffler, A. and Swilling, M. (2013) Valuing green infrastructure in an urban environment under pressure – the Johannesburg case. Ecological Economics. Volume 86, pp 246-257.

Seedat, R. (2013) Foreword in: A. Schaffler (Ed.) State of the Green Infrastructure in the Gauteng City-Region. Gauteng City-Region Observatory.

Serrano, M., Sanz, L., Puig, J. and Pons, J. (2002) Landscape fragmentation caused by the transport network in Navarra (Spain): two scale analysis and landscape integration assessment. Landsc. Urban Plan. Volume 58, pp 113-123.

Sianipar, C.P.M., Yudoko, G., Adhiutama, A. and Dowaki, K. (2013) Community empowerment through appropriate technology: sustaining the sustainable development. The 3rd International Conference on Sustainable Future for Human Security Sustain 2012. Procedia Environmental Sciences. Volume 17, pp 1007-1016.

State of the Environment Report (SoER) (2003) State of the Environment Report. City of Johannesburg. Johannesburg.

State of the Environment Report (SoER) (2008) State of the Environment Report. City of Johannesburg. Johannesburg.

Stewart, F.M., Mulholland, T., Cunningham, A.B., Kania, B.G. and Osterlund, M.T. (2008) Floating islands as an alternative to constructed wetlands for treatment of excess nutrients from agricultural and municipal wastes – results of laboratory-scale tests. Land Contamination and Reclamation, 16 (1), pp 25-33.

Strydom, A. and Bezuidenhout, R. (2014). Qualitative data collection. In: F. Du Plooy-Cilliers, C. Davis and R. Bezuidenhout (Eds), Research Matters. Cape Town: Juta and Company Ltd.

Sun, X., Li, F., Tao, Y. and Song, Y.S. (2015) Comprehensive evaluation of different scale cities' sustainable development for economy, society and ecological infrastructure in China. Journal of Cleaner Production. (In press), pp 1-9.

Teddlie, C. and Tashakkori, A. (2009) Foundations of Mixed Methods Research. Integrating Quantitative and Qualitative Approaches in the Social and Behavioural Sciences. Thousand Oaks, CA: Sage.

Theyel, G. (2000) Management practices for environmental innovation and performance. Int. J.Oper. Prod. Manag. Volume 20 (2), pp 249-266.

Timma, L., Blumberga, A. and Blumberga, D. (2015) Combined and mixed methods research in environmental engineering: when two is better than one. Energy Procedia. Volume 72, pp 300-306.

Tseng, M.L., Wang, R., Chiu, A.S.F., Geng, Y. and Lin, Y.H. (2013) Improving performance of green innovation practices under uncertainty. Journal of Cleaner Production. Volume 40, pp 71-82.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, J. and James, P. (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: a literature review. Landscape Urban Planning. Volume 81, pp 167-178.

United Nations (UN) (1974) Eco-Development. IV UN Conference on the Human Environment / UN Environment Programme years: 1970 – 1975 series.

United Nations (UN) (1992) Rio Declaration on Environment and Development. Report of the UN Conference on Environment and Development. UN Doc A/CONF 151/26/Rev 1, Volume 1.

United Nations (UN) Habitat (2013) Revised compilation for sustainable cities and human settlements in the sustainable development goals (SDGs) within the post 2015 development agenda. Available at www.pando.sc/sites/default/files/documents/revised_cities_sdg_compilation_20_dec_2013.pdf Accessed: 21 October 2014.

United Nations (UN) Sustainable Development Solutions Network (2014) Indicators and a monitoring framework for sustainable development goals. Available at www.unsdsn.org/wpcontent/uploads/2014/11/141125-indicator-working-draft-WEB.pdf Accessed: 12 January 2015.

Van de Moortel, A.M.K., Meers, E., De Pauw, N. and Tack, F.M.G. (2010) Effects of vegetation, season and temperature on the removal of pollutants in experimental floating treatment wetlands. Water Air Soil Pollution. Volume 212, pp 281-297.

Van Griensven, H., Moore, A.P and Hall, V. (2014) Mixed methods research – The best of both worlds? Manual Therapy. Volume 19, pp 367-371.

Verghese, K. and Lewis, H. (2007) Environmental innovation in industrial packaging: a supply chain approach. International Journal of Production Research. Volume 45 (18-19), pp 4381-4401.

Vinuales, J.E. (2013) The rise and fall of sustainable development. Reciel. Volume 22 (1), pp 3-13.

Vlek, C. and Steg, L. (2007) Human behaviour and environmental sustainability: problems, driving forces, and research topics. Journal of Social Issues. Volume 63 (1), pp 1-19.

Vymazal, J. (2007) Removal of nutrients in various types of constructed wetlands. Sc.i Total Environ. Volume 380 (1-3), pp 48-65.

Wong, N., Tan, A., Tan, P., Sia, A. and Wong, N. (2010) Perception studies of vertical greenery systems in Singapore. Journal of Urban Planning and Development. Volume 136 (4), pp 330-338.

WCED (World Commission on Environment and Development) (1987) Our Common Future. Oxford University Press, USA.

Weng, M.H. and Lin, C.Y. (2011) Determinants of green innovation adoption for small and medium-size enterprises (SMES). African Journal of Business Management. Volume 5 (22), pp 9154-9163.

Weragoda, S.K., Jinadasa, K.B.S.N., Zhang, D.Q., Gersberg, R.M., Tan, S.K., Tanaka, N. and Jern, N.W. (2012) Tropical application of floating treatment wetlands. Wetlands. Volume 32, pp 955-961.

Western Cape Department of Environmental Affairs and Development Planning (WC-DEADP) (2013) State of the Environment outlook report for the Western Cape Province. Cape Town.

World Wide Fund for Nature (WWF) and International Finance Corporation (IFC) (2015) The value of water: a framework for understanding water valuation, risk and stewardship. August 2015 discussion draft. Geneva, World Wide Fund for Nature.

Wu, Y.G. (2016) Sponge City Design. Nanjing: Phoenix Science Press.

Yin, R.K. (2009) Case Study Research: Design and Methods. Fourth edition. Thousand Oaks, CA: Sage.

Van Zeijl-Rozema, A., Corvers, R., Kemp, R. and Martens, P. (2008) Governance for sustainable development: a framework. Sustainable Development. Volume 16, pp 410-421.

APPENDIX A: ETHICS CLEARANCE

MONASH University
Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project Number: CF15/4391 - 2015001897

Project Title: The social sustainability of phytotechnological floating treatment wetlands in Integrated Watershed Management in South Africa

Chief Investigator: Assoc Prof Bimo Nkhata

Approved: **From:** 18 January 2016 **To:** 18 January 2021

Terms of approval - ***Failure to comply with the terms below is in breach of your approval and the Australian Code for the Responsible Conduct of Research.***

1. The Chief investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash University letterhead and the Monash University complaints clause must include your project number.
6. **Amendments to the approved project (including changes in personnel):** Require the submission of a Request for Amendment form to MUHREC and must not begin without written approval from MUHREC. Substantial variations may require a new application.
7. **Future correspondence:** Please quote the project number and project title above in any further correspondence.
8. **Annual reports:** Continued approval of this project is dependent on the submission of an Annual Report. This is determined by the date of your letter of approval.
9. **Final report:** A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
10. **Monitoring:** Projects may be subject to an audit or any other form of monitoring by MUHREC at any time.
11. **Retention and storage of data:** The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

[redacted]

Professor Nip Thomson
Chair, MUHREC

cc: Mrs Yolandi Schoeman

Monash University, Room 111, Chancellery Building E
24 Sports Walk, Clayton Campus, Wellington Rd
Clayton VIC 3800, Australia
Telephone: +61 3 9905 5490 Facsimile: +61 3 9905 3831
Email: muhrec@monash.edu http://intranet.monash.edu.au/researchadmin/human/index.php
ABN 12 377 614 012 CRICOS Provider #00008C

APPENDIX B: EXPLANATORY STATEMENT

MONASH University

EXPLANATORY STATEMENT

March 2016

The social sustainability of phytotechnological floating treatment wetlands in Integrated Watershed Management in South Africa

You are invited to take part in this study. Please read this Explanatory Statement in full before deciding whether or not to participate in this research. If you would like further information regarding any aspect of this project, you are encouraged to contact the student researcher via the phone numbers or email addresses listed above.

This information sheet is for you to keep.

Student research project

My name is Yolandi Schoeman and I am conducting a research project with Professor Bimo Nkatha from the Water Research Node towards a Masters Degree at Monash University (South African Campus). This means that I will be writing a thesis. I received funding from the university, the City of Johannesburg and Hydromulch to undertake this research.

Why did you choose this particular person as participant?

We believe that your input is valuable concerning the social sustainability of floating treatment wetlands.

The aim / purpose of the study

It is not always possible to install conventional wastewater treatment plants in areas where there is water pollution. Through floating treatment wetlands, units can be installed into any polluted water body which immediately starts treating contaminated water. There is not much research that has been done and published in South Africa on floating treatment wetlands, and especially work is limited globally on the social sustainability and acceptability (diffusion) of this eco-technology. This research will contribute immensely in understanding the important components that drives the diffusion and social sustainability of floating treatment wetlands as an eco-technology.

The following are the specific objectives of this research:

(a) To identify the factors contributing to the adoption (diffusion) of floating treatment wetlands amongst various stakeholders;

(b) To identify the process of diffusion to be followed contributing to the widespread acceptance of floating treatment wetlands as a tool in water quality enhancement.

(c) To determine the social sustainability of floating treatment wetlands in South Africa by selected and strategic stakeholder groups.

Participants will participate in interviews and open forum discussions. A video on the floating treatment wetlands will be shown to participants upfront before the questions will be asked (only applicable in open forum discussions). The questions for the focus group meetings and interviews will be the same. For Focus Group meetings it is envisaged that the session will take approximately 1 hour and 30 minutes where questions will be asked to participants to encourage participation. For interviews, the session will not be longer than 1 hour and the list of questions will be asked to the participant to respond to.

Possible benefits

A conceptual model for the development and implementation of floating treatment wetland islands will be presented in the thesis as an outcome of the research. This model can be used by water managers, conservation managers, environmental professionals and other professionals concerned with water quality and integrated water resource management for the development and implementation of eco-technology.

What does the research involve?

The study involves investigating the social sustainability of phytotechnological floating treatment wetlands in Integrated Watershed Management in South Africa

How much time will the research take?

An interview will take up to an hour to perform but can be shorter depending on the information sharing.

Inconvenience/discomfort

There is no discomfort to participants except for the inconvenience of giving their time for the interview.

Payment / risk

There is no risk to the participants of the study and there won't be any payment for participating in the study through interviews.

Can I withdraw from the research?

You are under no obligation to participate since participation in this study is voluntary. If you do consent to participate you may withdraw prior to participating in the interviews. Once interviews are complete, I will be able to use the data for my thesis.

Confidentiality

All information gathered from the interviews will be captured anonymously. Codes will be used to distinguish between various participants and there is no need, at any time, to disclose personal information.

Storage of data

The storage of data collected will adhere to the University regulations and kept on University premises in a locked cabinet for 5 years. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

If you would like to contact the researchers about any aspect of this study, please contact the Chief Investigator:

Chief Investigator's : Professor Bimo Nkatha
Water Node, School of Social Research
Phone: +27 11 950 4453
email: bimo.nkhata@monash.edu

Student's name : Yolandi Schoeman
[redacted]

Complaints

Should you have any concerns or complaints about the conduct of the project, you are welcome to contact the Executive Officer, Monash University Human Research Ethics (MUHREC):

Executive Officer
Monash University Human Research Ethics Committee (MUHREC)

Room 111, Building 3e
Research Office
Monash University VIC 3800

Tel: +61 3 9905 2052 Email: muhrec@monash.edu Fax: +61 3 9905 3831

Ms Hester Stols
Office of the Deputy Pro Vice-Chanecellor :
Research
Monash South Africa Ltd
Tel : +27 11 950 4143
Fax : + 27 11 950 4133
Hester.stols@monash.edu

Thank you,

Yolandi Schoeman

APPENDIX C: CONSENT FORMS

MONASH University

CONSENT FORM

(Interviews)

Project: The social sustainability of phytotechnological floating treatment wetlands in Integrated Watershed Management in South Africa

Note: This consent form will remain with the Monash University researcher for their records

I have been asked to take part in the Monash University research project specified above. I have read and understood the Explanatory Statement and I hereby consent to participate in this project.

I consent to the following:	Yes	No
I agree to be interviewed by the researcher	☐	☐
I agree to make myself available for a further interview if required	☐	☐
I agree that once the interview is complete, the information can be used for the research thesis	☐	☐

And

I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the interview without being penalised or disadvantaged in any way.

I understand that any data that the researcher extracts from the interviews and focus group for use in reports or published findings will not, under any circumstances, contain names or identifying characteristics.

I understand that I will be given a transcript of data concerning me for my approval before it is included in the write up of the research.

I understand that any information I provide is confidential, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party.

I understand that data from the interviews will be kept in a secure storage and will be accessible to the research team. I also understand that data will be destroyed after a 5 year period unless I consent to it being used in future research.

Name of Participant ______________________________

Participant Signature ______________________________ Date ____________

APPENDIX D: CODED INTERVIEWS AND TRANSCRIBED DATA

Interview with Regulatory Organization No 1 Interviewee

Questions and answers	Notes and themes	Codes
(a) How would you define the term integrated watershed management?		
Integrated approach. Considering the entire hydrological cycle and each component of the water cycle that is interlinked and impacts on each other through ground and surface water interflow.	Integrated approach Entire hydrological cycle consideration Water cycle is interlinked Impacts of water cycle components Ground and surface water interflow	IWSM1 IWSM2 IWSM3 IWSM4 IWSM5
(b) What are the current challenges experienced in urban water quality management?		
There are a number of challenges:		
- Huge out flux of competencies of local authorities	Competency outflow of local authorities	Chal1
- Budget related. Don't use funds for maintenance of water services, funds are used to cross subsidize social problem	Budget Funds not appropriately used Funds used to cross subsidize social problems	Chal2 Chal3 Chal4
- Poor enforcement. The Director General is asking to take municipalities to task.	Poor enforcement Municipalities need to be taken to task	Chal5 Chal6
(c) What measures or tools are applied to deal with urban water quality issues?		
From the Department of Water and Sanitation there are source directed controls. Licensing measures. Good conditions and standards are required for upgrades and developments. Enforcement and monitoring applicable. A requirement that Sustainable Urban Drainage Systems for part of new designs. Resource quality and resource integrity needs protection.	Department of Water and Sanitation use source directed controls Licensing measures Good conditions and standards required for developments Enforcement Monitoring Sustainable Urban Drainage Systems	MeTo1 MeTo2 MeTo3 MeTo4 MeTo5 MeTo6 MeTo7

	to form part of new designs Resource quality and resource integrity needs protection	
(d) In your opinion, how effective are current implemented sustainable urban drainage systems?		
Not very successful. Sustainable Urban Drainage Systems are a fairly new paradigm and way of thinking. Need to stop making rivers straight and in lined canals. Need to put rivers back in the landscape. This has caused many flood damages and is a big indicator of unsustainable urban drainage.	Not very successful Sustainable Urban Drainage Systems as new paradigm Stop making rivers straight and line canals Importance of river functioning in landscape Flood damages indicator of unsustainable urban drainage	MeTo8 MeTo9 MeTo10 MeTo11 MeTo12
(e) In your opinion, what are the social aspects and concerns associated with floating treatment wetlands?		
Informing and educating people and communicating the value of wetlands. A paradigm shift is required from ecosystem services to eco infrastructure and the huge value infrastructure has in ecosystem services. Ecological infrastructure provides ecosystem benefits to the society and one cannot take all the infrastructure away. Need to invest in ecological infrastructure. The United States of America decommissioned lined canals and it is cheaper to manage water in quantity and quality. People needs to be educated. There is huge value in investing in ecological infrastructure (natural and constructed).	Informing and educating people Communicating value of wetlands Paradigm shift is required Ecosystem services to eco infrastructure Ecological infrastructure benefits Investment required in ecological infrastructure	SoAs1 SoAs2 SoAs3 SoAs4 SoAs5 SoAs6
(f) In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands?		
We need to understand that it will cost money but it will provide many benefits. Active management is still required. Think of the canalized American rivers (risk and flooding)	Will cost money Benefits associated Active management required Economic benefit	EcAs1 EcAs2 EcAs3 EcAs4

versus uncanalized rivers. Management will not be intensive. Economic benefit is huge.		
(g) In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?		
Education to get people aware. Limitations to what can be achieved. Level of management / maintenance is required. If not well controlled, the use of alien plants on the islands can cause other invasive issues by escaping plants.	Education Limitations Level of maintenance required Use of alien plants	EnAs1 EnAs2 EnAs3 EnAs4
(h) What is your opinion in using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plant outperforms indigenous plants in the uptake of contaminants?		
Excellent idea. Definitely an option and worthwhile. Level of education is required.	Excellent idea Definite option Level of education required	NoIn1 NoIn2 NoIn3
(i) What modification suggestions do you have for floating treatment wetlands in the urban context?		
Excellent idea. More value can be offered than what people might think and can be implemented far and wide. Water quality can be addressed in a certain bracket.	Excellent idea More value in idea Implementation is far and wide Water quality (limited) can be addressed	MoSu1 MoSu2 MoSu3 MoSu4
(j) Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool?		
Yes	Yes	Opin1
(k) What is your general opinion of floating treatment wetlands?		
Lot of value and application potential. Has limitations. Can be used in conjunction with other tools in water quality management and mitigation.	Value and application potential Has limitations Can be used with other water quality management tools	GeOp1 GeOp2 GeOp3

Interview with Regulatory Organization No2 Interviewee

Questions and answers	Notes and themes	Codes
(a) How would you define the term integrated watershed management?		
The management of the watershed by all users towards a common goal.	Management of the watershed by all Management towards a common goal	IWSM1 IWSM2
(b) What are the current challenges experienced in urban water quality management?		
Water treatment facilities have collapsed on most small towns hence raw sewerage running into rivers.	Collapsed water treatment facilities Challenges in most small towns Raw sewage running into rivers	Chal1 Chal2 Chal3
(c) What measures or tools are applied to deal with urban water quality issues?		
Bottled water is sold and private companies contribute to water treatment.	Private companies contributing to water treatment	MeTo1
(d) In your opinion, how effective are current implemented sustainable urban drainage systems?		
If they are maintained they are effective depending on the age of the design.	If maintained effective Age of design also plays important role	MeTo2 MeTo3
(e) In your opinion what are the social aspects and concerns associated with floating treatment wetlands?		
Should species be used that can invade they will have a negative impact on recreation over the long term.	Alien plants and impact on recreation	SoAs1
(f) In your opinion what are the economic aspects and concerns associated with floating treatment wetlands?		
Should species be used that can invade they will be costly to control over the long term.	Invader species and control over long term	EcAs1
(g) In your opinion what are the environmental aspects and		

concerns associated with floating treatment wetlands?		
Should species be used that can invade they will have a negative impact on the environment over the long term.	Invader species and control over long term	EnAs1
(h) What is your opinion in using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plant outperforms indigenous plants in the uptake of contaminants?		
Only well-known and proven plants to be used.	Yes, only well-known and proven plants	NoIn1
(i) What modification suggestions do you have for floating treatment wetlands in the urban context?		
Mechanisms that will ensure the design is effective and within its original design goal over the long term. long-term	Long term design	MoSu1
(j) Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool (Yes/No)?		
Yes	Yes	Opin1
(k) What is your general opinion of floating treatment wetlands?		

Interview with Regulatory Organization Interviewee No 3

Questions and answers	**Notes and themes**	**Codes**
(a) How would you define the term integrated watershed management?		
Management of more than one characteristic of the watershed. Could also include more than one watershed.	Management of more than one characteristic in watershed Can be more than one watershed	IWSM1 IWSM2
(b) What are the current challenges experienced in urban water quality management?		
Modifications to flow drivers (surface flows, interflows, groundwater flows), water quality and responses (geomorphology habitat and biota), pollution, space, poor planning practices, poor maintenance, invasives	Modifications to flow drivers Water quality and responses Pollution Space Poor planning practices Poor maintenance Invasives	Chal1 Chal2 Chal3 Chal4 Chal5 Chal6 Chal7
(c) What measures or tools are applied to deal with urban water quality issues?		
Water use authorization	Water use authorization	MeTo1
(d) In your opinion, how effective are current implemented sustainable urban drainage systems?		
Designs look promising	Promising designs	EcAs1
Effective if maintained	Effective if maintained	MeTo2
(e) In your opinion what are the social aspects and concerns associated with floating treatment wetlands?		
It is secondary treatment....not treating real problem of non or poorly functioning WWTWs. Safety risk for fast boats?	Secondary treatment option Safety risk for fast boats	SoAs1 SoAs2
(f) In your opinion what are the economic aspects and concerns associated with floating treatment wetlands?		

Not sure on what scale it is economical.	Considerations of economical scale	EcAs2
(g) In your opinion what are the environmental aspects and concerns associated with floating treatment wetlands?		
Low ecological risk	Low ecological risk	EnAs1
(h) What is your opinion in using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plant outperforms indigenous plants in the uptake of contaminants?		
Shouldn't mixtures be used to keep % indigenous.	Percentage indigenous plants consideration	NoIn1
(i) What modification suggestions do you have for floating treatment wetlands in the urban context?		
Designs for easier monitoring	Designs for easier monitoring	MoSu1
(j) Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool (Yes/No)?		
Yes, DWS should make it compulsory	Yes Department of Water and Sanitation should make it compulsory	Opin1 Opin2
(k) What is your general opinion of floating treatment wetlands?		
Very good idea. I always included specs for these for the WTP lagoons.	Very good idea I include specs for these in Waste Treatment Plant Lagoons	GeOp1 GeOp2

Modderfontein Conservation Society Focus Group Meeting

Questions and answers	Themes	Codes
(a) How would you define the term integrated watershed management?		
The amount of management required in integrated watershed management. Beginning and end of all water problems.	Management required Beginning and end of water problems	IWSM1 IWSM2
What is coming in and what you wish to get out of it as most of our problems at the moment are manmade pollution and we want to get it back to the natural state for the benefit of our nation.	What is coming in Manmade pollution and natural state restoration	IWSM3 IWSM4
When building starts and we have runoff, that is very much of integrated watershed management	Commencement of development activities	IWSM5
(b) What are the current challenges experienced in urban water quality management?		
Chemicals from outside and chemicals from Modderfontein Factory days that are still leaching. We see it in springs in Limbro Park for example. Springs high in Nitrogen. Runoff from urban development in surrounding areas.	Chemicals from outside Chemicals from Modderfontein Factory days Springs in community, chemicals leaching Springs high in nitrogen Runoff from urban development	Chal1 Chal2 Chal3 Chal4 Chal5
(c) What measures or tools are applied to deal with urban water quality issues?		
There used to be lots and lots of reeds that would clean up water. But, they have all been taken out.	Reeds	MeTo1
Reed beds where more prolific in the past then what they are now. Turning the reserve into an urban park they are trying to keep the reeds at bay for picnics and enjoyment of the view.	Reed beds where prolific Turning the reserve in urban park	Chal6 Chal7
We were told that there would be a lot of storm water attenuation ponds. Certainly where we are we are influenced by Greenstone runoff. A lot of money was spent to control the runoff	Storm water attenuation ponds Stone gabions do not work Stream badly eroded	MeTo2 Chal8 Chal9

and it hasn't worked. The stream is badly eroded. In the reserve with runoff exceeding, amount of damage is done and the stone gabions do not work. There is a vast issue around runoff and its control. We understand it is being addressed, but don't know how. We do not see the effect.	Runoff issues Runoff control an issue	Chal10 Chal10
In speed and quantity, a lot of water comes down sometimes	Water quantity in runoff	Chal11
We have to deal with a lot of sewerage running into areas. Sewers enter storm water infrastructure.	Sewage runoff Sewers enters storm water infrastructure	Chal12 Chal13
Maintenance of urban water quality infrastructure	Maintenance of urban water quality infrastructure	Chal14
(d) In your opinion, how effective are current implemented sustainable urban drainage systems?		
Not effective	Not effective	MeTo3
(e) In your opinion, what are the social aspects and concerns associated with floating wetlands?		
Fishing and fishing lines getting caught up in the plants and island	Fishing and fishing lines	SoAs1
If birds use the islands and use plants for food source, they might get poisoned	Birds using islands for food source	EnAs1
Reptiles such as monitor using the islands	Reptiles like monitors	EnAs2
Theft of islands is also a matter of concern	Theft of islands	SoAs2
Islands that can carry a person's weight can become a playground for kids. Can fall through and off the islands. Can be a dangerous attraction in poorer areas and children can damage the plants.	Dangerous attraction to children in poorer areas Children can damage islands	SoAs3 SoAs4
In flood conditions, the islands' mounting should be adequate	Islands mounting mechanism to be adequate	EnAs3
People might use alien plants on the islands that can become problematic and invasive.	Using alien plants on islands	EnAs4
(f) In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands.		
Need to be self-sustaining	Self-sustaining needs	EcAs1

Cost benefit to natural areas where wetland degradation is off concern also need to be considered.	Cost benefit to natural areas	EcAs2
(g) In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?		
Application to natural environments need to be considered	Application to natural environments	EnAs5
Root system does not need pruning and are beneficial to fish	Root system no pruning requirement Root system beneficial to fish	EnAs6 EnAs7
Using exotic plants that can become invasive	Using exotic plants	EnAs4
(h) What is your opinion in using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plant outperforms indigenous plants in the uptake of contaminants?		
Too many unknowns	Too many unknown	NoIn1
Insects coming over from other countries with exotics	Insects introduced from other countries	NoIn2
Depends on the percentage of contaminant uptake vs that of outperforming endemic plants	Performance of non-indigenous vs indigenous	NoIn3
Depends on the application, in acid mine drainage environments it would not matter as little is growing there	Depends on application environment	NoIn4
Can get into riverine systems if not sterile	Threat to river systems	NoIn5
If there is 95% certainty, then use it	Level of certainty	NoIn6
One must not be too closed off to the idea if it works	Needs to be open minded on the idea	NoIn7
(i) What modification suggestions do you have for floating treatment wetlands in the urban context?		
An electric fence	Electric fence	MoSu1
The square shape is not natural. Need to make it curvier.	More natural shape	MoSu2
(j) Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool?		
Yes, with indigenous vegetation	Yes, with indigenous vegetation	Opin1

(k) **What is your general opinion of floating treatment wetlands?**		
It should not become a crowd pleaser and need to make a real difference	Not be a crowd pleaser and need to make a difference	GeOp1
Can potentially also have a positive impact on areas impacted by sewerage	Positive impact on sewage impacted areas	GeOp2
Need to prevent debris such as paper and junk that enters water sources from harming the islands	Need to prevent debris damage	GeOp3
Great idea	Great idea	GeOp4
Visually effective and appealing. Even if square you can see someone is doing something.	Visually effective and appealing	GeOp5
Environmentally desirable	Environmentally desirable	GeOp6
Problem where water hyacinth cling onto islands and therefore populate more	Alien plants that can cling to it	GeOp7
Lifespan is significant	Significant lifespan	GeOp8

Specialist Focus Group Meeting

<u>**Questions and answers**</u>	<u>**Notes and themes**</u>	<u>**Codes**</u>
(a) How would you define the term integrated watershed management?		
Understanding what is happening to water in the whole catchment and watershed	Understanding What happens to water Whole catchment Watershed	IWSM1 IWSM2 IWSM3 IWSM4
Understanding the hydrogeological processes and what happens with water. Where water comes from and where it goes	Understanding Hydrogeological processes What happens with water Where water comes from Where water goes	IWSM1 IWSM5 IWSM2 IWSM2 IWSM2
(b) What are the current challenges experienced in urban water quality management?		
Storm water control and storm water management. Waste water management. Sewerage farms maintenance and operation	Storm water control Storm water management Waste water management Sewerage farms maintenance Sewerage farms operation	Chal1 Chal2 Chal3 Chal4 Chal5
Illegally discharged effluent with chemical composition with biologically chemically reactions	Illegally discharged Illegally discharged effluent with chemical composition Biologically chemically reactions of illegal discharged effluent	Chal6 Chal7 Chal8
Oils, car oils, cooking oils, phosphates and cigarette buds	Oils Car oils Cooking oils Phosphates Cigarette buds	Chal9 Chal10 Chal11
Policy	Policy	Chal12
(c) What measures or tools are applied to deal with urban water quality issues?		
Legislation and monitoring	Legislation	MeTo1

	Monitoring	MeTo2
(d) In your opinion, how effective are current implemented sustainable urban drainage systems?		
Not effective	Not effective	MeTo3
Johannesburg had more than 50 sampling points in their river systems 15 years ago. Monitoring has ceased in many of the areas as the it is the point of view that the rivers are the responsibility of Water Affairs. Symptoms of licenses to be issued. The Department (Water Affairs) moved backwards and only issue licenses for specific activities. Integrated water use licenses side-lined and the guidance to local municipalities have been lost, as if the Department does not apply what is stated in the Water Act. The Act requires an integrated approach to every water use authorization. A ripple effect created to local authorities, to provincial and eventually to industry and to other water users.	Some monitoring has ceased Monitoring points decreased Opinion on responsibility shift Water licenses Guidance lost to local municipalities Integrated approach to water use lacking Department (DWS) not applying integrated approach Ripple effect created from local to industry to water users	MeTo4 MeTo5 MeTo6 MeTo7 MeTo8 MeTo9 MeTo10 MeTo11
(e) In your opinion, what are the social aspects and concerns associated with floating wetlands?		
Some people think that the islands are ugly and prefer open water	Perceptions that islands are ugly	SoAs1
Education	Education	SoAs2
Employment	Employment	SoAs3
The system is isolated, economically a lot of key players can come together. Build big islands on dams and have a visitors' and educational facility. It can make economic sense. In many cases the islands are characteristic of isolated systems on a dam. Can become a central feature of a dam. Take the worst problem and make it your best feature. What is often on the peripheral can become a central feature of a dam. Make into an economic initiative and integrate social aspects therein.	Isolated system Can make economic sense Central feature of a dam Integrate social aspects therein	SoAs4 EcAs1 SoAs5 SoAs6
(f) In your opinion, what are the economic aspects and concerns associated with floating treatment wetlands.		

Integrate a commercial value into the islands	Integrate a commercial value into islands	EcAs2
Although you want to save nature, one can also get a spin off from it. Investors would be willing to support. Timelines are important though. Investors would like to see start and finish of projects and when it can in fact sustain itself then it can be supported by investors.	Get a spin off from it Timelines important for investors Clear project schedule Prove that it can sustain itself	EcAs3 EcAs4 EcAs5 EcAs6
The vegetation can be too expensive for small community projects when they can't source it from the local area. So, they need to buy from nurseries and it is expensive.	Expensive vegetation Potential challenges in sourcing plants locally	EcAs7 EcAs8
(g) In your opinion, what are the environmental aspects and concerns associated with floating treatment wetlands?		
Species you use and the potential invasive nature of it	Type of species used Species with invasive nature	EnAs1 EnAs2
These types of islands can empower more than 15000 people of examples I have seen	Potential for job creation	EcAs9
(h) What is your opinion in using non-indigenous sterile plants in floating treatment wetlands if the non-indigenous sterile plant outperforms indigenous plants in the uptake of contaminants?		
Yes, but the invasive nature needs to be well researched	Yes but Invasive nature to be well researched	NoIn1
(i) What modification suggestions do you have for floating treatment wetlands in the urban context?		
To integrate into natural surroundings	Integrate into natural surroundings	MoSu1
Not be isolated systems	Not to be isolated	MoSu2
(j) Are you of the opinion that floating treatment wetlands can be utilized as a sustainable urban drainage system tool?		
Yes	Yes	Opin1

(k) **What is your general opinion of floating treatment wetlands?**		
As a tool in ecological engineering it adds to the complexity of things. To master ecological engineering, one needs to study further but also need to brings various teams together, as a team leader one can also bring things together.	Tool in ecological engineering application Further studying required to master ecological engineering Bring teams together in ecological engineering As team leader can bring things together in ecological engineering	GeOp1 GeOp2 GeOp3 GeOp4
I didn't think that ecological engineering existed up until now	Inexistence of ecological engineering	GeOp5
I am a big fan of ecological engineering and the thinking approach	Fan of ecological engineering Fan of the ecological engineering thinking approach	GeOp6 GeOp7
You gave a good presentation and introduction. Need to take the thought process back and integrate into our research. Projects need to be economically feasible.	Integrate thought process in our research Projects to make economic sense	GeOp8 GeOp9
The ecological engineering field is very valuable to address our challenges of today	Ecological engineering field very valuable Ecological engineering field can address our challenges today	GeOp10 GeOp11
It's our passion, ecological engineering and its field need to be advanced. It needs to be featured on the forefront of what we are doing.	Ecological engineering our passion Ecological engineering field to be advanced Ecological engineering to feature on the forefront of what we are doing	GeOp12 GeOp13 GeOp14
Ecological engineering needs to be more formalized in South Africa	Ecological engineering to be	GeOp15

	formalized in South Africa	

On-line survey random participants

1. How would you describe the status of the environment you live in?	Themes	Codes
Highly transformed due to agriculture, natural areas reasonably good condition	Highly transformed	StaE1
Anthropogenically transformed	Anthropogenically transformed	StaE2
Medium	Medium	StaE3
Pristine - I live in the Wilderness Section of iMfolozi Game Reserve	Pristine	StaE4
Reasonable condition	Reasonable	StaE3
EFFECTED BY ANTHROPOGENIC ACTIVITIES LEADING TO HABITATE AND BIODIVERSITY LOSS.	Anthropogenically transformed	StaE2
Healthy	Healthy	StaE4
Urban	Urban	StaE6
Semi Polluted	Semi-Polluted	StaE7
It is continuously being devastated, and this is what I consider to be the major "environmental degradators"	Continually devastated	StaE8
Overgrazing, deforestation, wetlands erosion, massive soil erosion and water pollution by the textile industries	Anthropogenically transformed and impacted	StaE2
Degraded	Degraded	StaE9
Degrading	Degraded	StaE9
Poor - urbanization high, veld degradation	Poor	StaE10
Good, but too much development	Good	StaE11
Okay, it could be worse but then again it could be better	Okay	StaE3
Degraded	Degraded	StaE9
Variable levels of degradation, negatively influenced by human influences	Degraded	StaE9
I live in a city, so it is maintained. But waste management is very bad so there is a ton of raw material pollution entering waterways and the sea sadly, never mind what we can see with our eyes	Urban	StaE6
Fair	Fair	StaE12
Fragmented urban landscape	Fragmented	StaE13
Artificial	Artificial	StaE14
From a biodiversity perspective, lots of critically endangered species due to pollution	Modified	StaE15

Impacted	Impacted	StaE16
Degraded with potential	Degraded	StaE9
There are many options to describe the environment - but I would consider the status of the natural environment as poor.	Poor	StaE10
Good	Good	StaE11
Nature reserve	Conservation area	StaE17
Conservation area in the Low veld with mixed bushveld	Conservation area	StaE17
Average	Average	StaE3
Healthy where private properties manage environment. Public space poorly managed and rivers and streams neglected	Healthy in private properties management area Poor in public governed areas	StaE18 StaE19
2. How would you describe the water quality in your area?		
Reasonable, depends on the season Highly polluted Very poor Good but limited Poor POLLUTED DUE TO UPSTREAM-DOWNSTREAM ACTIVITIES Very Good Bad Semi Polluted Degraded Eutrophic, degraded, high salinity and decreased quantity Moderate Average. The closest river is the Klein Jukskei, which is quite polluted The river flowing through town is polluted. Terrible	Reasonable Season depending Highly polluted Very poor Good Poor Polluted Very good Bad Semi polluted Degraded Eutrophic and degraded Moderate Average Polluted rivers Terrible Fair to poor	WaQu1 WaQu2 WaQu3 WaQu4 WaQu5 WaQu6 WaQu7 WaQu8 WaQu9 WaQu10 WaQu11 WaQu12 WaQu13 WaQu14 WaQu15 WaQu16 WaQu17

Fair to poor I live in a city, so the drinking water is very good. Storm water and freshwater ecosystems are struggling however. Poor Poor Good Impacted – poor Fair to good Terrible: don't touch It is not good, particularly in the urban and peri-urban areas The drinking water is mostly acceptable, but can be variable. The natural water quality I presume to be extremely poor. Excellent Silted poor Average Good in taps, strong taste. Very poor river water quality, Hennops River too many sulfates	Good drinking water Struggling storm water and ecosystems Poor Poor Good Impacted to poor Fair to good Terrible Poor Drinking water acceptable Natural water extremely poor Excellent Silted Poor Average Good drinking water Poor river water quality	WaQu18 WaQu19 WaQu6 WaQu6 WaQu5 WaQu20 WaQu5 WaQu16 WaQu6 WaQu21 WaQu22 WaQu23 WaQu24 WaQu6 WaQu14 WaQu25 WaQu26
3. Have you been affected by water quality problems? If so, please explain shortly.		
Not yet No, municipal water is used for day to day use Yes, raw sewage smell in the Kaalspruit Yes. Rainfall dependent. No not personally however water quality has been so bad that irrigation farmers had to stop using water for irrigation because it was badly contaminated by the sewage in the system OUTBREAK OF DESEASES AND BIODIVERSITY LOSS No Not directly Yes there was a time where in the dam in our reserve was polluted	Not yet No Yes Yes and rainfall dependent No but problems with irrigation water Yes No No Yes and dam in reserve was polluted	AfWa1 AfWa2 AfWa3 AfWa4 AfWa5 AfWa3 AfWa2 AfWa2 AfWa6 AfWa7

Elevated levels of chlorides and salts, eutrophication, dumping, foul odour Yes, water shortages, poor municipal maintenance of infrastructure No No No Not directly Indirectly only through recreational restrictions, although many of my professional projects relate to communities with poor access to water and negative impacts from pollution Not directly, however we are all affected in the long term. Through picking up pollutants in our drinking water and environment. And also by the environmental degradation of time which will mean we will soon suffer greatly from loss of ecosystem services, and we will lose biodiversity due to water quality issues, which creates a negative feedback loop, with even further declines in the services nature provides us. No Yes. Tap water causes diarrhea and streams cause through malodors from murky stagnant water. No Just in terms of treatment No Stagnant water & mosquitoes No From time to time yes. Stinking water, health consequences, No Siltation and turbidity of water Yes. The borehole water is very high in sodium and nitrates which is naturally that way. In some dams hippos defecate a lot and can cause eutrophication. No Use water filter to make water taste better	Yes, elevated levels of contaminants Yes No No No No Yes No No Yes No Yes No Yes No Yes No Yes Yes No	AfWa3 AfWa2 AfWa2 AfWa2 AfWa2 AfWa3 AfWa2 AfWa2 AfWa3 AfWa2 AfWa3 AfWa2 AfWa3 AfWa2 AfWa3 AfWa2 AfWa3 AfWa3 AfWa2
4. What would you plant in a floating treatment wetland? What type of plants would you use?		

Indigenous wetland plants preferably local varieties	Indigenous wetland plants	PiFw1
I would imitate that of riparian zones and wetlands (e.g. sedges and reeds)	Imitate riparian zones and wetlands	PiFw2
Thypha, Pragmites, Cypress species. Endemic, indigenous.	Indigenous plants. Endemic plants	PiFw1; PiFw3
Don’t know	Don’t know	PiFw4
Palmiet	Wetland plants	PiFw5
BURKIA SPP	Burkia species	PiFw6
Indigenous wetland plants adapted to the climate in the area they are being used in.	Indigenous wetland plants	PiFw1 PiFw5
Typha, Phragmites,	Wetland plants	PiFw7
No idea	Not sure	PiFw7
Not sure	Not sure	
Scirpus, Typha, Juncus and sphagnum species		PiFw5
Wetland plants, e.g. reeds	Wetland species	PiFw5
I have found that reeds and water lilies are good for removing sulphur from the water	Wetland species	PiFw5
Indigenous wetland plants, plants that have the ability to tolerate heavy metals and other pollutants	Wetland species Indigenous wetland plants	PiFw1 PiFw5 PiFw8
Reeds and sedges	Wetland plants	
High nutrient uptake plants, as well as those providing aesthetic value and / or non-edible cash crops such as lilies or vetiver grasses	High nutrient uptake plants	PiFw1
Indigenous wetland species (i.e. no introduced species because they may 'work' better). No sure species names – there must be loads!	Indigenous wetland plants	PiFw9 PiFw5
Water plants with large root systems		PiFw1
Typha. Floating aquatic plants	Water plants	PiFw5
Indigenous aquatic plants	Wetland plants	PiFw10
Typha and Cyperus spp.		
A diverse range that would create habitat for a diverse range of faun	Indigenous wetland plants	PiFw5 PiFw5
Wetlands marsh plants, and combine with rare plant species	Wetland plants	PiFw1

Suitable plants that perform specific functions related to the treatment of water/wetland settings Indigenous water plants Aquatic species Phragmites for our area No idea Indigenous aquatic plants. No invasive aquatic water weeds	Diverse range for biodiversity Wetland plants Wetland plants Indigenous wetland plants Aquatic species Wetland plants Not sure Indigenous wetland plants	PiFw11 PiFw5 PiFw7 PiFw1
5. What is your opinion in using non-indigenous non-invasive plants in floating treatment wetlands if it is the case that the non-indigenous plants outperform the indigenous plants in the uptake of contaminants?		
Not a good idea It is completely dependent on the research put into these species and determining how likely it would be that these plants could become invasive with the increase of propagule pressure that these devices would provide Not allowable – especially in light of other aquatic invasive in our waterways. If controlled and not in a protected area – no problem There is always a chance that exotic plants escape so would rather look at indigenous plants first SO AS TO HAVE CONTROL MEASURES IN PLACE Fine for cities, not for natural or rural areas Cautious At the end, they will take over and end up being invasive As long as they are noninvasive and provided habitat for indigenous fauna Due to protected species acts, and biodiversity preservation I would not take the risk, the FTWIs should be region specific. If no other detrimental effect is present (non-invasive) it could be worth while conducting a study on its efficacy	Not a good idea Dependent on research Not allowable Yes, if controlled Chance of invasiveness Yes, if control measures in place Yes, for cities With caution Will take over Yes, if non-invasive No, FTWI to be region specific Yes, dependent on research Yes, if non-invasive	OpNi1 PoNi2 OpNi3 OpNi4 OpNi5 OpNi6 OpNi7 OpNi8 OpNi9 OpNi10 OpNi11 OpNi12 OpNi10 OpNi13

Its ok as long as one is sure they are non-invasive and will not spread in an epidemic	Yes	OpNi10
If not why not, if it can do it better than the indigenous species without the fear of it becoming invasive	Yes, if non-invasive	OpNi10
I think it would be acceptable as long as the species are proven to be non-invasive or sterile	Yes, if non-invasive	OpNi12
Acceptable but not preferable – depends on the cost / benefit and potential value add of the species	Yes, research dependent	OpNi11
"non-invasive" not sure about, freshwater habitats already face so many challenges- pollution, alien fish species, global warming. A truly "non-invasive" sure-- but you wouldn't know until it is too late, except of course if rigorous scientific studies has been done - then sure. Also, some species might be indigenous, in one part of a country, but be alien in another part. I.e. fynbos wetland species and savannah species for example, you have to stick with the availability of species in a freshwater bioregion, safest option. two wrongs don't make a right	Yes, but region specific for indigenous	OpNi14
It's something that should be carefully considered. In the majority of cases introducing non-indigenous plants is not a good idea.	No	OpNi15
I think it is a better way of managing water quality. However, minor their impact, it should be considered.	Yes, managing water quality	OpNi12 OpNi16
If these have been proven to be highly efficient in the uptake of contaminants, then they will be the preferred species for the project. However, the process will have to be actively managed to ensure that these species do not become a problem in the wetlands and surrounding areas. The treatment sites will need to be continuously monitored.	Yes, research dependent Yes, active management and monitoring	OpNi17
Sterile species such as vetiver (sterile vetiver) is fine as reduction takes place in the root mass. but if the non-indigenous has the ability to spread downstream it would be a big no no.	Yes, if sterile	OpNi18 OpNi19
Yes, they should be used unless something better is available	Yes, if none other available	OpNi12
I think that is a good idea because we will be rescuing those rare plants that await erosion, we shall be conserving them for that matter	Yes, provide good chance to other plants to survive	OpNi15
The margin of out-performance would be interesting. The answer depends on the context. If one has the scope to choose one's preference would be for indigenous. But another plant can fulfil a very specific and targeted role which no other indigenous plant can fulfil, then it may be an option to use a non-indigenous, non-invasive, for a targeted problem and period.	Yes, research dependent	OpNi20
Water quality is more important than boosting indigenous plants. If exotic plants can improve water quality better than indigenous plants, then it is exotic plants that should be used.		OpNi21
Use them if there is no risk		OpNi22

I prefer to use the indigenous plants in a conservation area but if I needed to solve a crisis I would consider this for a short period If it works then use it Invasive aquatic exotic plants have clogged many water ways in south Africa. How would you be sure if non-indigenous plants would not thrive in? If the plant already outperforms it could become invasive.	Yes, water quality is more important that non-indigenous plants Yes, if no risk Yes, if it will address a crisis (short term) Yes, if it works No, non-indigenous plants pose risk	OpNi23
6. What concerns do you have pertaining to floating treatment wetland island systems?		
Use of non-indigenous plant species and contamination of water bodies by construction material of defunct islands Within JHB region, if they may provide more surface area for waste to catch on which could result in a buildup and finally a blockage. The use of non-indigenous plants without enough research on the species. I would also want to know what materials the device is made from. None – love the idea. It works if applied correctly. Long term effectiveness Flood events could wash these systems downstream and break them up CONCERNS FOR BIODIVERSITY AND THE ENVIRONMENT is it financially viable for areas that actually need them Would they be anchored in place? If it can kill the fishes Lifespan? Efficacy? What are the timelines concerned, they should not become permanent features of wetlands, if the island has to remain in the wetland that means that wetland functionality is not being restored? I don't think their use should be chronic.	Use of non-indigenous plants Contamination of water by island construction material Surface area for waste to collect on Use of non-indigenous plants Love the idea if it works Long term effectiveness Flood events Biodiversity and environment Financially viable Anchor mechanisms Impact to fish Lifespan and effectiveness	CoFw1 CoFw2 CoFw3 CoFw1 CoFw4 CoFw5 CoFw6 CoFw7 CoFw8 CoFw9 CoFw10 CoFw11 CoFw12

Maintenance, disruption of ecological processes, effects of non-indigenous non-invasive plants on native fauna, water usage of native plants, blockage of water systems Throughput or the amount of water that can be treated. It does not compare to traditional chemical treatment facilities. Wetland water treatment is notoriously slow and does not allow for large volumes of water. Also, the level of contamination is a big concern. If the water is too contaminated, a wetland will just die. I fear that it will not be as effective as a natural wetland as it cannot retain water and it might not be able to serve as a barrier during a flooding event rendering it useless Impact on aquatic life, if any? Plants may die? Management and maintenance consistency Very little, I think it is a marvelous idea – we need more like this. It is also a potentially huge job creator, if you are making them in SA. however, there must be a decommissioning protocol, when that raft is saturated with pollutants it must be taken out of the system, and disposed of in an environmentally sound manner, they don't bring the suspended pollutant back into the system. Also, the saturated raft, cannot remain there, because if flooding occurs or damage, and those pollutants are released back- it will over load the system, and you may have die out, for example, the situation at the Loskop dam on the Olifants River. None This looks like a great idea (without having read about the practicalities in detail). The only concern I have at the moment is the cost, which looks like it may be quite expensive. As always with environmental issues, where is the funding going to come from? And would this money be better spent on preventing the contamination in the first place? The only concern that needs to be investigated is when the contaminant is bound it will end up in the sludge if the sludge is exposed what kind of secondary pollution will then take place	For short – medium term use Maintenance Disruption of ecological processes Non-indigenous plants Water usage by island plants Blockage of river systems Amount of water that can be treated Level of contamination islands can handle Versus natural wetland functioning Impact on aquatic life Management and maintenance Marvelous idea Job creator Decommissioning protocol None Great idea Cost Funding sources Contaminant release	CoFw13 CoFw14 CoFw1 CoFw15 CoFw16 CoFw17 CoFw18 CoFw19 CoFw20 CoFw21 CoFw22 CoFw23 CoFw24 CoFw25 CoFw26 CoFw27 CoFw28 CoFw29

Maintenance (or the lack thereof) Might be expensive to construct because of its complexity and fragility Being a contaminant itself, harboring invasive species, proving it has a net societal benefit (as opposed to a net cost) It might be hazardous to boats if not clearly visible Washed away during floods Wildlife like elephant destroying it. In areas where there are no large animals to destroy, I think the more we create habitat for wildlife to return it means positive results. None How frequently are the islands maintained? What is the water consumption of the islands	Maintenance Cost Harboring invasive species Societal benefit Hazardous to boats Flood events Wildlife impact on islands None Maintenance frequency Water consumption of islands	CoFw13 CoFw27 CoFw30 CoFw31 CoFw32 CoFw6 CoFw33 CoFw25 CoFw13 CoFw15
7. What improvements would you suggest to current available floating treatment wetlands?		
Not sure, have not had exposure to the current models I can only suggest looking at the role bacteria could play among the roots to try to improve the uptake of metallic and organic components MORE wetlands are needed Don't know Don't know enough about this treatment method to comment RESEARCH FURTHER ON MORE PLANTS SPP Don't know at this stage I do not know of any None I can think of None	Not sure Role of bacteria among roots More wetlands are needed Don't know Don't know Research on more plants required Don't know None None Low maintenance Eco-friendly	ImFw1 ImFw2 ImFw3 ImFw4 ImFw4 ImFw5 ImFw4 ImFw6 ImFw6 ImFw7 ImFw8 ImFw9

Low maintenance, eco-friendly and bio-degradable materials I would suggest putting a small solar panel on each of them to power a air pump to bubble air into the water below. Oxygen in the water will help kill anaerobic bacteria. I can't think of any Not sure Not qualified to answer this question Not 100% clued up about this, but they could be used in dams as well, then they don't need to be secured, they can just float around – but in river channels and estuaries they should be fixed Don't know enough Control fires on floating wetlands used as fishing camps by fishermen I do not know enough about this field to be able to suggest any improvements Construction material improvements in terms of cost, maybe subsurface funneling to capture assimilated pollutants for removal... Let someone design a new shape – it does not have to be square! Excellent idea. Could provide interesting options for agriculture (if the products are healthy to consume) in the form of semi-hydroponics. Cannot think of anything Not had experience with them Haven't seen one in operation to be able to comment To monitor the full environmental impact of using floating treatment to enhance design and installations	Bio-degradable Solar pump with oxygenation Can't think of any Not sure Don't know Don't know Let them float around in dams To be fixed in river channels and estuaries Don't know Control fires on fishing camps Don't know Cost effective construction materials New shape Excellent idea Options for agriculture (semi-hydroponics) Don't know Don't know Don't know Monitor full impact	ImFw10 ImFw11 ImFw1 ImFw4 ImFw4 ImFw12 ImFw13 ImFw4 ImFw14 ImFw4 ImFw15 ImFw16 ImFw17 ImFw18 ImFw4 ImFw4 ImFw4 ImFw19
8. How can floating treatment wetland islands benefit communities?		
Cleaning water sources and encouraging habits for wildlife	Clean water sources Encouraging habitats for wildlife	BeCo1 BeCo2

It would hopefully improve water quality, maybe to an extent that it could be used for ingestion. It could be used as refuge for species which could improve the ecosystem within the area.	Improve water quality	BeCo3
	Refuge for species	BeCo4
	Increasing water quality	BeCo3
Increasing water quality, providing habitat	Providing habitat	BeCo2
	Cheap and effective	BeCo5
Cheap and effective – limit disease	Limit disease	BeCo6
	River systems for safe	BeCo7
They could ensure that river systems can be safely used for human use	human use	
	Sustainable	BeCo8
	socioeconomic	
	development	BeCo3
CREATING SUSTAINBLE SOCIOECONOMIC DEVELOPMENT	Improve water quality	BeCo9
Anything that helps improve water quality is a benefit	Removal of toxins and	
The removal of toxins and pollutants to remove health hazards	pollutants to remove	
	health hazards	BeCo10
	Aesthetically pleasing	BeCo11
Aesthetically pleasing, water purification, habitat for fauna, increase biodiversity	Water purification	BeCo4
	Habitat for fauna	BeCo12
	Increase biodiversity	BeCo3
	Improved water quality	BeCo13
Improved water quality and overall habitat conditions; they facilitate the rehabilitation of degraded wetlands	Improved habitat	
	conditions	
	Facilitate the	BeCo14
	rehabilitation of	
Job opportunities, better quality water	degraded wetlands	BeCo15
Cleaner water, non-threatening treatment technology	Job opportunities	BeCo3
	Better quality water	BeCo3
	Cleaner water	BeCo16
	Non-threatening	
If they work as they should the benefits of the ecosystem services will be the benefits. Flood protection, clean water, increase in biodiversity.	treatment technology	BeCo17
	Ecosystem service	BeCo18
	benefits	BeCo11
	Flood protection	BeCo12
	Clean water	BeCo19

Improve wetland eco-services and functioning. Improved water quality may allow for fishing, farming, harvesting of material in wetlands. Increase property value, economic use of harvested material, increase biodiversity, reduced cost of water quality management mechanisms Better water quality – very important in rural areas, and in areas in lower reaches of catchments. Better quality water for food production (subsistence and commercial) and livestock. Better freshwater. Ecosystems could result in better flood attenuation, and better water provisioning. People would be able to enjoy water resources again – swim and play in them, if less polluted. Better for environment and better water for community Provide access to clean water and improve environmental quality Well, a reduction in levels of contamination would of course be positive. And perhaps along with their implementation would be an educational drive to help prevent contamination in communities in the first place. Water quality improvement	Increase in biodiversity Improve wetland eco-services and functioning Improved water quality for fishing and farming Harvesting of material in wetlands Increase property value Economic use of harvested material Increase biodiversity Reduced cost of water quality management Better water quality in rural areas Better water quality for food production and livestock Better freshwater Better flood attenuation Better water provisioning Recreation activities promoted in cleaner water Better for environment and community Access to clean water Improve environmental quality Reduction in levels of contamination	BeCo20 BeCo21 BeCo22 BeCo23 BeCo12 BeCo24 BeCo25 BeCo26 BeCo27 BeCo18 BeCo28 BeCo29 BeCo30 BeCo31 BeCo32 BeCo33 BeCo34 BeCo3 BeCo35

Attract birdlife (and other small animals), it can be beautiful with diverse flora, or it could have more than just a filtration function. Reeds and grasses used for weaving baskets and other things could be planted & harvested by community and help with job creation. Environmental improvement, food production, complementary approach to other approaches, assembly and maintenance could create jobs in poor areas It should be able to improve water quality Filtration and cleansing water and promoting functioning aquatic ecosystem It enhances the beauty, creating natural habitat for birds, amphibians and more but it would be enhancing the water quality They can improve water quality and enhance aesthetic appeal	Educational drive to address water contamination sources Water quality improvement Attract birdlife Filtration function Reeds and grasses for basket weaving and job creation Planting and harvesting economic opportunities Environmental improvement Food production Complementary approach to other approaches Job creation in poor areas Filtration and cleaning of water Promoting functioning aquatic ecosystems Enhance ecosystems Create natural habitat for biodiversity Enhance water quality Improve water quality Enhance aesthetic appeal	BeCo36 BeCo37 BeCo38 BeCo32 BeCo39 BeCo40 BeCo15 BeCo36 BeCo41 BeCo42 BeCo43 BeCo3 BeCo3 BeCo10

9. **In your opinion, what influences the social acceptance of Floating Treatment Wetland Island systems?**		
Knowledge	Knowledge	InSa1
The way it is presented to the general public. Underlining the benefits it provides. Cost of the product.	Presentation to general public – benefits	InSa2
Knowledge and understanding of how the systems functions	Cost of product	InSa3
	Knowledge	InSa1
	Understanding functioning of system	InSa4
	Cost and effectiveness	InSa5
Cost and effectiveness	Reduction of sewage impacts by floating	InSa6
Stench and visual sewerage reduction would increase acceptance of this floating wetland system.	islands	InSa7
CO MANAGEMENT /PARTICIPATORY	Cooperative	InSa8
	management	InSa9
Water quality	Water quality	InSa10
The low cost	Low cost	InSa3
	Knowledge of benefits	InSa11
Knowledge about the benefits, general knowledge about what they are	Cost	InSa12
Cost, time, proven results and accessibility	Time	InSa13
	Proven results	InSa14
	Accessibility	InSa15
Social leadership, knowledge of the working and reasons for Floating Treatment Wetland Island systems	Social leadership	InSa3
	Knowledge of operation	InSa16
Cost and perceived effectiveness of the wetland. It is difficult for the general public to envisage that "those floating plants" are actually doing any good.	Cost	InSa17
	Perceived effectiveness	
	Communicating in language public	InSa18
	understands	InSa19
	Lack of knowledge	InSa20
	Ignorance of people	InSa21
Lack of knowledge, the ignorance of people, taboos and the disrespect of nature and others	Taboos	
Aesthetics and level of informed-ness of the public about its function	Disrespect of nature	InSa22
Perception of efficiency, cost, management requirements	and others	InSa23

FTWI systems, seem like they could be dismantled and damaged. Communities need to be educated about the benefits of these systems in order to respect them and maintain them. Lots of media Awareness of the importance of the floating wetlands Communities need to be properly briefed about the thinking behind the systems, and why they have been chosen. But they also need to feel as if they have been consulted and properly involved when outsiders come in and try to impose solutions. Perhaps there should be opportunities for communities to be more actively involved in the project; whether it is from piece jobs or social media exposure. Perception, understanding, buy-in and proof Education Education Education That it has a specific purpose and function which is more valuable than the detraction caused by the concept that there is a “foreign flotation device" in the wetland I cannot think of anything that would negatively affect social acceptance of this system Knowledge of benefits, cost and ease of implementing Education of the benefits Capacity build needed on pros and cons of use of islands and examples of working Island systems	Aesthetics Level of awareness of public on its functioning Perception of efficiency Cost Management requirements Educating communities to prevent damage Lots of media Awareness of importance Community education Community involvement Perception Understanding Buy-in Proof Education The specific purpose of the island versus foreign floating device Cannot think of negative aspects Knowledge of benefits Cost Ease of implementation Education of benefits Capacity building Pros and cons of islands Examples of working islands	InSa16 InSa3 InSa24 InSa25 InSa26 InSa27 InSa28 InSa29 InSa30 InSa31 InSa32 InSa33 InSa34 InSa35 InSa36 InSa37 InSa3 InSa38 InSa39 InSa40 InSa41 InSa42 GeOp1 GeOp2 GeOp3

10. What is your general opinion of floating treatment wetlands when considering the social sustainability thereof? Great idea that can be of enormous value I am unable to truly comment but from my limited knowledge of the product it seems like it is something that can be made relatively cheaply (assumption based on the price range given), which could improve water quality within a semi-arid country Directly linked to education around the functionality of the systems Good A good idea but it needs to be sold to municipalities urgently GOOD IN FACILITATING DEVELOPMENT Good idea They have to provide a tangible, visible benefit Hypothetically, I like the idea That society will be so dependent on them for treating polluted water that they won't take responsibility over their actions and that is to prevent such pollution in the first place. The quick fix mentality will take over which is not sustainable thinking when it comes to conservation and preservation. Would depend on social leaders and community attitude I think they are a good idea. Pay upfront and then let nature take its course. The only problem is that some water is so contaminated that a floating wetland will either die or not treat the water effectively. Think it is a good idea, especially in an arid country such as South Africa People have to be educated in a clear manner about its function Strongly in favour	Great idea Enormous value Can be made cheaply that can improve water quality in a semi-arid country Directly linked to education around system functionality Good Good idea, but need to be sold to municipalities urgently Good in facilitating development Good idea Need to provide tangible and visible benefit I like the idea Social dependence on system leading to continued pollution Depend on social leaders and community attitude Good idea Might not work in all polluted environments Good idea for arid countries, as South Africa	GeOp4 GeOp5 GeOp6 GeOp7 GeOp5 GeOp8 GeOp9 GeOp10 GeOp11 GeOp5 GeOp12 GeOp13 GeOp14 GeOp5 GeOp15 GeOp16 GeOp17

If rolled out on a much larger/country wide scale if would improve water quality. If this were possible it would create more equality, and reduce inequality and situations where communities lack access to safe and abundant water. I think they are a good idea Sustainability can be achieved through payment for ecosystem services From the little I know I would say that they seem to be pretty socially sustainable, as long as the communities themselves do not need to come up with the funding for them In terms of job creation, it does have short term merit with the spin off in long term ecological sustainability. Nurseries can supply to larger areas, construction crews can be trained up and small businesses can be established. A very useful tool It is an excellent idea. To provide a proper evaluation of the social sustainability there should, however, be a metric to measure the social standing and weight this against some trade-off scenarios between having a device and improving the environment or vice versa. One's option should be driven by what one prioritizes – and what one prioritizes depends on your social status (like Maslow's hierarchy of needs). I think it is an excellent idea and it should be rolled out on a large scale Good option	Education required Good idea Much larger / country wide roll out to improve water required Would create more equality and reduce in-equality Access to safe and abundant water for communities Good idea Sustainability through payment of ecosystem services Pretty socially sustainable if community does not need to fund them Job creation and ecological sustainability Nurseries can supply plants Construction crews be trained up Establishment of small businesses Very useful tool Excellent idea Metric to measure social standing required Priorities depend on social status Excellent idea	GeOp5 GeOp18 GeOp19 GeOp20 GeOp21 GeOp22 GeOp23 GeOp24 GeOp25 GeOp26 GeOp27 GeOp25 GeOp28 GeOp29 GeOp30 GeOp31

Great concept They require periodic monitoring and maintenance	Need to be rolled out on large scale Good option Great concept Require periodic monitoring and maintenance	

Transcribed Data – Selected Interview with No 1 Regulatory Organization Interviewee

Topics

A. IWSM: integrated watershed management components as identified by participants
B. Chal: Current challenges identified by participants in urban water quality management
C. MeTo: Measures or tools applied in urban water quality as identified by participants
D. SoAs: Social aspects of floating treatment wetlands as identified by participants
E. EcAs: Economic aspects of floating treatment wetlands as identified by participants
F. EnAs: Environmental aspects of floating treatment wetlands as identified by participants
G. NoIn: Opinions of participants in using non-indigenous plants in floating treatment wetlands
H. MoSu: Modification suggestions by participants
I. Opin: Opinion by participants if floating treatment wetlands can be used as a sustainable urban drainage system tool
J. GeOp: General opinion on floating treatment wetlands by participants

Themes

A. IWSM

IWSM1: Integrated approach

IWSM2: Entire hydrological cycle consideration

IWSM3: Water cycle is interlinked

IWSM4: Impacts of water cycle components

IWSM5: Ground and surface water interflow

B. Chal

Chal1: Competency outflow of local authorities

Chal2: Budget constraints

Chal3: Funds not appropriately used

Chal4: Funds used to cross subsidize social problems

Chal5: Poor enforcement

Chal6: Municipalities need to be taken to task

C. **MeTo**

MeTo1: Department of Water and Sanitation use source directed controls

MeTo2: Licensing measures

MeTo3: Good conditions and standards required for developments

MeTo4: Enforcement

MeTo5: Monitoring

MeTo6: Sustainable Urban Drainage Systems to become compulsory

MeTo7: Resource quality and integrity needs protection

MeTo8: Not successful

MeTo9: Sustainable urban drainage systems as new paradigm

MeTo10: Stop making rivers straight and line canals

MeTo11: Importance of river functioning in landscape

MeTo12: Flood damages indicator of unsustainable urban drainage

D. **SoAs**

SoAs1: Informing and educating people

SoAs2: Communicating value of wetlands

SoAs3: Paradigm shift is required

SoAs4: Ecosystem services versus eco-infrastructure

SoAs5: Ecological infrastructure benefits

SoAs6: Investment required in ecological infrastructure

E. **EcAs**

EcAs1: Will cost money

EcAs2: Benefits associated

EcAs3: Active management required

EcAs4: Economic benefit

F. **EnAs**

EnAs1: Education

EnAs2: Limitations

EnAs3: Level of maintenance required

EnAs4: Use of alien plants

G. **NoIN**

NoIn1: Excellent idea

NoIn2: Definite option

NoIn3: Level of education required

H. MoSu

MoSu1: Excellent idea

MoSu2: More value in idea

MoSu3: Implementation is far and wide

MoSu4: Water quality can be addressed (limitation)

I. Opin

Opin1: Yes

J. GeOp

GeOp1: Value and application potential

GeOp2: Has limitations

GeOp3: Can be used with other water quality management tools

Transcribed Data – Selected Interview with No 2 Regulatory Organization Interviewee

Topics

A. IWSM: Integrated watershed management components as identified by participants
B. Chal: Current challenges identified by participants in urban water quality management
C. MeTo: Measures or tools applied in urban water quality as identified by participants
D. SoAs: Social aspects of floating treatment wetlands as identified by participants
E. EcAs: Economic aspects of floating treatment wetlands as identified by participants
F. EnAs: Environmental aspects of floating treatment wetlands as identified by participants
G. NoIn: Opinions of participants in using non-indigenous plants in floating treatment wetlands
H. MoSu: Modification suggestions by participants
I. Opin: Opinion by participants if floating treatment wetlands can be used as a sustainable urban drainage system tool
J. GeOp: General opinion on floating treatment wetlands by participants

Themes

A. **IWSM**

IWSM1: Management of the watershed by all
IWSM2: Management towards a common goal

B. **Chal**

Chal1: Collapsed water treatment facilities
Chal2: Challenges in most small towns
Chal3: Raw sewage running into rivers

C. **MeTo**

MeTo1: Private companies contributing to water treatment
MeTo2: Affective if maintained
MeTo3: Age of design also plays important role in wastewater infrastructure

D. **SoAs**

SoAs1: Alien plants and impact on recreation

E. **EcAs**

EcAs1: Invader species and control over long term

F. **EnAs**

EnAs1: Invader species and control over long term

G. **NoIN**

NoIn1: Yes, only well-known and proven plants

H. **MoSu**

MoSu1: Long term design

I. **Opin**

Opin1: Yes

J. **GeOp**

No answer

Transcribed Data – Selected Interview No 3 Regulatory Organization Interviewee

Topics

A. IWSM: Integrated watershed management components as identified by participants
B. Chal: Current challenges identified by participants in urban water quality management
C. MeTo: Measures or tools applied in urban water quality as identified by participants
D. SoAs: Social aspects of floating treatment wetlands as identified by participants
E. EcAs: Economic aspects of floating treatment wetlands as identified by participants
F. EnAs: Environmental aspects of floating treatment wetlands as identified by participants
G. NoIn: Opinions of participants in using non-indigenous plants in floating treatment wetlands
H. MoSu: Modification suggestions by participants
I. Opin: Opinion by participants if floating treatment wetlands can be used as a sustainable urban drainage system tool
J. GeOp: General opinion on floating treatment wetlands by participants

Themes

A. **IWSM**

IWSM1: Management of more than one watershed characteristic

IWSM2: Can be more than one watershed

B. **Chal**

Chal1: Modifications to flow drivers

Chal2: Water quality and responses

Chal3: Pollution

Chal4: Space

Chal5: Poor planning practices

Chal6: Poor maintenance

Chal7: Invasives

C. **MeTo**

MeTo1: Water use authorization

MeTo2: Affective if maintained

D. **SoAs**

SoAs1: Secondary treatment option

SoAs2: Safety risk for fast boats

E. **EcAs**

EcAs1: Promising designs

EcAs2: Considerations of economical scale

F. **EnAs**

EnAs1: Low ecological risk

G. **NoIN**

NoIn1: Percentage indigenous plant consideration

H. **MoSu**

MoSu1: Designs for easier monitoring

I. **Opin**

Opin1: Yes

Opin2: Department of Water and Sanitation should make compulsory

J. **GeOp**

GeOp1: Very good idea

GeOp2: I include specifications for these in Waste Treatment Plant Lagoons

Transcribed Data – Modderfontein Conservation Society Focus Group Meeting

Topics

A. IWSM: Integrated watershed management components as identified by participants
B. Chal: Current challenges identified by participants in urban water quality management
C. MeTo: Measures or tools applied in urban water quality as identified by participants
D. SoAs: Social aspects of floating treatment wetlands as identified by participants
E. EcAs: Economic aspects of floating treatment wetlands as identified by participants
F. EnAs: Environmental aspects of floating treatment wetlands as identified by participants
G. NoIn: Opinions of participants in using non-indigenous plants in floating treatment wetlands
H. MoSu: Modification suggestions by participants
I. Opin: Opinion by participants if floating treatment wetlands can be used as a sustainable urban drainage system tool
J. GeOp: General opinion on floating treatment wetlands by participants

Themes

A. **IWSM**

IWSM1: Management required

IWSM2: Beginning and end of water problems

IWSM3: What is coming in

IWSM4: Manmade pollution and natural state restoration

IWSM5: Commencement of development activities

B. **Chal**

Chal1: Chemicals from outside

Chal2: Chemicals from Modderfontein factory days

Chal3: Springs in community leaches chemicals

Chal4: Springs high in nitrogen

Chal5: Runoff from urban development

Chal6: Reedbeds were prolific

Chal7: Turning the reserve in urban park

Chal8: Stone gabions do not work

Chal9: Streams get badly eroded with runoff

Chal10: Runoff control

Chal11: Water quantity in runoff an issue

Chal12: Sewage runoff

Chal13: Sewers enters storm water infrastructure

Chal14: Maintenance of urban water quality infrastructure

C. **MeTo**

MeTo1: Reeds

MeTo2: Storm water attenuation ponds

MeTo3: Not effective

D. **SoAs**

SoAs1: Fishing and fishing lines

SoAs2: Theft of islands

SoAs3: Dangerous attraction to children in poorer areas

SoAs4: Children can damage islands

E. **EcAs**

EcAs1: Self-sustaining needs

EcAs2: Cost benefit to natural areas

F. **EnAs**

EnAs1: Birds using islands as food source

EnAs2: Reptiles, like monitors

EnAs3: Island's mounting mechanisms

EnAs4: Using alien plants on islands

EnAs5: Application to natural environments

EnAs6: Root system no pruning required

EnAs7: Root system beneficial to fish

G. NoIN

NoIn1: Too many unknowns

NoIn2: Insects introduced from other countries

NoIn3: Performance of non-indigenous vs indigenous

NoIn4: Depends on application environment

NoIn5: Threat to river systems

NoIn6: Level of certainty required

NoIn7: Needs to be open minded on the idea

H. MoSu

MoSu1: Electric fence

MoSu2: More natural shape required

I. Opin

Opin1: Yes, with indigenous vegetation

J. GeOp

GeOp1: Not be a crowd pleaser but need to make a difference

GeOp2: Positive impact on sewage impacted areas

GeOp3: Need to prevent island damage from debris

GeOp4: Great idea

GeOp5: Visually effective and appealing

GeOp6: Environmentally desirable

GeOp7: Alien plants that cling to it

Geop8: Significant lifespan

Transcribed Data – Specialist Focus Group Meeting

Topics

A. IWSM: Integrated watershed management components as identified by participants
B. Chal: Current challenges identified by participants in urban water quality management
C. MeTo: Measures or tools applied in urban water quality as identified by participants
D. SoAs: Social aspects of floating treatment wetlands as identified by participants
E. EcAs: Economic aspects of floating treatment wetlands as identified by participants
F. EnAs: Environmental aspects of floating treatment wetlands as identified by participants
G. NoIn: Opinions of participants in using non-indigenous plants in floating treatment wetlands
H. MoSu: Modification suggestions by participants
I. Opin: Opinion by participants if floating treatment wetlands can be used as a sustainable urban drainage system tool
J. GeOp: General opinion on floating treatment wetlands by participants

Themes

A. **IWSM**

IWSM1: Understanding (Awareness)

IWSM2: What happens to water, where it comes from and where it goes

IWSM3: Whole catchment

IWSM4: Watershed

IWSM5: Hydrogeological processes

B. **Chal**

Chal1: Storm water control

Chal2: Storm water management

Chal3: Waste water management

Chal4: Sewerage farms maintenance

Chal5: Sewerage farms operation

Chal6: Illegally discharges

Chal7: Illegally discharge effluent with chemical composition

Chal8: Biologically chemically reactions of illegally discharged effluent

Chal9: Oils discharged

Chal10: Phosphates

Chal11: Cigarette buds

Chal12: Policy

C. **MeTo**

MeTo1: Legislation

MeTo2: Monitoring

MeTo3: Not effective

MeTo4: Some monitoring has ceased in City of Johannesburg

MeTo5: Monitoring points have decreased

MeTo6: Responsibility shift from City of Johannesburg to Department of Water Affairs

MeTo7: Water licenses issued for specific activities

MeTo8: Guidance lost to local municipalities

MeTo9: Integrated approach to water use lacking

MeTo10: Department of Water Affairs and Sanitation not applying integrated approach

MeTo11: Ripple effect created

D. **SoAs**

SoAs1: Islands are ugly

SoAs2: Education

SoAs3: Employment

SoAs4: Isolated

SoAs5: Central feature of a dam

SoAs6: Integrate social aspects required

E. **EcAs**

EcAs1: Can make economic sense

EcAs2: Integrate commercial value into islands

EcAs3: Get a spin off from it

EcAs4: Timelines important for investors

EcAs5: Clear project schedule required

EcAs6: Prove that islands can sustain itself

EcAs7: Expensive vegetation

EcAs8: Potential challenges in sourcing plants locally

EcAs9: Job creation potential

F. **EnAs**

EnAs1: Type of species used

EnAs2: Species with invasive nature

G. NoIN

NoIn1: Yes, but well researched

H. MoSu

MoSu1: Integrate into natural surroundings

MoSu2: Not to be isolated

I. Opin

Opin1: Yes

J. GeOp

GeOp1: Tool in ecological engineering application

GeOp2: To master ecological engineering further studying is required

GeOp3: Bring teams together in ecological engineering

GeOp4: As team leader can bring things together in ecological engineering

GeOp5: Inexistence of ecological engineering

GeOp6: Fan of ecological engineering

GeOp7: Fan of ecological engineering thinking approach

Geop8: Integrate thought process in our research

GeOp9: Projects to make economic sense

GeOp10: Ecological engineering field very valuable

GeOp11: Ecological engineering field can address our challenges today

Geop12: Ecological engineering our passion

GeOp13: Ecological engineering field to be advanced

GeOp14: Ecological engineering to feature on forefront of what we are doing

GeOp15: Ecological engineering to be formalized in South Africa.

Transcribed Data – Open ended internet survey

Topics

A. StaE: Status of Environment
B. WaQu: Water Quality description of area
C. AfWa: Affected by water quality
D. PiFw: Vegetation planting in floating treatment wetlands
E. OpNI: Opinion of using non-indigenous plants in floating treatment wetlands
F. CoFw: Concerns associated with floating treatment wetlands
G. ImFw: Improvements suggested to floating treatment wetlands
H. BeCo: Benefits of floating treatment wetlands to communities
I. InSA: Opinion concerning elements influencing social acceptance of floating treatment wetlands
J. GeOp: General opinion on floating treatment wetlands by participants

Themes

A. StaE

StaE1: Highly transformed
StaE2: Anthropogenically transformed and impacted
StaE3: Medium
StaE4: Pristine
StaE5: Healthy
StaE6: Urban
StaE7: Semi-Polluted
StaE8: Continually devastated
StaE9: Degraded
StaE10: Poor
StaE11: Good
StaE12: Fair
StaE13: Fragmented
StaE14: Artificial
StaE15: Modified
StaE16: Impacted
StaE17: Conservation area

StaE18: Healthy in private property managed areas

StaE19: Poor in public governed areas

B. WaQu

WaQu1: Reasonable

WaQu2: Season depending

WaQu3: Highly polluted

WaQu4: Very poor

WaQu5: Good

WaQu6: Poor

WaQu7: Polluted

WaQu8: Very good

WaQu9: Bad

WaQu10: Semi-polluted

WaQu11: Degraded

WaQu12: Eutrophic and degraded

WaQu13: Moderate

WaQu14: Average

WaQu15: Polluted rivers

WaQu16: Terrible

WaQu17: Fair to poor

WaQu18: Good drinking water

WaQu19: Struggling storm water and ecosystems

WaQu20: Impacted to poor

WaQu21: Drinking water acceptable

WaQu22: Natural water extremely poor

WaQu23: Excellent

WaQu24: Silted

WaQu25: Good drinking water

WaQu26: Poor river water quality

C. Afwa

AfWa1: Not yet

AfWa2: No

AfWa3: Yes

AfWa4: Yes, rainfall dependent

AfWa5: No, but problems with irrigation water

AfWa6: Yes, dam in reserve was polluted

AfWa7: Yes, elevated contaminants

D. PiFw

PiFw1: Indigenous wetland plants

PiFW2: Imitate riparian zones and wetlands

PiFw3: Endemic plants

PiFw4: Don’t know

PiFw5: Wetland plants

PiFw6: Burkia species

PiFw7: Not sure

PiFw8: High nutrient uptake plants

PiFw9: Water plants

PiFw10: Diverse range for biodiversity

PiFw11: Aquatic species

E. OpNi

OpNi1: Not a good idea

OpNi2: Dependent on research

OpNi3: Not allowable

OpNi4: Yes, if controlled

OpNi5: Chance of invasiveness

OpNi6: Yes, if control measures are in place

OpNi7: Yes, for cities

OpNi8: With caution

OpNi9: Will take over

OpNi10: Yes, if non-invasive

OpNi11: No, FTWI to be region specific

OpNi12: Yes, dependent on research

OpNi13: Yes

OpNi14: No

OpNi15: Yes, managing water quality

OpNi16: Yes, active management and monitoring

OpNi17: Yes, if sterile

OpNi18: Yes, if none other available

OpNi19: Yes, provide good chance to other plants to survive

OpNi20: Yes, if no risk

OpNi21: Yes, if it will address a crisis (short term)

OpNi22: Yes, if it works

OpNi23: No, non-indigenous plants pose risk

F. CoFw

CoFw1: Use of non-indigenous plants

CoFw2: Contamination of water by island construction material

CoFw3: Surface area for waste to collect on

CoFw4: Love the idea if it works

CoFw5: Long term effectiveness

CoFw6: Flood events

CoFw7: Biodiversity and environment

CoFw8: Financially viable

CoFw9: Anchor mechanisms

CoFw10: Impact to fish

CoFw11: Lifespan and effectiveness

CoFw12: For short to medium term use

CoFw13: Maintenance

CoFw14: Disruption of ecological processes

CoFw15: Water usage by island plants

CoFw16: Blockage of river systems

CoFw17: Amount of water that can be treated

CoFw18: Level of contamination islands can handle

CoFw19: Versus natural wetland functioning

CoFw20: Impact on aquatic life

CoFw21: Management and maintenance

CoFw22: Marvelous idea

CoFw23: Job creator

CoFw24: Decommissioning protocol

CoFw25: None

CoFw26: Great idea

CoFw27: Cost

CoFw28: Funding sources

CoFw29: Contaminant release

CoFw30: Harboring invasive species

CoFw31: Societal benefit

CoFw32: Hazardous to boats

CoFw33: Wildlife impacts on islands

G. ImFw

ImFw1: Not sure

ImFw2: Role of bacteria among roots

ImFw3: More wetlands are needed

ImFw4: Don't know

ImFw5: Research on more plants required

ImFw6: None

ImFw7: Low maintenance

ImFw8: Eco-friendly

ImFw9: Bio-degradable

ImFw10: Solar pump with oxygenation

ImFw11: Can't think of any

ImFw12: Let them float around in dams

ImFw13: To be fixed in river channels and estuaries

ImFw14: Control fires where used as fishing camps

ImFw15: Cost effective construction materials

ImFw16: New shape

ImFw17: Excellent idea

ImFw18: Options for agriculture (semi-hydroponics)

ImFw19: Monitor full impact

H. BeCo

BeCo1: Clean water sources

BeCo2: Encouraging habitats for wildlife

BeCo3: Improve and enhance water quality

BeCo4: Refuge for species

BeCo5: Cheap and effective

BeCo6: Limit disease

BeCo7: River systems for safe human use

BeCo8: Sustainable socioeconomic development

BeCo9: Removal of toxins and pollutants to remove health hazards

BeCo10: Aesthetically pleasing

BeCo11: Water purification

BeCo12: Increase biodiversity

BeCo13: Improved habitat conditions

BeCo14: Facilitate the rehabilitation of degraded wetlands

BeCo15: Job opportunities and creation

BeCo16: Non-threatening treatment technology

BeCo17: Ecosystem service benefits

BeCo18: Flood protection

BeCo19: Improve wetland eco-services and functioning

BeCo20: Improved water quality for fishing and farming

BeCo21: Harvesting of material in wetlands

BeCo22: Increase property value

BeCo23: Economic use of harvested material

BeCo24: Reduce cost of water quality management

BeCo25: Better water quality in rural areas

BeCo26: Better water quality for food production and livestock

BeCo27: Better freshwater

BeCo28: Better water provisioning

BeCo29: Recreation activities promoted in cleaner water

BeCo30: Better for environment and community

BeCo31: Access to clean water

BeCo32: Improve environmental quality

BeCo33: Reduction in levels of contamination

BeCo34: Educational drive to address water contamination sources

BeCo35: Attract birdlife

BeCo36: Filtration function

BeCo37: Reeds and grasses for basket weaving and job creation

BeCo38: Planting and harvesting economic opportunities

BeCo39: Food production

BeCo40: Complementary approach to other approaches

BeCo41: Promoting functioning of aquatic ecosystems

BeCo42: Enhance ecosystems

BeCo43: Create natural habitat for biodiversity

I. InSa

InSa1: Knowledge

InSa2: Presentation to general public – benefits

InSa3: Cost of product

InSa4: Understanding functioning of system

InSa5: Cost and effectiveness

InSa6: Reduction of sewage impacts by floating islands

InSa7: Cooperative management

InSa8: Water quality

InSa9: Low cost

InSa10: Knowledge of benefits

InSa11: Time

InSa12: Proven results

InSa13: Accessibility

InSa14: Social leadership

InSa15: Knowledge of operation

InSa16: Perceived effectiveness

InSa17: Communicating in language public understands

InSa18: Lack of knowledge

InSa19: Ignorance of people

InSa20: Taboos

InSa21: Disrespect of nature and others

InSa22: Aesthetics

InSa23: Level of awareness of public on its functioning

InSa24: Management requirements

InSa25: Educating communities to prevent damage

InSa26: Lots of media

InSa27: Awareness of importance

InSa28: Community education

InSa29: Community involvement

InSa30: Perception

InSa31: Understanding

InSa32: Buy-in

InSa33: Proof

InSa34: Education

InSa35: The specific purpose of the island versus foreign floating device

InSa36: Cannot think of negative aspects

InSa37: Knowledge of benefits

InSa38: Ease of implementation

InSa39: Education of benefits

InSa40: Capacity building

InSa41: Pros and cons of islands

InSa42: Examples of working islands

J. GeOp

GeOp1: Great idea

GeOp2: Enormous value

GeOp3: Can be made cheaply that can improve water quality in semi-arid country

GeOp4: Directly linked to education around system functionality

GeOp5: Good idea

GeOp6: Good idea, needs to be sold to municipalities urgently

GeOp7: Good in facilitating development

GeOp8: Need to provide tangible and visible benefits

GeOp9: I like the idea

GeOp10: Social dependence on system leading to continued pollution

GeOp11: Depend on social leaders and community attitude

GeOp12: Might not work in all polluted environments

GeOp13: Good idea for arid countries, such as South Africa

GeOp14: Education required

GeOp15: Much larger / country wide roll out to improve water quality required

GeOp16: Would create more equality and reduce inequality

GeOp17: Access to safe and abundant water for communities

GeOp18: Sustainability through payment of ecosystem services

GeOp19: Pretty socially sustainable if community does not need to fund them

GeOp20: Job creation and ecological sustainability

GeOp21: Nurseries can supply plants

GeOp22: Construction crews can be trained up

GeOp23: Establishment of small businesses

GeOp24: Very useful tool

GeOp25: Excellent idea

GeOp26: Metric to measure social standing required

GeOp27: Priorities depend on social status

GeOp28: Need to be rolled out on large scale

GeOp29: Good option

GeOp30: Great concept

GeOp31: Require periodic monitoring and maintenance

APPENDIX E

PROJECT ACHIEVEMENTS

The Master's thesis in Integrated Water Resource Management has been the most impactful postgraduate study I have done. Through postgraduate research, the student developed a high impactful innovation that can make a difference in each household in South Africa and altogether have a positive impact on water security. Numerous awards have been won by the floating treatment wetlands developed by the researcher, including the 2016 Eco-Logic award in the category Eco-Innovation. The floating treatment wetland technology was taken a step further and the researcher developed the first natural filter for households that promotes water security. The "a wetland in a box" won the South African Global Cleantech Innovation Competition in 2016 and was announced as the overall runner up in the Global Cleantech Innovation Competition amongst various countries globally that took place in San Francisco, California during February 2017. Various journal publications are planned for 2017. Thank you, Monash South Africa, for this opportunity. It has been a life changer!