LEGACIES, UNCERTAINTIES AND OWNERSHIP: GREEN INFRASTRUCTURE AS PRACTICE IN JOHANNESBURG, SOUTH AFRICA

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I, Kerry Leigh Bobbins, confirm that the work presented in this thesis is my own. In instances where I have derived information from other sources, I have referenced them accordingly.

ABSTRACT

Green infrastructure has emerged as a promising concept for urban development, where policymakers consider it to offer a range of benefits for the economy, society and the environment. While literature tends to illuminate its many benefits for urban development in measured scientific and financial terms to support a policy rhetoric, less is known about how green infrastructure concepts are used in practice. I contend that green infrastructure comes to exist in practice as part of a social process, where project level actors such as government officials, private sector professionals and members of civil society negotiate its many meanings in response to their interests, local context and historic setting. To explore how green infrastructure evolves as part of a social process, I develop a practice theory approach to investigate how they are conceptualised in Johannesburg, South Africa.

I used an abductive research design to explore how 74 participants conceptualise green infrastructure in Johannesburg. I gathered their accounts using in-depth interviews at the city level, before focusing on Bruma Lake and Paterson Park, which were identified as two striking examples of green infrastructure projects. At both projects, a form of green infrastructure called river renaturalisation was used to address water pollution (Bruma Lake) and flooding concerns (Paterson Park). Exploring these two projects in more detail enabled me to illuminate how green infrastructure was conceptualised as part of a social process, where participants drew on the concept in a variety of ways at different points in time.

Findings reveal that green infrastructure concepts were practiced through participants' activities to leave a manageable and viable legacy. Interests to leave a legacy brought actors together where it encouraged them to carry out activities to claim ownership to manage the uncertainties they faced around the future of the project sites, technical parameters of the projects and civil society interests. Green infrastructure, therefore, became what actors claimed ownership of and which uncertainties they could manage at the project sites. By carrying out activities to leave a legacy, participants (re)conceptualised the meanings of green infrastructure over time, where they could be held individually or shared among participants.

IMPACT STATEMENT

My thesis contributes to knowledge on how green infrastructure concepts are understood and used in practice. Findings of the thesis build on the broader literature on green infrastructure by setting out how concepts are (re)conceptualised as part of a social process. While broader literature on green infrastructure illuminates its complexity, where it can have more than one meaning at any one time in disciplinary knowledge and policy (Horwood, 2011; Wright, 2011; Mell, 2015a; Horwood, 2020), not enough is known about how they come to exist in practice and where they are implemented in actual physical terms. Generating data on how green infrastructure concepts are used, therefore, has both academic and practical impacts.

I create an impact in academia by demonstrating 'how' understandings of green develop according to how they are used. For example, activities to manage uncertainties associated with using green infrastructure points to the locus for the evolution of experiential knowledge or 'know-how'. According to the context within which they are used, green infrastructure encourages actors such as municipal officials, private sector professionals and members of civil society to evolve their practical understandings of physical nature-infrastructure interactions to respond to infrastructure concerns. Conceptualising green infrastructure as a social concept points to how it evolves as an embedded phenomenon, where it illustrates the need to consider the situated and contextual features of its use in practice.

The practical impact of the thesis is immediate. By disseminating the academic findings of the thesis with study participants and other city actors interested in green infrastructure, such as the regional and international research networks I refer to in the Introduction. Findings demonstrate ways that green infrastructure concepts can be included in policy as a contextual and embedded feature of urban development. For example, by exploring the critical questions of 'who', 'where' and 'when', concepts are understood and used as a situated and contextually bound phenomenon. Through this exploration, I illuminate how green infrastructure comes to exist in particular settings. Consequently, this detail can be used to develop the concept in policy in more considered or balanced ways.

In addition to the academic and practical impacts, I also intend to create an impact by encouraging future research collaboration around the situated and contextual aspects of green infrastructure concepts. I have set up the thesis to explore green infrastructure as a situated phenomenon to share my project findings so that the meanings of green infrastructure can be explored in other contexts. To share the findings of the thesis, I plan to publish my study findings on academic platforms such as journal articles and online publications. I also intend to publish my findings on more easily accessible platforms such as policy briefs and blogs. Therefore, by sharing my research, I hope to influence the study of green infrastructure as a situated and embedded concept in other cities and/or contexts across the world.

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PUBLICATIONS RELATED TO THE THESIS

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PROLOGUE

In the thesis, I explore the many meanings of green infrastructure concepts and how they are conceptualised as a social phenomenon. As I chose to frame green infrastructure as something that is socially constructed, I feel it is necessary to reflect on my positionality as it influenced how I carried out and constructed social knowledge. As my age, race, gender, history and nationality, for example, have all shaped the ways that I carried out this research, I feel I must explore them in more detail to illuminate how they shaped my research and my contribution to knowledge. Toward exploring my positionality, I have selected to focus on aspects of my race, gender, professional history and nationality. While this is not an extensive list of all possible factors that may have influenced how I carried out my research, I feel these factors had had a marked influence on how I conducted the research and generated data. I will later build on these insights in the Methodology chapter (Chapter 4), where I will reflect more on how participants responded to my positionality in the field.

I am a young white South African woman who has lived in South Africa for 29 years. This means that I have already had a history of living and working in South Africa. While I did not grow up in Johannesburg, the geographical location of the research project, I have lived in areas classified as being predominately white all my life. This includes schools and education facilities. Given my upbringing in a predominately white area, I have developed certain beliefs and values about people and cities, which may influence the kind of topics I choose to focus on in the thesis. For example, my understandings and beliefs about South African cities may have supported my selection of two case studies in formerly white suburbs under Apartheid because they form part of something I am already familiar with, while also presenting an academic topic of interest given their recent political and social transformation since the end of Apartheid.

My academic and professional history also influenced how I carried out the research. When I began my thesis, I already had experience of working with green infrastructure concepts in Johannesburg. At the time, I worked as a researcher at a provincial government think-tank called Gauteng City-Region Observatory, located in Johannesburg. My role at the think-tank involved researching and advising regional and local governments on how to manage urban sustainability issues across the broader city-region. Much of my work focused on policy formulation, where investments in nature or 'semi-natural' features were used to support greater urban resilience and sustainability[1].

At Gauteng City-Region Observatory, my daily work involved researching international 'best practice' to encourage urban sustainability through developing environment and infrastructure to achieve development objectives, while also creating additional services in the city-region through providing multifunctional services. As I highlight in the Introduction, the think-tank I worked for has set up a research thrust around green infrastructure, which has influenced a handful of green infrastructure projects in the region. While the work was technically progressive, the use of green infrastructure concepts tended to be confined to a

[1] Fell under Gauteng City-Region Observatory's multi-year project on 'Green Assets and Infrastructure', which began in 2012.

policy rhetoric, which was supported by technical/scientific studies. An example of some of this work is evidenced in the section on *Publications related to the thesis*.

International trends in urban management influenced how I approached green infrastructure as a topic in policymaking. When I began researching the green infrastructure concept, the use of financial and other models to quantifying green infrastructure at the city level was popular among policymakers. Policymakers such as government officials, private sector professionals and civil society in the United States of America, United Kingdom and Europe began measuring the benefits of physical nature and the environment for humans to make the case for interest and investment in green infrastructure. The approach intended to compare the benefits provided by physical nature alongside infrastructural ones, where they had a financial value, lifespan and could be adapted and enhanced through their management.

My disciplinary background also influenced how I conceptualised green infrastructure. I am formally trained as a Physical Geographer focusing on environmental water management, or the *ecosystem services approach* I detail in Section 2.1. My approach to green infrastructure was strongly orientated toward the need to quantify the physical services and benefits of physical nature to support its retention or preservation in urban and rural settings under a positivist mindset. While working as a researcher, I adapted this focus to include an *engineered approach*, see Section 2.1, where the services provided by the physical nature could be used to provide and support infrastructure services such as water and waste management. Therefore, green infrastructure presented me with a bridging concept to explore how physical nature could be used to enhance and support urban areas in a variety of ways.

With these factors in mind, I began my PhD to investigate which quantifiable factors could encourage investments in green infrastructure at the city level. In my PhD proposal, I demonstrated the need to understand which actors used green infrastructure as part of my methodological approach. That said, I had not developed exactly how I would explore the 'doing' elements of green infrastructure in detail. At the time, I believe my ability to consider how actors influenced how green infrastructure concepts was limited due to my academic background in Physical Geography. Therefore, my academic background did not focus strongly on the role and impacts of society on the environment or where the environment was conceptualised as a socially constructed phenomenon.

Embarking on a PhD expanded my horizon of understanding in more ways than one. I read widely and began to engage with a range of academic world views, critical approaches on policy and development and explore the multiple conceptualisations of nature or physical nature as I have framed it in this thesis. Over time, I began to stretch and mould my PhD topic to explore some of the questions I had around green infrastructure which were deeply rooted in the social aspects of its understandings and use. Over time, I adapted my focus to include more critical questions on who, where, how and why green infrastructure concepts are used. In addition to being understood as a technical and/or policy concept, I contend it is equally a social one.

As a young female, I felt that I needed to approach certain aspects of my research project with caution. Firstly, I found the engineering discipline to be a male-dominated field, with many of my participants and professionals being male engineers. While I endeavoured to ask as many questions as I could, my positionality as a young female likely influenced the kind of data that I was able to gather in the field. Secondly, I often felt vulnerable travelling to and being in my study sites alone. As such, I found it necessary to visit my research sites with participants or a research companion so that I could carry out my research. While in many cases this may have formed part of my data gathering process. In other words, the participants and companions I was with directed me to certain aspects of the project site that the participants felt were of importance. In both cases, my gender influenced the kind of data I was able to gather from participants and at the project sites.

Chapter 1 INTRODUCTION

This thesis explores how green infrastructure concepts are practiced in Johannesburg, South Africa. Green infrastructure concepts have risen in their popularity among policymakers such as government officials, private sector professionals and members of civil society where they have been framed as a promising concept for the development in cities across the globe. The concept has been used widely to support the joining up of fragments of green space within urban areas for their environmental preservation or infrastructure services according to its functional or service-based values. That said, despite developing connotations as a simple concept, it can have a range of different understandings and interpretations in policy and practice. Illuminating how policymakers negotiate these factors to use green infrastructure illustrates the importance of studying green infrastructure as a social phenomenon, where actors can draw on its many meanings in disciplinary knowledge or policy in planned or unplanned ways.

Policy rhetoric on green infrastructure

Green infrastructure has primarily appeared at the policy level. To support the inclusion of green infrastructure in policy, studies have coalesced around two main themes. First, disciplinary studies in architecture, planning, landscape architecture, engineering and environmental science have tended to focus on illustrating the benefits of green infrastructure. For example, disciplinary studies tend to measure the scientific, financial or social values of green infrastructure, where its benefits are quantified in relation to the economy, society and the environment. While disciplinary approaches can often be measured in numerical or financial terms for supporting the use of green infrastructure decision-making processes, translating these values into policy and practice presents itself as a foremost challenge for achieving its intended benefits.

The second area of interest is around mainstreaming, where measured technical and scientific benefits are used to institutionalise green infrastructure in policy according to their proposed benefits. As there are relatively few examples of the use of green infrastructure in cities, policymakers tend to draw on the opportunities or its promise for urban development. Studies tend to frame green infrastructure as a ‘win-win’ for development, where evidence of their most beneficial aspects are drawn on to make the case for the use of green infrastructure in the city. To bring about the benefits of green infrastructure on the ground, best practice is used to guide policy and practice by setting out the steps and expectations for how translation and mainstreaming ought to take place. By implication, mainstreaming literature has tended to refer to green infrastructure as a relatively simple concept that can shift seamlessly from the world of disciplinary knowledge into policy and practice.

While advocates of the green infrastructure concept have illuminated its many disciplinary and policy meanings, how they come to gain meaning in practice has received less attention. The focus in mainstreaming can be justified by the recent interest around the use of green infrastructure for urban sustainability and the importance of creating legislative frameworks where implementation is possible. In other words, while we know a lot about the benefits of green infrastructure, we know less about how policymakers across government, private sector, and civil society negotiate its many disciplinary meanings and policy representations to respond to a range of real urban concerns such as flooding, water pollution, poor air quality and environmental degradation. Again, policy studies that tend to focus on the mainstreaming of green infrastructure draw attention to how translation ought to take place to bring about its anticipated benefits, but less so on the process through which concepts such as green infrastructure are actually used. This thesis focuses on how green infrastructure concepts are conceptualised according to how they are used.

Translating the measured benefits of green infrastructure from disciplinary knowledge into policy and practice is not simple. Amid the concept's many technical and scientific understandings, opportunities and barriers for mainstreaming lies something that is complex. To start, green infrastructure can mean different things to a range of people, and for this reason, there cannot be a straightforward jump from knowledge into policy and practice (notwithstanding that the generation of knowledge, policymaking and practice are discrete). While incentives for using the concept are rooted in measured values, in reality, the concept is stretched and moulded in different ways to pursue some actor's personal or collective interests over others. One additional layer of complexity exists around the concept's meaning, where in addition to being understood in different ways across a range of actors, the concept can also evolve in its meaning over time. The complex characteristics of green infrastructure concepts signal the need to broaden the scope of existing disciplinary and policy work to include how concepts come to gain meaning in practice as part of a social process.

Green infrastructure as a social process

Focusing on how green infrastructure comes to exist as a social phenomenon draws attention to the ways that green infrastructure concepts are understood and used. It illuminates how meanings of green infrastructure are stretched and adapted to respond to a range of concerns, interests and historical settings that can be unique to a particular context and setting. By choosing to focus on green infrastructure, and how it comes to gain meaning as part of a social process, I offer insights on the specific translation and/or learning pathways that evolve among policymakers in specific contexts and settings. Producing knowledge on green infrastructure as a social phenomenon builds on the two broad themes I identified above on measured values and mainstreaming to illuminate one further layer of understanding around green infrastructure – around how it is drawn on and shaped in practice.

Focusing on a wide range of meanings

To explore how green infrastructure concepts come to have meaning in practice, I refer to a wide range of understandings of green infrastructure in disciplinary knowledge and policy. I contend that meaning is derived from the context or setting within which it is used or researched, where it gains a specific meaning and/or understanding to the scholars and users. As this thesis is about understanding meaning, I have purposely pursued the understandings and representations of green infrastructure as they demonstrate the complexity of using green infrastructure in practice. Exploring the many understandings of green infrastructure illuminates how policymakers such as government officials, private sector professionals and members of civil society negotiate them through their daily work and activities. Therefore, by taking this focus, enables me to conduct aa deeper analysis of the many interconnected elements of green infrastructure concept and how they come to exist in the social world.

To explore how green infrastructure is conceptualised by policymakers at any one time, I have developed a conceptual device called *physical nature-infrastructure interactions* to explore the multiplicity of meaning. Physical nature-infrastructure interactions underscore my contribution to knowledge, where I was able to identify a range of socially-constructed meanings of green infrastructure. Physical nature-infrastructure interactions tend not to be illuminated in critical geography and literature on the 'infrastructural turn' in sociology. Including a focus on physical nature-infrastructure interactions underscores my contribution to knowledge as it enables me to contextualise a range of positions on physical nature and infrastructure and how these can shift and evolve in relation to one another. I will explain the processes through which these can change and shift in relation to one another in Chapter 3, where I explain how I use practice theory to explore the many individuals and share meanings of green infrastructure concepts in practice.

Physical nature resonates with existing literature on the social construction of nature. In other words, it acknowledges that nature is something that can mean different things to a variety of people and that meaning varies at different points in time. For example, within the social sciences, nature is conceptualised as something that is “a socially constructed interpretation”, where its meaning is influenced by a range of individual and collective factors such as those attributed to history, culture and interests (Bird, 1987, p. 255). As such “scientific knowledge” on nature should be regarded as a “representation of nature” where it has “already socially constructed natural-technical object of inquiry” (Bird, 1987, p. 255). By implication, the representation/s of nature should be acknowledged in the development of green infrastructure knowledge, where it forms the basis for understanding how it is practiced in situated settings.

The material aspects of physical nature infrastructure interactions form an essential component of the conceptual framework I outline in Chapter 3. While materiality is a concept that is considered in a range of scholarly texts in the social sciences, I have chosen to use it here as it is conceptualised under Schatzki’s practice theory. As I later explain in the conceptual framework, I consider materiality as being the “stuff” that makes up social life which is an interwoven social phenomenon (Schatzki, 2000, p. 125). I have chosen to anchor the study of green infrastructure around a physical outcome, which enables me to consider the range of meanings that can evolve among a range of actors in time and space. While this choice serves to narrow the scope of meanings that I explore in the thesis, I feel it is justified and it enables me to consider how meaning evolves in more detail.

Materiality has not always formed part of academic enquiry in the social sciences. In many instances, it was considered the backdrop for social life, where it was treated separately from the object or subject under investigation. Authors such as Durkheim and Giddens attend to materiality as something that is associated with the social phenomena under investigation, where it enters the realm of understanding when it bears significance on the social phenomena under investigation (Giddens, 1987). In addition, social phenomena under investigation can also develop or create material, or physical, phenomena. I have chosen to use Schatzki's definition of materiality that builds on relational understandings of infrastructure, which support an understanding of social life and how it comes to exist through an interplay between actors and social life (Schatzki, 2010a). While this understanding is embedded in notions of actor-network theory, where there are constitutive and causal links between objects or 'things'.

To demonstrate why using physical nature-infrastructure interactions to illuminate the multiplicity of green infrastructure contributes to knowledge, it is necessary to demonstrate the range of positions on physical nature and infrastructure and how they interact when using a green infrastructure approach. Actors can have vastly different understandings of physical nature and infrastructure according to their background and/or professional training. For example, an engineer will have a different understanding of what physical nature and infrastructure is compared to an environmental scientist when they carry out their activities to plan, design and implement infrastructure solutions. An engineer tends to focus on the use of only synthetic or constructed materials to manage infrastructure, while an environmental scientist may support the preservation of physical nature to enhance or support infrastructure services provision. That said, depending on their background and experience, these professionals may also fall somewhere in between these two extremes. By implication, it becomes important to acknowledge the many meanings of physical nature and infrastructure and how they come together under a green infrastructure approach.

Physical nature-infrastructure interactions

I define physical nature-infrastructure interactions as a range of constructed understandings of the social world. By *physical nature,* I refer to tangible non-human features such as wetlands, native forests and open space (Figure 2-1). I acknowledge 'nature' is a highly contested concept in the social sciences, where it can have many disputed and/or congruent meanings. In the thesis, I have chosen to focus on *physical nature*, rather than nature. I have selected to focus on physical nature rather than nature as it enables me to explore the material aspects of green infrastructure. Focusing on the materiality of green infrastructure enables me to explore the many meanings and understandings of green infrastructure that are not only attached to one use of the concept, but how meanings can evolve according to how the concept is interpreted.

On the other hand, I define *infrastructure* as something that is created by humans that can provide a service or function. In other words, infrastructure is a synthetic or constructed material phenomenon such as pipes, stormwater infrastructure or roads (Figure 2-1). Depending on the city or project level actor's background, they may understand green infrastructure in a variety of ways. For example, in much the same way that an engineer or environmental scientist can understand physical nature (above) they can also understand infrastructure differently, including how it interacts with physical nature as part of physical nature-infrastructure interactions. For example, an engineer may consider infrastructure as the primary way in which services can be managed, or it can include both human and non-human features. By implication, physical nature-infrastructure can exist along a spectrum.

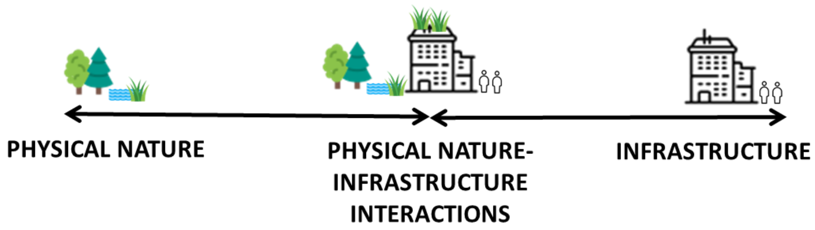

Figure 2-1: Physical nature and infrastructure and how they interact

It is noteworthy to flag that actors like policymakers always have an understanding of physical nature-infrastructure interaction at any one time. In other words, whether actors use green infrastructure concepts or not, they already have an understanding of how physical nature and infrastructure interact in some way or form. For example, an engineer that builds a concrete canal will conceptualise it through their understanding of physical nature-infrastructure interactions. The same can be said for a botanist that develops a project to preserve biodiversity. Therefore, despite being conceptualised as something with two polar extremes, such as the example I produced in Figure 2-1, understandings of the social world can be constructed through a range of understandings of physical nature-infrastructure interactions that can be held simultaneously. How these meanings evolve and merge in practice forms a key component of the thesis.

I use physical nature-infrastructure interactions to create a wide conceptual frame in which different meanings of green infrastructure could emerge. Although I have not made it apparent from the start, I have chosen to define green infrastructure according to what my participants identified it to be in Johannesburg, South Africa. To support this in the methodology, I selected two 'environment and infrastructure'[2] projects at Bruma Lake and Paterson Park that were identified by the study participants to explore how green infrastructure concepts were conceptualised as physical nature-infrastructure interactions (Section 4.3). It is noteworthy to mention that both these projects used a river renaturalisation approach to respond to material concerns.

'Environment and infrastructure' projects

As the intention of the study was to explore how policymakers conceptualised green infrastructure, I broke down the concept into its two fundamental elements, or 'environment and infrastructure'. Rather than using the terminology 'green infrastructure', I chose to focus on terminology that was easy to understand and something that they could identify with. For example, I could have chosen to focus on physical nature and the built environment, I chose 'environment' and 'infrastructure', which I felt were terms that were common across a range of actors from different backgrounds. Using the 'environment' and 'infrastructure' terminology, I was able to identify and explore a range of physical nature-

[2] *'Environment and infrastructure'* is the terminology I used when interviewing participants in the field instead of 'green infrastructure' (Section 4.3). Therefore, when I refer to *'environment and infrastructure'* I am referring to responses or categorisations identified by participants in the field. I also use environment and infrastructure in the thesis, which refers to a broad category around environmental and infrastructural topics in the city.

infrastructure interactions, rather than one preconceived idea of green infrastructure. By doing so, I was able to contribute knowledge on the multiplicity of meanings around green infrastructure, including gathering a range of meanings that may have fallen outside of my pre-conceived ideas about green infrastructure. The latter of which becomes significant when I present on the methods (Section 4.3).

Participants identified river renaturalisation or ‘daylighting’ at Bruma Lake and Paterson Park as two examples of ‘environment and infrastructure’ projects. River renaturalisation follows an *engineered approach* to green infrastructure, which I explain in more detail in Section 2.1. The underlying focus of the approach is to ‘bring nature back into cities’ (Delibas and Tezer, 2017, p. 22). Bringing nature back into cities to manage infrastructure diverges from a conventional engineered approach, where it is intended to reintroduce physical nature into the city. Since the mid-1900s, engineers have tended to build pipes and channels to convey stormwater and other urban water flows away from the city to reduce flood risk. In many instances, water was conveyed through hidden conduits and channels below the ground. However, renaturalisation focuses on transforming these hidden conduits such as pipes and channels into river-like interventions that support the opening and spreading out of the water so that it can be absorbed by the surrounding landscape through ecological processes. River renaturalisation is often paired with the creation of parklike environments which demonstrate one further inclusion of physical nature, which is aesthetically pleasing and provides space to absorb water.

To set out the relevance of conceptualising green infrastructure concepts in Johannesburg, I begin by describing international trends in green infrastructure. I then highlight how Johannesburg has engaged with the green infrastructure concept (Section 1.1). After establishing this context, I then outline my overarching research question (Section 1.2), which I use to define my argument and the main contribution of the thesis (Section 1.3). To show how I answer the research question, I present how I structure the thesis (Section 1.4). Last, I provide a summary of the research conclusions (Section 1.5)

1.1 A global concept for local problems

Green infrastructure concepts have been drawn on by a range of policymakers as part of a rising trend toward managing cities more sustainably. While the concept is defined in a variety of ways, it tends to refer to the inclusion and enhancement of existing physical nature in the design and management of cities. While the concept has been used widely in the United Kingdom, United States of America and Australia, it has received less attention in Asia and Africa. While in the former, green infrastructure is used to provide infrastructure services and associated recreational functions to balance development objectives under the growth and development debate; in the latter developing contexts, it tends to be used to achieve developmental goals as well as responding to global agreements around sustainability. I now reflect on global agreements around sustainability and urban development and how they have encouraged the use of green infrastructure concepts in cities.

1.1.1 Green infrastructure for sustainable urban development

International agreements such as the Paris Agreement on Climate Change, Sustainable Development Goals, Convention on Biological Diversity, and New Urban Agenda have set the tone for the development of national, regional and city development plans (United Nations, 1992, n.d., 2015, 2017). Urban development forms a major focus of these agreements, where it has become commonly acknowledged among politicians, government officials, researchers, academics and practitioners alike that cities need to be designed and managed more sustainably. The need to become more sustainable stems from the way cities are designed and managed at present:

> Since 2007, more than half the world's population has been living in cities, and that share is projected to rise to 60 per cent by 2030…Rapid urbanisation is resulting in a growing number of slum dwellers, inadequate and overburdened infrastructure and services (such as waste collection and water and sanitation systems, roads and transport), worsening air pollution and unplanned urban sprawl.

(United Nations, 2020, p. n/p)

Therefore, the rate at which urbanisation is taking place has been identified by overarching environmental policy as being inherently unsustainable.

Toward creating more sustainable cities, the abovementioned agreements set an impetus for change, where it encouraged the design and management of urban areas more sustainably. For example, the United Nations outline that transformation is needed to influence the way that development takes place, including how infrastructure networks are designed and managed:

> Sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces…[this] involves

> investment in public transport, creating green public spaces, and improving urban planning and management in participatory and inclusive ways.
>
> (United Nations Development Programme, 2020, p. n/p)

Setting out the need to significantly transform the way urban areas are built and managed marks a first step toward designing more sustainable cities.

Cities have gained increasing attention as the sites for supporting sustainable development. On the one hand, cities are the sites for urban development, where they are a “major driver of economic growth and employment” (Organisation for Economic Co-operation and Development, 2018, p. 11). While on the other, they are the “loci where many environmental, economic and social challenges will have to be tackled”, where transformation is necessary to ensure development takes place in a more sustainable way (Organisation for Economic Co-operation and Development, 2018, p. 11). Therefore, toward tackling the challenges associated with development, cities are identified as a site for transformation.

The practices and processes that underpin the development of cities are identified as the levers for transformation. In other words, “business as usual” needs to be modified to enhance sustainability (Evans et al., 2016, p. 1). Toward transforming unstainable development practices in alignment with global agreements, there has been a “search for alternative ways to organise, plan, manage, and live in cities” (Evans et al., 2016, p. 1). Consequently, the need to ‘search’ for these alternatives has stimulated a range of academic studies around the various options for transforming urban areas.

Table 2-1: Approaches for supporting the sustainable design and management of cities using physical nature

APPROACHES	DESCRIPTION	EXAMPLES	REFERENCES
Nature-based solutions	The use of physical nature to address concerns associated with water, air and waste management. Typically includes addressing socio-environmental concerns such as climate change. Used mainly in urban areas, but also includes a focus on rural areas.	Catchment rehabilitation Ecological engineering Biomimicry Constructed wetlands Trees Parks Open space	Thorslund et al., 2017
Green infrastructure	The use of physical nature as a partner to enhance the service and function-based values of urban and rural areas. Can include enhancing existing and new forms of physical nature and infrastructure.	Trees Plants Parks Open space Constructed wetlands Bioswales River renaturalisation	Benedict and McMahon, 2002; Black et al., 2016; Reimer and Rusche, 2019
Ecological infrastructure	The use of physical nature to enhance the services provided by ecosystems. Can include enhancing existing physical nature or planting new kinds of physical nature. Tends to focus on indigenous kinds of physical nature, but not always a rule.	Trees Plants Open space Riverbank restoration Restoration/ Wetland rehabilitation	Ignatieva et al., 2011; South African Biodiversity Institute, 2016
Sustainable urban drainage systems	The use of physical nature to address water concerns where water services are required. Tends to focus on the development of urban infrastructure to support the more sustainable	Constructed wetlands Bioswales River renaturalisation Permeable paving	Mguni, 2015; Hoang and Fenner, 2016

	management of urban water resources.		

Policymakers (such as government officials), private sector professionals and members of civil society already use physical nature as part of their approach for developing cities. While physical nature, such as trees, rivers, parks and open spaces, have always been part of the city in varying forms, global agreements on sustainable development have encouraged the inclusion of physical nature in new ways, where they are intended to mitigate any negative impacts of development. For example, instead of managing urban water flows in contained channels and culverts, it can be managed to create value. Flows can be made more visible and aesthetically pleasing, where the ways they are developed can balance the provision of built-up and physical nature elements. Another way physical nature is used is through its benefits for humans where it can provide a service or function-based values such as stormwater attenuation or flood management.

To illustrate the different ways that physical nature can be drawn on to create more sustainable urban areas, I have put together a table with prominent concepts that have been developed to support the transformation of cities. Approaches include green infrastructure, ecological infrastructure, nature-based solutions, and sustainable urban drainage system (Table 2-1). While each of these approaches draws on physical nature in different ways, they all encourage a range of outcomes toward creating more sustainable cities such as addressing concerns associated with water, air and waste management (nature-based solutions), for the enhancement of infrastructure (green infrastructure) and services (ecosystem services) and water concerns (sustainable urban drainage systems). While I return to each of these approaches in more detail when I reflect on disciplinary knowledge in Section 2.1, it is important to flag that they conceptualise physical nature and development in different ways, where there are multiple meanings and linkages between them.

In this thesis, I focus on green infrastructure as one way to create more sustainable cities. Green infrastructure is a broad umbrella concept for a range of sub-approaches that aim to re-establish and enhance physical nature in the city for supporting sustainable development. Green infrastructure has “gained the attention of academics and practitioners” in recent years as it presents an opportunity to support sustainability outcomes in policy and practice (Reimer and Rusche, 2019, p. 1542). Under the green infrastructure approach, physical nature is considered an “indispensable part” of the city, where it can be used in a variety of ways as a “useful complement to grey infrastructure” through its provision of services and functions in urban and/or rural areas (Reimer and Rusche, 2019, p. 1543). Therefore, by focusing on green infrastructure, it initiates a study on one sub-set of approaches that draw on physical nature to achieve urban sustainability.

Green infrastructure concepts have gained increasing interest from policymakers to enhance services functions to support sustainable development. While they tend to be framed as a ‘win-win’ concept in cities as they enable actors to meet a range of urban developmental objectives, they are often used without much consideration or reflection. Critical planners caution the hidden implications for following a green infrastructure approach as it may “conceal cultural prejudices” (Lennon, 2015, p. 10). For example, in the Republic of Ireland, green infrastructure concepts have been used in planning policy, with little critical reflection on the “deployment of green infrastructure thinking” (Lennon, 2015, p. 3). Therefore, while green infrastructure concepts have formed part of international development practice, they are often used without considering what they mean for cities.

Reflecting on green infrastructure as a developmental approach

To begin, critical literature on the green infrastructure concept is not used in a vacuum. While green infrastructure tends to be understood in technical and policy terms, they can be influenced to support certain interests in the city. For example, green infrastructure can be a “corrupted” concept, where influential policymakers can shape its meaning and use it to achieve their outcomes (Wright, 2011, p. 1004). Similarly, the practices and processes that underpin ‘business as usual’ can serve to “cloak” the benefits of green infrastructure, where instead of bringing about more democratic change, it can perpetuate certain elements of business as usual (Finewood, 2016; Finewood et al., 2019). Accordingly, the use of green infrastructure concepts to manage any sustainability transitions requires greater scrutiny.

The use of technical and/or scientific language also points to the concept’s technocratic connotations. In other words, researchers, academics and practitioners produce knowledge for experts or technocrats. For example, green infrastructure studies such as best practice around constructed wetlands, stormwater management and flood abatement tend to be “grounded in the principles and practices of diverse professionals[3]” (Benedict and McMahon, 2002, p. 15). Disciplines such as planning, engineering, environmental and architectural and landscape architecture serve to develop detail on the use of green infrastructure urban water solutions as a "sound science” (Benedict and McMahon, 2002, p. 15). By implication, managing urban development using a green infrastructure approach tends to be located in disciplinary knowledge and policy development and appeals to professionals or experts that tend to draw on technical knowledge.

Using technical and scientific measures to quantify the benefits of green infrastructure have implications for how they are understood. Demonstrating the measurable benefits of green infrastructure concepts tend to create a focus on opportunities or avenues for their use. The implications are that green infrastructure has becomes clouded by “things that we need” to do, which implicitly implies “burden for proof”, where it becomes necessary to find out the things that need to be done (Lennon, 2015, p. 10). The burden for proof is driven by “expectations” for sustainability transformations through green infrastructure that has now become part of standard practice in policy development (Lennon, 2015, p. 10). Therefore, using green infrastructure as part of a developmental approach tends to be situated in the realms of what should or ought to be done,

[3] Scholars refer specifically to landscape ecology, urban and regional planning, and landscape architecture disciplines (Benedict and McMahon, 2002).

and does not always have an implicit focus of how the concepts come to exist in cities.

1.1.2 Green infrastructure and policy in Johannesburg

In South Africa, green infrastructure has been drawn on to address a range of existing urban challenges, while also meeting economic, societal, and environmental objectives. The concept has been used in policy to support development across a range of South African cities such as Johannesburg, Cape Town, Durban and Port Elizabeth (Pasquini and Enqvist, 2019; Gulati and Scholtz, 2020). In these contexts, green infrastructure has been drawn on by a range of actors such as government officials, private sector professionals and members of civil society in a variety of ways to respond to economic, social and environmental concerns. By implication, this points to its situated or contextual use.

Understanding the situated or contextual use of green infrastructure concepts are important as despite offering an avenue for achieving more sustainable urban development, green infrastructure concepts are wrapped in complexity. In the case of South Africa, the political context and setting of the country have implications for the way the concept is drawn on and used. For example, limited municipal budgets tend to place a priority on areas previously disadvantaged under Apartheid as a political objective, which places sustainability and ‘environmental’ concerns as secondary or tertiary objective. In addition, redressing infrastructure inequalities tends to support new connections and upgrading basic or communal supplies. Subsequently, existing infrastructure networks tend to get left behind, where limited budgets for maintaining existing infrastructure can influence how concepts such as green infrastructure are used in practice.

In Johannesburg, academics and researchers, government officials and members of civil society, such as local non-profit organisations, have worked to create a coordinated vision for the use of green infrastructure concepts to respond to global sustainability agreements. While the focus has largely been at a regional and city level, the allure of green infrastructure can be attributed to its multifunctionality (Bobbins, 2016; Schäffler, 2018), which enables policymakers to respond to existing urban challenges such as water pollution, flooding and air quality through one approach, while also achieving the goals set out by international agreements on the environment.

Since 2012, the abovementioned policymakers in Johannesburg have developed a dialogue around the use of green infrastructure concepts in policy. The main aim for dialogue was around mainstreaming the concept, where it can be drawn on by a range of policymakers and practitioner to support development. The outcome of these policy dialogues influenced policy development in the city. For example, green infrastructure featured as a concept in Johannesburg Spatial Development Plan 2040, as well as a range of supporting guidelines such as the Johannesburg stormwater guidelines and climate change adaptation plan[4] (City of Johannesburg Metropolitan Municipality, 2016). While the latter two

[4] The guidelines and adaptation plan were being drafted during the fieldwork period. They have not yet been made publicly available on the Johannesburg Municipality website.

documents were finalised during and after the fieldwork was conducted for the study, they do demonstrate the effectiveness of dialogue around green infrastructure to influence policy, where the concept has been referenced as an option for managing urban development.

Setting the tone for green infrastructure

The meaning of green infrastructure concepts in Johannesburg has been influenced by policymakers such as researchers and municipal officials and private professionals. The initiation of the Gauteng City-Region Observatory's research project on *Green Assets and Infrastructure* in 2012 created the impetus for green infrastructure investments in the broader Gauteng City-Region, the region within which Johannesburg is located, including a shared understanding of its value and use. The definition used throughout the project is focused on a broad description of green infrastructure concepts, where they are:

> The interconnected set of natural and man-made ecological systems, green spaces and other landscape features. It [green infrastructure] includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation, such as green roofs. Together these assets form an infrastructure network providing services and strategic functions in the same way as traditional 'hard' infrastructure.
>
> (Schäffler et al., 2013, p. 30)

The broad meaning of green infrastructure articulated by Gauteng City-Region Observatory resonated with a range of professional actors that had already worked with a similar concept such as *ecological infrastructure* and *sustainable urban drainage systems* (Table 2-1).

The Gauteng City-Region Observatory is an influential actor in Johannesburg. It is a solely government-funded research organisation with political ties to the Gauteng Provincial Government. Given its influence in the city, the Gauteng City-Region Observatory has helped to set the tone for the inclusion of the green infrastructure concept due to its close organisational relations with Gauteng Provincial Government[5]. Their definition and focus on green infrastructure has been solidified across a range of research reports released by Gauteng City-Region Observatory such as the *State of Green Infrastructure in the Gauteng City-Region (*2013), *A framework for a green infrastructure planning approach in the Gauteng City-Region* (2016) (Schäffler et al., 2013; Culwick et al., 2016). One further report, drafted before my fieldwork, was published later in 2019[6] (Culwick, Khanyile, et al., 2019). The string of research reports has influenced how green infrastructure concepts are understood, where their research activities have served to define the development of a common understanding of the green infrastructure concept among across government, private sector and civil society.

Influential activities to support the inclusion of the green infrastructure concept in city-wide policy is the *Green Infrastructure CityLab*. The *CityLab was* held initially in 2014, with an additional session in 2016. The *CityLab* brought together groups of fifteen local government officials from environment and planning departments in Gauteng, national environmental, non-governmental organisations and practitioners to problematise ways to mainstream the concept in the policy. The

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[5] Gauteng City-Region Observatory is a partnership between the University of Johannesburg, the University of the Witwatersrand, Gauteng Provincial Government and organised local government in Gauteng, South Africa.
[6] The report published in 2019 was entitled, *Towards applying a green infrastructure approach in the Gauteng City-Region* (Culwick, Khanyile, et al., 2019).

CityLab aimed to create a "strategic dialogue amongst government officials concerned with the development of more sustainable urban infrastructure" (Gauteng City-Region Observatory, 2014, p. 1). In reflection, policy dialogue facilitated at the *CityLab* was identified to enhance "shared understandings" of what green infrastructure was and "fostered and new ways of thinking" about development (Culwick et al., 2019, p. 14). While research activities of the Gauteng City-Region set the tone for green infrastructure in the broader city-region, the elements of how it ought to be used as part of the daily activities of municipal officials and private sector professionals remained an overlooked feature.

Research interests around green infrastructure at Gauteng City-Region Observatory dovetailed with other research activities around policymaking. For example, South African institutions working on green infrastructure included the South African Cities Network[7], including staff and student projects at the University of Witwatersrand, which is one of the host institutions of the Gauteng City-Region Observatory. Collaboration has also developed with international partners such as Science, Technology, Engineering and Public Policy (STEaPP) at University College London[8], where staff and student projects have endeavoured to develop the policy case or develop technical and scientific evidence to facilitate the uptake of the green infrastructure concept in practice. In sum, the research agenda in Johannesburg around green infrastructure has been

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[7] Produced a document entitled, *Planning for Green Infrastructure in South African Cities* (Cilliers and Cilliers, 2016).
[8] Project considers the value of green infrastructure for managing urban food security in Johannesburg. Project is in partnership with Gauteng City-Region Observatory.

influenced and developed through policy dialogue and research reports that have been drafted and supported by a handful of policymakers, which tend to be professionals or experts.

Therefore, a dominant definition of green infrastructure in Johannesburg held among professionals and experts is affiliated to the Gauteng City-Region Observatory's definition. While it does draw attention to the material features that constitute a range of physical nature-infrastructure interactions from indigenous trees to constructed green roofs, it exists as only one interpretation of green infrastructure. In addition, discussing the concepts as part of dialogues such as the *CityLab* sessions, various research reports and case study examples, facilitated (re)conceptualised understanding of what green infrastructure is, or more specifically what it ought to be among the professionals such as researchers, municipal officials, non-profit organisations and practitioners involved in them. Therefore, by setting up a coordinated vision of what green infrastructure is, it has set the tone for how the concept ought to be drawn on in the city going forward.

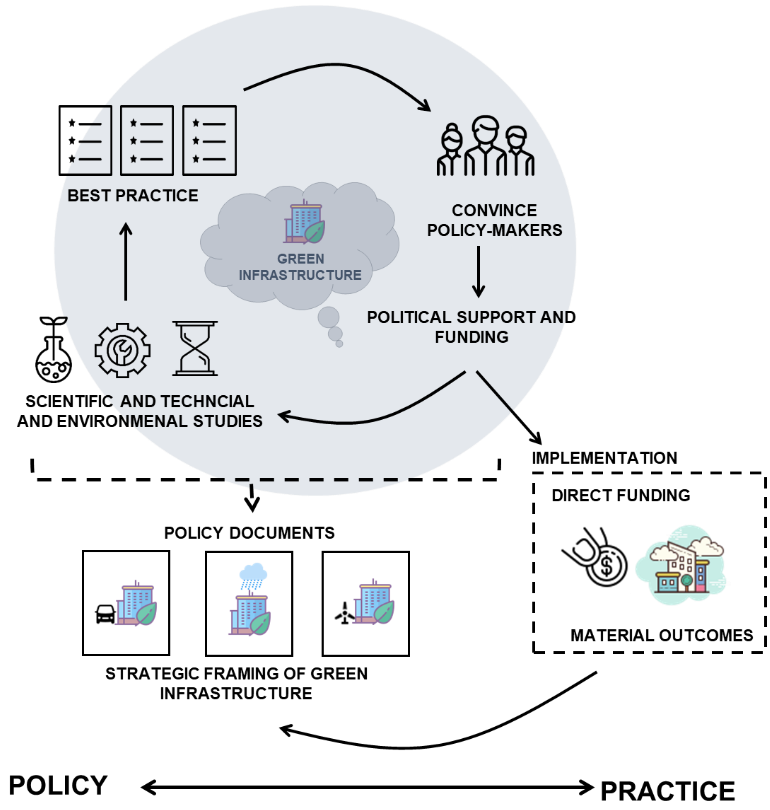

Figure 2-2: Policy rhetoric around green infrastructure in Johannesburg

Research activities have set a strong policy tone for green infrastructure in Johannesburg. A key focus of this approach is generating the necessary technical or scientific evidence to support the use of green infrastructure concepts in policy. While this forms one aspect of understanding green infrastructure concepts and how they can be drawn on, placing a strong focus on its policy uptake can detract from other kinds of knowledge that may support understandings for how concepts can be used (Figure 2-2). In addition, conforming to one definition of green infrastructure can limit a study of how other kinds of green infrastructure take root and are used are part of a more organic and socially orientated process. Toward exploring how the unplanned ways green infrastructure concepts are understood and used, according to the local context and historic setting in Johannesburg, I consider how they are conceptualised in practice.

1.2 Aim and research question

To investigate how green infrastructure concepts gain meaning in practice, I explore how actors in Johannesburg negotiate understandings of green infrastructure concepts. To investigate this further, I pose the following research question:

> How do municipal officials, private sector professionals and members of civil society practice green infrastructure in Johannesburg, South Africa?

Investigating how green infrastructure is practiced enables me to focus on how concepts come to gain meaning according to what is done by these actors. Focusing on green infrastructure in this way encourages moving beyond a policy rhetoric to focus on how they are used. While we understand green infrastructure as having technical and scientific value, where it can be mainstreamed in policy, not enough is known about how green infrastructure concepts are used in practice in Johannesburg.

At this early stage of the thesis, I draw attention to one implication of the research questions for the kinds of participants I selected for the study. As I describe in the methodology chapter (Chapter 4), I did not refer to the terminology ‘green infrastructure’. Rather, I used ‘environment and infrastructure’ to enable a broader study on how green infrastructure concepts gain meaning in practice. That said, while I intended to interview a wide range of participants with a wide range of understandings of green infrastructure, I ended up interviewing a self-selecting group.

I classify participants as forming part of a self-selecting group because they were the ones that chose to respond to my requests for interviews on 'environment and infrastructure' projects. They were also participants who were willing to meet with me to speak about Bruma Lake and Paterson Park project. As such, participants tended to be those who were either interested in 'environment and infrastructure' approaches in general, or they were interested in talking about what they believed to be a successful project they were self-selecting. Gathering responses from a self-selecting group has implications for answering the research question.

Gathering the accounts of self-selecting participants that were interested in or working on 'environment and infrastructure' had two implications for the study. First, it revealed a relatively small group of actors in the city were involved in 'environment and infrastructure' projects. For example, the design engineer and residents had not only been involved on a range of 'environment and infrastructure' projects in the city, but they were also aware of and/or involved at the Bruma Lake and Paterson park projects I selected as a focus for the study. I return to cross-over between participants in the methodology chapter, where I describe the actors I interviewed at the city and project levels (Section 4.3).

Second, the self-selecting project level participants revealed how knowledge manifested across a relatively small range of actors from municipal government, private sector professionals and members of civil society. By implication, the study focused on only one way of doing green infrastructure in the city. Should I have included a wider range of practitioners, I would have gathered a more diverse range of participants views, including different kinds of green infrastructure applications. I feel this loss is justified by the need to focus on actual projects to explore how concepts are practices. Incorporating a more diverse range of views present a concern that can be taken forward as part of future research (Section 8.3).

1.3 Argument and contribution of the thesis

I claim green infrastructure concepts are practiced according to actor ambitions to create a manageable and viable legacy in the city. To create a legacy, participants explained that they claimed ownership in a variety of ways to manage uncertainties in practice. Green infrastructure concepts therefore become what actors, such as municipal officials, private sector professionals and members of civil society, could claim ownership of and which uncertainties they could manage. Establishing how green infrastructure is conceptualised through the relationship between ownership and uncertainty demonstrates how green infrastructure concept gains meaning in practice according to the setting and context, including how green infrastructure is translated into practice. Exploring how green infrastructure concepts are practiced as part of a situated process, demonstrates how their meaning can be (re)conceptualised over time.

Illuminating how green infrastructure is (re)conceptualised as a situated and contextually bound phenomenon underscores my contribution to knowledge. At present, the literature on green infrastructure illuminates its complexity, where the concept can have many representations and understandings in disciplinary knowledge and policy (Mell, 2015a; Lennon, 2019), and where it has fluid boundaries in its meaning (Horwood, 2011, 2011). Critical studies also underscore that it is not used in a vacuum (Wright, 2011; Finewood, 2016; Finewood et al., 2019). Understanding how green infrastructure concepts come to have meaning through actor's interests to leave a legacy in the city shows how understandings of green infrastructure can be stretched and adapted over time. Therefore, I make a contribution to knowledge by building on broader literature on green infrastructure by exploring how the concept comes to gain meaning through the ways that the boundaries in their meaning are stretched and defined over time as part of a situated process.

I have chosen practice theory in particular as it enables me to focus specifically on the process and how it unfolds, or evolves, in practice. While I could have explored green infrastructure using the social construction of nature scholarship and/or urban political ecology, I feel that it would have not enabled me to illuminate two features of green infrastructure that underscore my contribution to knowledge in the thesis. For example, while the social construction of nature scholarship highlights how concepts such as 'nature' gain meaning and can have a range of meanings, it largely conceptualises these elements in theory, without understanding the ambiguity around meaning and how it is socially constructed in practice. As such, I consider the social construction of nature literature as a starting point for the thesis, which I have identified and developed further in my use of physical-nature infrastructure interactions as a conceptual device (Chapter 2).

Urban political ecology provides a critical lens to begin to untangle some of the power and governance complexities associated with concepts like green infrastructure in urban settings. While urban political ecology scholarship identifies the interaction between nature and infrastructure in cities, it tends not to focus on the continuous and evolutionary aspects of practice. For example, under urban political ecology scholarship, green infrastructure is conceptualised as a hybrid entity that is continually being produced and re-produced, where the focus is on going ‘backstage’ to consider the actors, decision-making process and how they produce the urban in a variety of ways. As such, urban political ecology tends to follow a ‘backward’ looking approach to exploring and describing power relations. In addition, while it conceptualises nature and infrastructure as a hybrid or interconnected entity, it tends to not illuminate the multiple social meanings in practice and how these develop over time, where actors can exhibit a range of understandings that straddle positions from being wholly ‘infrastructural’ in a utilitarian sense, to wholly ‘natural’ in terms of its organic and aesthetic value, or anything in-between.

By focusing on the (re)conceptualised meanings of green infrastructure using a practice theory approach I contribute knowledge to these two areas of scholarship. In other words, I take heed of the socially constructed elements of nature and how it can mean different things to different actors and I consider the fact that the urban is produced and reproduced through nature and infrastructure. By taking a practice theory approach, I contribute knowledge on how meanings come to exist and evolve in practice and how a range of understanding and ways of producing the city can be divided among actors according to their understandings of nature and infrastructure. Therefore, by taking a practice theory approach, I contribute to knowledge around how meaning is (re)conceptualised in a variety of ways as part of a situated and contextually bound process.

By following a practice theory approach, I contribute to broader social science scholarship on infrastructure. While I explain how I make a contribution in more detail in the paragraphs to follow, I feel it is necessary to provide context on the 'infrastructural turn' that comprises a relatively recent thrust of the social sciences. For the last 20 years, the 'infrastructural turn' has explored the socio-political aspects of infrastructure where it is not only understood as a material or hidden feature of the city such as pipes, wires and roads, but is also part of a socio-political process. For example, infrastructure is considered to not only be a study of "mundane things", rather it is more complex having been produced through a range of physical and legal constructs such as "plugs, standards, [and] bureaucratic forms" (Star, 1999, p. 377). The need to focus on these more complex elements have encouraged the study of infrastructure beyond its "lists, numbers and technical specifications", to reveal its "hidden mechanisms" through exploring "dramas inherent in the [infrastructure] system" (Star, 1999, p. 379). By focusing on infrastructure as a socio-political process in addition to being a 'thing' that make up the urban form encourages a study of infrastructure as something relational rather than being a static feature.

Conceptualising green infrastructure as a socio-political process contributes to the infrastructural turn by illuminating the more "lively" or everyday ways in which social life is constituted through infrastructure and how it manifests as a material phenomenon (Amin, 2014, p. 137). In particular, the thesis builds on the following debates, which lie at the heart of scholarly literature on the infrastructural turn. It shows how infrastructure can form the “hidden” or “forgotten” aspects of the urban that mediates daily life, which is both constituted and constituted by social actors in a relational way[9] (Star, 1999, p. 379)). As such, I illuminate one of the many “superimposed, contested and interconnected infrastructure landscapes” or splintering ways in which it can comprise urban settings (Graham and Marvin, 2001, p. 8). Furthermore, it sets up a study to explore how green infrastructure can “create its own modes of spatiality”, where it can both influence and be influenced by culture and society through socio-technical means (Larkin, 2004, p. 310). Therefore, the lively, or more social aspects of infrastructure, enables a study of the cross-cutting presence of infrastructure and how it comes to bear significance on the daily lives of practitioners and city dwellers.

Scholars writing on the infrastructural turn have illuminated a wide range of social aspects that influence the everyday life of social actors. Green infrastructure, including considerations around urban nature and/or nature in the city, tends to not form the basis of many studies that contribute to the infrastructural turn. For example, scholars have investigated already established forms of infrastructure such as housing (Lemanski, 2019a, 2020), sanitation (McFarlane, 2019) and water (Peša, 2019), where they can have “profound consequences” for social life (Lemanski, 2019b, p. 2). By focusing on nature in the city, I build on this body of

[9] I refer to social actors as a generic category for actors within a particular context or setting.

knowledge where I consider some of the socio-political processes associated with meanings and understandings of infrastructure and how it interacts with physical nature.

I build on the social and ethnographic accounts of infrastructure using a practice theory approach to delve deeper its social, or lively, aspects to explore how it mediates social life. Practice theory enables me to focus on the connections and interconnections between infrastructure and the social world, where actors can have a variety of understandings of nature and infrastructure in practice, which shape what and how they ‘do’ what they ‘do. In other words, it enables me to build on the social construction of nature and urban political ecology scholarship. Practice theory has been previously used to explore the infrastructure turn, where it has enabled a study of how and why social actors do ‘things’. For example, Shove and Spurling use practice theory to illuminate the politics associated with infrastructure, which tends to be hidden or concealed element of the city (Shove et al., 2012; Shove, 2016). Shove and Spurling build on Schatzki’s practice theory approach, where they have classified or characterised Schatzki’s broad focus on materiality (Shove et al., 2012). While their approach does take logical steps toward exploring how infrastructure influences social life as a material phenomenon, I have chosen not to use it to explore green infrastructure as it sets out with an assumption that infrastructure already exists and it follows a fixed idea of what infrastructure is. Consequently, following Shove and Spurling’s approach, would not enable me to explore multiplicity and complexity around the many physical nature-infrastructure interactions and how meanings evolve over time.

To build on existing knowledge around practice theory and the sociology of infrastructure, I draw directly on Schatzki's practice theory. I have chosen Schatzki's practice theory approach as it enables me to use a broader conceptual account of materiality and how a range of actors can develop and evolve their understandings of physical nature-infrastructure interactions over time. For example, Shove defines infrastructure as a particular category of materiality, where it can characterise social life it three ways, where it forms part of broader infrastructure networks, where it is used a device to influence practice and last, where it can develop out of available resources (Shove et al., 2012). While this provides a useful starting point for exploring how existing forms of conventional infrastructure networks influence social life, the starting point is too narrow for investigating the complexity green infrastructure concepts, which is comprised by a range of physical nature-infrastructure interactions and be capacious enough to bring different actors together in practice. Accordingly, by developing Schatzki's practice approach, I begin with an exploratory study to identify how a green infrastructure project comes to exist, and where it can evolve in unplanned ways that are defined by the local context.

Setting up an explorative study on green infrastructure supports recent debates in decolonisation. Decolonisation identifies the prominence of theories and understandings of cities being rooted in western ideologies and/or settings. Post-colonial scholars identify "intellectual traditions" and "experiences of the west" in mainstream views around planning and development (Harrison, 2006, p. 319). Focusing on the unplanned ways in which Johannesburg is made supports an understanding of the "incessantly flexible mobile and provisional" ways in which intersections and activities evolve in practice, rather than relying on interpretations of best practice that tend to dominate texts on green infrastructure and its conceptualisation in practice (Simone, 2004, p. 407). Using a practice theory approach, therefore, reveals one of the “other ways” of “seeing and acting” in the city that fall outside of existing notions of planning and development and how they ‘should’ unfold in cities (Harrison, 2006, p. 320). Revealing the multiple understandings and meanings of the city and how they are (re)conceptualised enables a different way of seeing Johannesburg and supports a decolonial way of seeing the city.

1.4 Outline of the thesis

To answer the research question, I have divided the thesis into eight chapters. I have included an overview schematic that details the structure of the thesis (Figure 2-3). To present the research case, I begin by presenting a review of the literature on green infrastructure concepts to show their many complex meanings (Chapter 2). I then develop Schatzki’s practice theory approach to foreground physical nature-infrastructure interactions as a scaffold for my argument (Chapter 3). To explore how green infrastructure is practiced in Johannesburg, I set out how I conducted the study, where I gathered data at the city and at the project levels to explore how green infrastructure concepts are used (Chapter 4). To focus on how green infrastructure concepts are conceptualised at the project level, I selected two projects, Bruma Lake and Paterson Park, where river renaturalisation, a form of green infrastructure was used. Analysing the data demonstrated that green infrastructure concepts are conceptualised by municipal officials, private sector professionals and members of civil society according to the ways they claim ownership (Chapter 6) to manage uncertainty (Chapter 7). Last, I summarise my research findings and reflect on how I answered the research question (Chapter 8). I also propose avenues for future research.

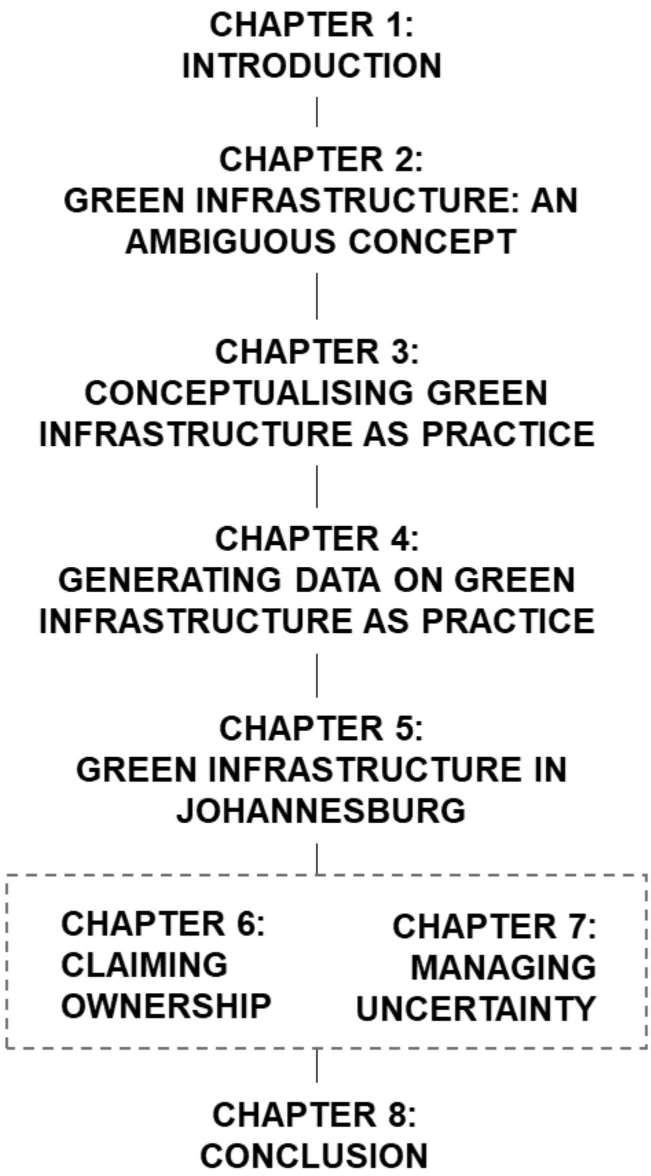

Figure 2-3: Thesis overview and structure

1.5 (Re)conceptualised meanings and their implications for urban management

Findings of the research study demonstrate that green infrastructure concepts were conceptualised through project level actor interests to leave a legacy at Bruma Lake and Paterson Park. Actors working on Bruma Lake and Paterson Park projects were united in their interests to leave a legacy at the project sites, where they claimed ownership to create a manageable and viable legacy in the city going forward. The study identifies 'ownership' and 'uncertainty' as two key themes for using green infrastructure concepts in practice. While 'ownership' and 'uncertainty' as themes are not unique to green infrastructure projects, the contribution to knowledge is established by illuminating specific features of green infrastructure in practice that were supported by 'ownership' and 'uncertainty' in different ways, where it enabled elements specific to the use of green infrastructure to be explored in greater detail. Therefore, by focusing on 'ownership' and 'uncertainty', I was able to explore how these themes are not only encountered on projects such as infrastructure projects, but also how they specifically support the use of green infrastructure through creating the grounds for actors to negotiate meaning in practice.

Using 'ownership' and 'uncertainty' as an analytical theme enabled me to illuminate my contributions to knowledge, where I showed how green infrastructure gains meaning as a situated and contextually bound concept. Actors on the Bruma Lake and Paterson Park projects claimed ownership in different ways to manage uncertainties associated with the future of the project sites, where they experienced uncertainty around political interest, funding and worsening environmental and health concerns. By claiming ownership to own the future, actors working on the projects contributed to uncertainty around its technical and operational features. It then became necessary to claim ownership in different ways to respond to environmental and health concerns that emerged from their activities. Therefore, the range of ways that actors claimed ownership to manage uncertainty formed a mutually constitutive relationship that influenced how project actors conceptualised green infrastructure concepts according to their daily work.

Wanting to leave a legacy played an important role in influencing how participants carried out their activities at Bruma Lake and Paterson Park. As I further elaborate on in the conclusion, leaving a legacy formed an intangible, unspoken, or unwritten about interest among participants that is rarely considered in the design and management of projects (Chapter 8). Wanting to create a manageable and viable legacy encouraged actors to work in more open or flexible ways on infrastructure projects, where they drew on different understandings of physical nature and infrastructure as part of their daily activities. Being flexible and open influenced actor activities, encouraged them to experiment with different physical nature-infrastructure interactions. Therefore, their understandings of physical nature-infrastructure interactions were (re)conceptualised by wanting to create a manageable and viable legacy.

I already highlighted how uncertainty emerged at the start of the project, where participants from all groups claimed ownership to own the future. By carrying out activities to own the future, actors contributed to further uncertainty associated with the need to work outside of existing rules and their roles and responsibilities. In addition, uncertainty arose out of the way participants carried out their activities to claim ownership at the sites, where they worked outside of professional guidelines that had predefined understandings of physical nature-infrastructure interactions. Therefore, by claiming ownership to create a manageable and viable legacy, participants worked outside of existing rules to develop and use different conceptualisations of physical nature-infrastructure concepts in practice.

Civil society, such as the Bruma Lake Owners Association and Orange Grove residents, claimed ownership of the future of the Bruma Lake and Paterson Park sites by using environmental law and the media to place pressure on Johannesburg Municipality to deliver on their legal duty of care for infrastructure and park management. Municipal officials at the Environment and Infrastructure Services Department and Development Planning Department carried out activities to attract greater budgets within Johannesburg Municipality, support multifunctional solutions and negotiate multiple interests – political, financial and infrastructural – through social platforms. Last, private sector actors such as the design engineer claimed ownership to experiment with the river renaturalisation project design and materials and manage the geographic condition and adapt the design to available financial and material resources.

While actors understood physical nature-infrastructure interactions in different ways, they all had a common objective to leave a viable legacy in the city. While leaving a legacy could not be reduced to a measurable technical or scientific objective, actors worked to leave a legacy in the city in their own way. For example, the Bruma Lake Owners Association and Norwood and Orange Grove wanted to leave a legacy by achieving the kinds of outcomes they wanted at the Bruma Lake and Paterson Park projects to improve their local areas. Municipal officials at the Environment and Infrastructure Services Department, Development Planning departments and Johannesburg Development Agency widened the scope to include the kinds of projects they felt would be of value to residents and the city. Last, the private sector claimed ownership to leave a legacy by adding value, where they provided more than one service to manage urban water such as providing infrastructural and recreational functions.

While working on Bruma Lake and Paterson Park, the abovementioned actors (re)conceptualised their understandings of physical nature-infrastructure interactions where they tended to negotiate disciplinary approaches and social meanings. How meaning is (re)conceptualised underscores one further way that I contribute to knowledge. While studies on green infrastructure tend to illuminate specific meanings of the concept and how they are defined according to disciplinary or other parameters, using ‘ownership’ and ‘uncertainty’ as analytical themes to explore physical nature-infrastructure interactions enabled me to illuminate meanings and meaning evolves and be reconceptualised as a situated and contextually bound process over time. As I later show in the analysis chapters, actors re-aligned their roles and responsibilities to claim ownership over the use of green infrastructure in practice (Chapter 6 and Chapter 7). Carrying out these activities signalled the need to develop various kinds of knowledge to support future ownership of projects, where uncertainties evolved around the future longevity and functionality of the projects over time. The development of new kinds of knowledge highlights the evolution in the understanding and use of green infrastructure concepts.

Chapter 2 GREEN INFRASTRUCTURE: AN AMBIGUOUS CONCEPT

In this chapter, I illuminate the ambiguous meanings of green infrastructure concepts and how they can create complexity. To begin, green infrastructure concepts have been used in a range of urban policy documents spanning city plans, guidelines and bylaws to support and incentivise their benefits for urban development. In many cases, policy often only draws attention to the benefits of green infrastructure concepts for society and the environment without much reflection around what they represent and how they ought to be used in practice. Focusing on the benefits of such an approach sets up the idea that green infrastructure concepts are relatively straightforward, where they can be applied in a range of other settings to bring about similar benefits through making small interventions in the daily activities of project actors. While this may give the impression that green infrastructure is relatively straightforward, in reality, it is misleading.

Green infrastructure concepts exhibit a range of tensions, overlaps and ambiguities, where they draw differentially on disciplinary knowledge, local parameters, or contexts, where they can be broad enough to include similar or complementary meanings. In light of its complexity, the use of green infrastructure concepts in policy may not bring about what is envisaged in practice. Therefore, by exploring the complexity, I show what is at stake when using a complex concept such as green infrastructure, including why the need to consider how it is conceptualised in practice.

I use physical nature-infrastructure interactions as a conceptual device to explore the complexity of green infrastructure concepts. I contend that physical nature-infrastructure interactions lie at the heart of green infrastructure concepts, where they encompass a range of meanings of physical nature and infrastructure and how they interact with each other along a spectrum (Figure 2-1). By using physical nature-infrastructure interactions as a conceptual device illuminates the range of meanings that actors attribute to physical nature and infrastructure. In addition, it also enables me to show the overlaps and capaciousness of green infrastructure concepts that can draw together a range of actors with different backgrounds, experience, and interests. By implication, physical nature-infrastructure interactions allow me to show the multiplicity of green infrastructure concepts.

Using physical nature-infrastructure as a conceptual device, I illuminate three ways that green infrastructure concepts can be complex. To start, I show tensions and overlap in the many disciplinary meanings of green infrastructure, which can represent a wide range of physical nature-infrastructure interactions (Section 2.1). I then build on this to show conflicts between representations of green infrastructure in policy, where it can support a range of interests and outcomes at any one time (Section 2.2). Finally, I show a third way that green infrastructure concepts are complex, where despite having relatively fixed disciplinary understandings and different representation in policy, they can also exhibit a degree of capaciousness, where meanings of green infrastructure can bring actors together (Section 2.3). Across these three broad avenues of complexity, I point to the many layers of ambiguity and the many complementary and contested ways they interact with one another.

2.1 Overlaps and tensions between disciplinary meanings

Green infrastructure concepts can be represented and conceptualised in a variety of ways. One way that green infrastructure can be represented different is across disciplines such as planning, landscape architecture, environmental science, engineering and finance. These disciplines have a common understanding of the green infrastructure concept, where it can support a shared objective or “environmental ethic”, which is centred on an “eagerness to improve the wellbeing of people” (Austin, 2014, p. 1). That said, despite representing a shared ethic, there can be a multitude of disciplinary meanings of green infrastructure concepts in operation at any one time, where it can create a “noisy place of multiple definitions” (Lennon, 2014, p. 439). Therefore, despite being framed as a common concept that is held across many disciplines, green infrastructure can have a range of meanings (see Table 2-1).

Multiple disciplinary meanings

Drawing out the many conceptualisations of green infrastructure reveals its multiplicity. While green infrastructure can be framed as a neat concept, with one succinct disciplinary meaning, it can support a range of approaches and understandings of physical nature-infrastructure interaction (Table 2-1). To illustrate, while the green infrastructure concept can imply a shared environmental ethic around stormwater management, it can support a range of “heterogeneous approaches” (Austin, 2014, p. 1). Each of these approaches can support different “practice types and application scales” that define different aims, starting points and modes of intervention (Austin, 2014, p. 1). Therefore, by using the green infrastructure concept in disciplinary knowledge there can be overlaps and conflicts between them.

The many disciplinary meanings of physical nature support the broader social construction of nature scholarship. Under the social construction of nature, nature is defined as being something that is constructed by actors based on its meaning, where it can be a range of different things to a variety of actors. For example, there is “no singular 'nature' as such, only [a] diversity of contested natures” that influences how the social world is comprised and constituted (Macnaghten and Urry, 1999). As each of these meanings is “constituted through a variety of socio-cultural processes” it becomes necessary to not only identify different meanings, but also their relations and how they interact (Macnaghten and Urry, 1999). To explore the multiplicity and contestation between meanings of green infrastructure, I have chosen to focus on how these different meanings manifest around a range of disciplinary backgrounds here. I feel this choice is justified as it enables me to illuminate the ambiguity around meanings of nature in theory, which influences understandings or conceptualisations in practice. The importance of which will become apparent in the section to follow, where I consider meanings of physical nature and infrastructure in policy and practice (Section 2.2 and 2.3).

Table 2-1: Disciplinary meanings of green infrastructure concepts

DISCIPLINES	EXEMPLARY DEFINITIONS	SOURCE
Planning	"Our nation's natural life support system – an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other spaces that support native species, maintain natural ecological processes, sustain air and water resources, and contribute to the health and quality of life of America's communities and people".	Benedict and McMahon, 2002, p. 2
Landscape architecture	"Green infrastructure is an emerging planning and design concept that is principally structured by a hybrid hydrological/drainage network, complementing and linking relict green areas with built infrastructure that provides ecological functions"	Ahern, 2007, p. 267
Environmental Science	"Green infrastructure can be defined as a network of green spaces planned and managed as an integrated system to provide synergistic benefits through multifunctionality"	Lovell and Taylor, 2013, p. 1452
Engineering	"Green infrastructure is usually understood as a natural and semi-natural network that is planned and maintained in order to provide multiple benefits to humans"	Black et al., 2016, p. 2
Finance	"All natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales	du Toit et al., 2018, p. 249

As I identify, there are many meanings of physical nature within disciplines that contribute knowledge on green infrastructure. My conceptualisation of 'physical nature' closely relates to references to nature part of social construction scholarship. For example, both consider a range of meanings of understandings of nature that can be held across a range of actors. That said, physical nature refers specifically to material forms of nature as a way to anchor a study on green infrastructure, where the same material outcome can be viewed and described in a variety of ways. Therefore, by focusing on the social construction of physical nature in this regard, where I focus on disciplines, enables me to focus on a variety of meanings of one form of physical nature.

The many representations of physical nature and infrastructure in disciplinary knowledge can create ambiguity. Ambiguity can arise around the many approaches followed by each of the disciplines, the different understandings of physical nature-infrastructure interactions therein, and the use of these approaches to guide strategy or to respond to material urban concerns. The many different meanings of green infrastructure can contribute to a "lack of understanding" around how the concept ought to be used (Wright, 2011, p. 1003). In water management, for example, it can result in actors going about "advancing ecologically focused […] and anthropocentric values" in different ways (Austin, 2014, p. 1). Therefore, ambiguity around the meanings of green infrastructure concepts can have implications for urban areas where they can place a slightly different focus on physical nature-infrastructure interactions.

2.1.1 Three disciplinary approaches to green infrastructure

To show the many overlaps and tensions between meanings of physical nature in disciplinary knowledge I have developed three broad disciplinary approaches to green infrastructure - *connected landscape, ecosystem services* and *engineered approaches*. The three disciplinary approaches I have identified form part of my contribution to knowledge as I have distilled these and elaborated on them to enable me to draw out the ambiguous features of green infrastructure.

By developing these three disciplinary approaches, I contribute to knowledge on meanings of green infrastructure concepts, where I use it as an analytical lens to draw together a range of disciplines where physical nature-infrastructure interactions are represented differently across planning, landscape architecture, environmental science, engineering and finance and thus highlighting overlaps and fractures in their meaning (Table 2-1). To aid the discussion, I have developed a summary table, which I have located after my descriptions (Table 2-2).

The range of meanings of green infrastructure concepts I refer to in the thesis do not necessarily represent my own, or the meanings described by the participants. While I describe which meanings I focus on in more detail in the methodology, it is important to flag the meanings used by participants in the two study sites I explore in the thesis as being primarily associated with the *engineered approach*. River renaturalisation was a green infrastructure intervention that was used to manage urban water flows. That said, as I describe in more detail in Section 5.4, different participants understood the projects differently in ways that broadly corresponded to their disciplinary knowledge, which was rooted in architecture, planning, engineering, and landscape architecture.

2.1.1.1 ***Connected landscape approach***

As a starting point, I explain the *connected landscape approach* that I have developed as a conceptual device to draw out overlaps and fractures between different meanings of physical nature and infrastructure. The *connected landscape approach* comes from the disciplines of planning and landscape architecture. Both disciplines conceptualise green infrastructure as a “strategic approach” for supporting urban development (Benedict and McMahon, 2002, p. 12). To reduce the negative impacts of growth and development on human and physical nature, the approach encourages “economic, environmental and socially-equitable sustainability” through linking and connecting physical nature (Ahern, 2007, p. 267). Consequently, physical nature is conceptualised as an important feature in urban areas, where it offers value for reducing the negative impacts of urban development.

Curbing the negative impacts of urban development

The *connected landscape approach* focuses on balancing the negative impacts of development on humans and physical nature. Development is conceptualised as contributing to the decline of physical nature in urban areas, where green space and other features of physical nature such as trees and plants have been removed or replaced by housing and other infrastructure services. The decline of existing elements of physical nature is believed to create “problems associated with climate change, economic under-development and social inequality” (Evans et al., 2016, p. 1). Toward finding solutions to urban concerns, the approach is to pursue “alternative ways to organise, plan, manage, and live in cities” in a way that is “in harmony” with physical nature (Evans et al., 2016, p. 1; Hirt, 2011, p. 145). Therefore, the *connected landscape approach* aims to bring ‘balance’ back into the city, where development takes place alongside physical nature.

The approach tends to resonate with planners and landscape architects who typically search for alternative ways for planning, designing and managing the city in more inclusive ways. In many cases, the *connected landscape approach* takes a strategic focus on green space management, where existing parks and open space can be modified or extended to enhance their connectivity. For example, the *connected landscape approach* guides the planning of open or green space “in concert with land development”, where “growth management and built infrastructure planning” are planned to support the benefits and values of physical nature (Benedict and McMahon, 2002, p. 12). The implications of this are that the *connected landscape approach* is intended to curtail the “ecological and social impacts” on humans (Benedict and McMahon, 2002, p. 12). Consequently, a *connected landscape approach* focuses on including physical nature in the development of urban areas by shaping decision-making processes.

Physical nature as an ever-present feature of the city

Planning and landscape architecture have always encouraged the use of physical nature as part of the development to create liveable spaces. For example, early accounts of pioneers in the planning and landscape architecture field, such as Olmstead, encouraged the inclusion of physical nature as a “central feature” of urban development (Olmstead, 1970, p. 184). Olmstead supported the use of physical nature in the form of trees and parks to create a “play of surface and […] a variety of light and shade” (Olmstead, 1970, p. 184). Therefore, physical nature has been a part of early planning and landscape architecture, where it has supported aesthetic and functional values.

Howard, another pioneer of planning and landscape architecture also encouraged the use of physical nature in his model of urban development.

Physical nature in the city was intended to support a “perfect combination” of city and country in urban areas through the provision of designated green spaces (Howard, 1902, p. 15). By implication, physical nature was intended to support development through being the “the source of life, of happiness, of wealth, and of power” (Howard, 1902, p. 15). Physical nature was considered to have implicit benefits for urban areas, where these benefits are not necessarily tangible or measurable.

Taking a strategic approach to planning infrastructure in the *connected landscape approach* situates prospecting as a key activity. Using existing physical nature to support development requires that the “’potential’ for ecological spaces within the city” are located and then utilised as a starting point in planning and decision-making processes (Ignatieva et al., 2011, p. 22). Green space is one example as an area of potential future value, where existing parks and waterways are prioritised in planning processes. For example:

> Remnants of the original natural vegetation are always prioritised in this networking as a unique source of native biodiversity and local identity.
>
> (Ignatieva et al., 2011, p. 22)

Investing in existing green spaces is also one way to support the identity of an area, where green infrastructure can encourage the use of native forms of physical nature, such as plants or trees, and particular activities that may be attached to them such as local medicinal practices, religious events or conservation practices.

Reflecting on the *connected landscape approach* and its focus on physical nature, it is important to draw out one key feature of the kinds of physical nature supported by the approach. The approach includes a focus on a wide range of physical nature, whether it is native to a particular area or not. For example, "urban woodlands, public parks and gardens, golf courses, cemeteries, waterways, wetlands, […] continue to be a focus" (Ignatieva et al., 2011, p. 22). In the sub-section below, I demonstrate the wide range of understandings of physical nature. The many understandings of physical nature illustrate the fracture points between the *connected landscape approach* and *ecosystem services approach*, the latter which tends to focus more on the services provided by 'native types' of physical nature.

Spatial connections

Following the strategic focus on planning for physical nature and infrastructure, the *connected landscape approach* draws on a range of spatial and visual methods for supporting the use of green infrastructure in policy and practice. For example, to "spatially organis[e] urban environments to support a suite of ecological and cultural functions" where physical nature plays an integral role for achieving this vision at a broad scale (Ahern, 2007, p. 267). A central component is on the creation of maps and other kinds of spatial representations of physical nature such as the modelling of corridors and habitats[10] to allow planners and landscape architects to work toward "complementing and linking green areas with

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[10] Common methods include node and corridor models that calculate the spread of physical nature. Models are used to determine where resources should be allocated to enhance the connectivity of existing occurrences of physical nature. One such example of a corridor model is outlined by Zhang et al., (2019).

built infrastructure that provides ecological functions" (Ahern, 2007, p. 267). Therefore, representations of green infrastructure under the *connected landscape approach* tend to take written or visual forms and are used at broad or general planning scales.

2.1.1.2 ***Ecosystem services approach***

The *ecosystem services approach* I have developed draws on more specific representations of physical nature when compared with the *connected landscape approach*. Representing physical nature in this way aligns with the ecosystem services concept which tends to be drawn on by environmental scientists, ecologists and hydrologists. Ecosystem goods and services are "benefits human populations derive, directly or indirectly" from physical nature (Costanza et al., 1997, p. 253). The benefits provided by ecosystems are two-fold namely, "ecosystem goods (such as food) and services (such as waste assimilation)" (Costanza et al., 1997, p. 253). Consequently, the *ecosystem services approach* focuses on physical nature and the services, or benefits they can provide in urban settings.

Addressing urban development as an exploitative process

In a similar way to the *connected landscape approach*, the *ecosystem services approach* conceptualises urban development as being inherently unsustainable due to its exploitative approach to the environment. I already presented how the *connected landscape approach* focuses on finding solutions to urban concerns "spatially complement[ing] grey infrastructure" (Cameron and Blanuša, 2016, p. 377). The *ecosystem services approach*, however, focuses more on physical nature to “counterbalance some of the negative effects associated with grey infrastructure” rather than using it as part of a wider, or general, approach to balance physical nature and infrastructure in the development of cities (Cameron and Blanuša, 2016, p. 377). Unlike the *connected landscape approach* that is used to encourage more balanced urban planning, the *ecosystem service approach* is often used to “justify” the preservation or inclusion of specific of kinds of physical nature to fulfil particular service-based functions on programmes or projects (Cameron and Blanuša, 2016, p. 389). Therefore, a key difference between the *connected landscape* and *ecosystem services approaches* is its specificity around what kinds of physical nature it supports.

Native or non-native?

Environmental science disciplines often support the conservation or preservation of biodiversity by using specific kinds of physical nature. Under the *ecosystem services approach*, specific plant species tend to be used to respond to localised needs for enhancing biodiversity. In particular, it focuses on “genotypes”, or specific types of physical nature, where they can be “placed strategically at different locations” to provide an ecosystem good or service (Cameron and Blanuša, 2016, p. 378). One feature of the *ecosystem services approach* is that it can be so specific in that it draws on certain plants to the level at which it is nature or non-native. The focus on particular kinds of plant species to provide specific goods and services is unlike the *connected landscape approach*, which often uses physical nature as a general category to provide public amenity or aesthetic values on a project.

While focusing on native and non-native species is a feature of the *ecosystem services approach*, it can create contestation among environmental professionals. To elaborate further, environmental scientists, such as botanists, who support the conservation or preservation of native habitats may argue the "merits/risks" of introducing other non-native physical nature under a green infrastructure approach may be detrimental to green space management (Cameron and Blanuša, 2016, p. 378). On the one hand, botanists and environmental scientists consider non-native species of plants and trees to have a "potential future threat" to the native systems, where it can have "negative impacts" for how they function over time (Shackelford et al., 2013, p. 56). On the other, there is also a "desirability" for "non-native species in systems to promote their active use in conservation and restoration planning" among other environmental professions such as geographers or environmental scientists (Shackelford et al., 2013, p. 56). Hence, tensions can arise around whether it is beneficial to introduce native or non-native species in certain areas.

Measured benefits

To motivate for the use of physical nature alongside infrastructure, the *ecosystem services approach* focuses on measuring the benefits of physical nature using scientific evidence. The "spatial-temporal structural characteristics" of physical nature is measured such as their "type, time, structure, and configuration" (Wang et al., 2018, p. 140). Examples of spatial-temporal structural characteristics can include "water surface ratio, density and configuration of river networks" or the "green space ratio and connectivity" (Wang et al., 2018, p. 140). Consequently, the need to measure the benefits of ecosystem good and services drives the need for technical or measured values to create the impetus for green infrastructure.

Another way of demonstrating the value of physical nature is through indirect methods, including financial valuation. To measure the financial value of physical nature it tends to be conceptualised as “natural capital stocks” that are “critical to the functioning of the Earth's life-support system” (Costanza et al., 1997, p. 253). To calculate the financial value of green infrastructure, environmental economists tend to work with environmental scientists to demonstrate ‘asset values’ to “represent” their benefits to inform decision-making[11] (Costanza et al., 1997, p. 253). Therefore, under the *ecosystem services approach*, physical nature can be measured and represented as a numerical figure or monetary value.

A criticism of the *ecosystem services approach* is that not all benefits that can be derived from physical nature can be measured by a single measure or scientific unit. This argument is held across sociologists and environmental disciplines that draw on urban political ecology. For example, the “move” from physical nature to financial “capital” allows for “different forms of capital - human, financial, natural – to be made equivalent and exchanged” (Büscher and Fletcher, 2016, p. n/p). Reducing physical nature to one unit such as financial value removes emphasis on the “complex, qualitative [and] heterogeneous” features of physical nature as

[11] A range of academics across environmental and financial backgrounds carried out The Millennium Ecosystem Assessments project between 2001 and 2005. The project calculated the estimated financial value of all global ecosystems.

I have demonstrated in the chapter (Büscher and Fletcher, 2016, p. n/p). Therefore, while measuring of valuing physical nature in scientific or numerical terms is believed to support decision-making, where it can enable comparison between types of infrastructure, it serves to reduce the many meanings of the physical nature and other benefits it can provide under the connected landscapes approach.

2.1.1.3 ***Engineered approach***

Finally, I explain the *engineered approach* I have developed as the third disciplinary approach I use to highlight overlaps and points of deviation between different definitions of physical nature-infrastructure interactions. The *engineered approach* tends to be followed by engineering disciplines such as environmental or hydrological engineers to design site-level solutions to urban concerns. The main focus of the approach is the provision of infrastructure to protect humans such as protecting "human settlements against floods" (Wlodarczyk and Mascarenhas, 2016, p. 690). While protecting humans using constructed infrastructure is something that you might expect under an *engineered approach*, it is also supported by an emphasis on included physical nature in the form of "fauna and flora" to manage rivers as a "connected" part of the city (Wlodarczyk and Mascarenhas, 2016, p. 690). Physical nature under the *engineered approach*, therefore, focuses on constructed or hybrid physical nature-infrastructure interventions that can support service functions.

Supporting functional values for urban development

An *engineered approach* aims to include physical nature into the design of urban infrastructure solutions. While physical nature has always been a constituent part of infrastructure projects through providing the context, setting or resources that need to be managed, it has not always been actively included in the design of urban solutions to utilise its functional and material values. In other words, the approach encourages what engineers understand to be “working with nature” instead of “solving our problems at nature’s expense” (Sarte, 2010, p. 1). Utilising physical nature to “address problems” is intended to “come-back to nature” to “produce better places for people, all leading to beneficial environmental outcomes” (Black et al., 2016, p. 1; Wlodarczyk and Mascarenhas, 2016, p. 690). Accordingly, the *engineered approach* aims to include physical nature as a replacement or enhancement to existing infrastructure.

To design solutions to manage infrastructure, such as urban water flows, the benefits of physical nature are understood through their functions and material characteristics. For example, a tree can provide functional services at the site-level by anchoring the soil beside a river. Likewise, a constructed wetland can provide services to filter or reduce the level of pollution in water. When compared alongside constructed infrastructure such as pipes, roads or electricity lines, these elements of physical nature can provide similar services to the constructed elements of projects such as gabions or water treatment plants. For this reason, the benefits of physical nature are compared alongside the functions of infrastructure.

Physical properties of physical nature and infrastructure

Another way the *engineered approach* understands physical nature is according to its material characteristics. The material characteristics of physical nature refer to its properties such as composition, texture, rigidity and colour. The characteristics enable engineers to select which kinds of physical nature to use to design solutions to urban problems. For example, physical nature such as water, sediment and aquatic plants are “categorised [and used] according to the various design parameters” and are used alongside other constructed or synthetic materials, such as concrete and asphalt (Vymazal, 2008, p. 725). The use of physical nature is measured in similar ways to constructed materials, where its use is based on how it exists or ‘performs’ under certain conditions such as flooding, rain or heat (Vymazal, 2008, p. 725). As a consequence, the specific functions of physical nature are drawn on to respond to functional needs.

Including physical nature in urban design solutions can raise concerns within engineering practice given limited disciplinary knowledge and rules to follow for including it in policy and practice. Traditionally, engineering disciplines have tended to focus on infrastructure more than physical nature. As such, bodies of knowledge and rules have tended to focus on designing infrastructure. For example, to manage urban water resources, engineers would typically use synthetic materials such as concrete, bricks, steel, or plastic sheeting instead of physical nature such as grass, soil, and trees to convey water flows according to fixed standards and guidelines. Therefore, due to the reliance on guidelines and studies and the relatively recent use of physical nature as part of an engineered green infrastructure approach, the body of knowledge on the use of physical nature is still largely being developed as a disciplinary approach.

Building an evidence-base

Compared to the ecosystem service approach, the *engineered approach* relies on evidence derived from existing studies, guidelines, and rules to support the use of physical nature. This means, instead of searching out opportunities to measure or quantify physical nature to include it in infrastructural projects, there is a tendency to rely on and work with, existing guidelines, standards, and best practice examples. As I hinted above, relying on existing rules can create challenges for the use of physical nature in practice, as there is a need to justify or innovate to use the *engineered approach* with associate challenges and perceived risks. Therefore, engineering knowledge supports the use of physical nature required through technical studies that show its functional value.

In summary, while the green infrastructure concept may seem relatively straightforward, I have shown it can have a range of physical nature-infrastructure interactions. While all meanings of green infrastructure have a shared environmental ethic, or general thrust toward creating more sustainable urban areas, different disciplinary approaches present a range of understandings of physical nature-infrastructure interactions. That said, according to these understandings, the green infrastructure concept can support development in different ways, where it can encourage the development of land and connectivity (*connected landscape approach*), enhancing ecological services (*ecosystem *services approach*) or support functional service-based values (*engineered approach*). Therefore, despite often being referred to as one concept, green infrastructure can have multiple disciplinary understandings, and these understanding can influence its use in policy and practice.

Table 2-2: Overview disciplinary approaches to green infrastructure (adapted from Szulczewska et al., 2017; Mell, 2015b; Ely and Pitman, 2014)

APPROACH	DISCIPLINES	DESCRIPTION	USE	SCALE	EXEMPLARY SCHOLARS
Connected landscapes	Planning, architecture, urban design and landscape architecture	Preserves and enhances green features such as green spaces and their links. This is typically through the creation of regional greenways, green corridors or other forms of enhancing national or regional connectivity such as the development of reserves or brownfield sites.	Landscape connectivity, urban development, nature conservation and biodiversity.	National, regional or city scale	Hostetler et al., 2011; Ignatieva et al., 2011; Benedict and McMahon, 2002, 2006
Ecosystem services	Environmental scientists, ecologists, hydrologists	Promotes the ecosystem services concept where environmental services and physical nature are enhanced and used for the benefits it can provide to society. This includes the city and site-level interventions where the physical environment is included or enhanced. This can include tree planting, the provision of parks or the planting of specific plant species to provide services.	Climate change adaptation and mitigation, sustainability and resilience; quality of life and human wellbeing.	Regional or city level	Costanza et al., 1997; Lovell and Taylor, 2013; Wang et al., 2018

Engineered	Environmental and hydrological engineers	Encourages niche engineered solutions to support and enhance the provision of infrastructure services. This includes city level or site-specific engineered solutions such as green walls or roofs for purifying the air and reducing heat island effects. A sub-category is the hydrological or urban water management approach supporting sustainable water management practices. Used most widely in urban settings it can include the renaturalisation of urban streams to manage stormwater or constructed wetlands for purifying water in areas where there is sewerage overflow.	Infrastructure provision; climate change mitigation and adaptation; sustainability and resilience; and urban water management.	City or project level	Margolis and Robinson, 2007; Kinesis, 2012; Black et al., 2016 Pyke et al., 2011; Dietz, 2007

2.2 Conflicting representations in policy

I have drawn attention to the various overlaps and tensions between disciplinary understandings of green infrastructure concepts, where physical nature-infrastructure interactions can be understood in different ways. I now consider how disciplinary approaches are configured in policy. While only one meaning of green infrastructure tends to be used in policy at any one time, different meanings can be used across policy scales and applications. Using a variety of representation of physical nature-infrastructure interactions in policy documents can create conflict in policy, where the green infrastructure concept can represent different avenues for supporting urban development. Responding to development through a range of fractured activities has implications for how resources are used.

Before I continue, I define what I mean by ‘policy’. I define policy as the ways green infrastructure concepts can be spoken or written about in disciplinary knowledge and how they are drawn on to develop a strategic vision. Dialogue and rules such as legislation, guidelines or administrative processes form two ways green infrastructure concepts can be spoken and written about. In most cases, there is a link between the two, where disciplinary knowledge is used to inform strategic planning through written accounts such as scientific papers or academic reports or dialogue such as seminars, conferences or workshops. Therefore, actors that tend to draw on green infrastructure concepts are academics and researchers, but also actors that straddle these two worlds such as policy researchers and professionals (such as planners) and government officials.

Policy plays a role in creating a strategic vision that is intended to support a collective approach to urban management. Toward creating a collective vision, policy tends to use one meaning of physical nature-infrastructure interactions that are intended to reduce uncertainty and guide a range of actors in policy and practice. To develop policy as a collective strategy or vison, actors with “diverse interests in green space” come together to devise a collective meaning that is used across legislation, guidelines and administrative rules (Horwood, 2020, p. 14). While a policy can imply a “shared conceptualisation of green infrastructure” according to its representation and use, in reality, this may not always be the case due to the range of understandings of physical nature-infrastructure interactions (Horwood, 2020, p. 14). Therefore, while policy can represent green infrastructure as one simple concept, policy meanings of green infrastructure concepts can be ambiguous.

The ambiguous meanings of green infrastructure in policy can create conflict or tension, where it serves to fragment resources and efforts toward achieving sustainable development. Having a range of meanings in use at any one time can confuse efforts to influence urban development such as the allocation of resources across different scalar jurisdictions. For example, green infrastructure can be represented in different ways across national, regional and city level policy, where meanings of physical nature-infrastructure interactions are understood in different ways, which may encourage resources being spent on a range of different types of physical nature such as trees, brownfield developments, or constructed forms of green infrastructure such as wetlands. Each of these kinds of physical nature requires inputs and funds from different departments (environment and/or infrastructure-related) and inputs from different professionals (planners, landscape architects and engineers). By implication, efforts to use green infrastructure concepts can be fragmented and ineffectual toward supporting sustainable urban development. This can even serve counter to the intended policy outcomes.

2.2.1 Tensions between scalar approaches

The first way green infrastructure concepts can be represented differently across policy is according to its scale. The disciplinary approaches I illuminated above, tend to lend themselves one or more policy scales given their understanding of physical nature-infrastructure interactions. Consequently, more than one approach can be drawn on between national, regional, city and project scales at any one time. By implication, having different meanings across different scales means there can be conflict around the overall strategy and allocation of resources toward achieving sustainable development. In this section, I explore how more than one understanding of physical nature-infrastructure interactions, including its implications for studying the use of green infrastructure concepts.

Different representations at varying scales

The disciplinary approaches I presented lend themselves to different policy scales. To start, I have demonstrated the *connected landscape approach* as supporting physical nature through spatial and visual means. To support the use of physical nature in urban planning, the *connected landscape approach* tends to use spatial analyses and visualisation methods to manage existing green or open space at a national, regional or city scale (Table 2-3). Given the focus on supporting connectivity between features of physical nature, the approach tends to begin by appraising existing physical nature, before identifying the links where physical nature can be strengthened or broadened under a shared strategic vision. Therefore, the *connected landscape approach* is used in policy, where it plays a role in broad-level planning, by enhancing the links between green or open spaces form the first step to using green infrastructure.

Table 2-3: Scale and focus of the three green infrastructure approaches

SCALE	CONNECTED LANDSCAPE	ECOSYSTEM SERVICES	ENGINEERED
National	*X*		
Regional	*X*	*X*	
City	*X*	*X*	*X*
Project			*X*

Despite having a strong focus on spatial representations of physical natures, the *connected landscape approach* in many cases lacks specificity in the policy. In other words, while it can be used to support the development of physical nature in the city, it lacks detail around exactly how it ought to be done. Identifying the benefits of physical nature at a broad spatial scale is “limited” by its approach to physical nature that is too broad to be used at finer scales due to a lack of technical or scientific information (Cameron and Blanuša, 2016, p. 377). As a result, the *connected landscape approach* tends to be “too generic” to be used wholly at finer scales such as the city and site-levels (Cameron and Blanuša, 2016, p. 377). Consequently, given its focus on the technical and/or scientific elements of green infrastructure concepts, other expertise is often required to support the use of the *connected landscape approach* in practice.

The *ecosystem services approach* enables a more focused application of the *connected landscape approach*, where it can specify exactly how physical nature can be enhanced by qualifying its value for managing urban water. The *ecosystem services approach* tends to be used in regional and or city level policy based on its focus to incentivise the use of green infrastructure concepts using tangible values (Table 2-3). For example, the *ecosystem services approach* supports an overall policy approach to green infrastructure by encouraging the scientific or financial quantification of green infrastructure to “accentuate” their service-based benefits (Cameron and Blanuša, 2016, p. 378). Quantifying the benefits of green infrastructure requires specificity that can be achieved at finer scales that can detail the “relative values or benefits” of ecosystem services

(Cameron and Blanuša, 2016, p. 377). Therefore, used together with the *connected landscape approach*, it can provide focus through a more detailed or narrowed framing of physical nature, where it can be used according to their service-based values.

In a similar way to the *ecosystem services approach*, the *engineered approach* also provides specificity at finer scales due to its technical focus. The *engineered approach* tends to be used at the city or project level (Table 2-3). I demonstrated the *engineered approach* supports the design of specific plans or 'how-to' guidelines to support the use of green infrastructure concepts in practice (Section 2.1). In other words, the *engineered approach* can provide the "practical guidelines" for incorporating physical nature into urban development where it is prescriptive around the kinds of settings and contexts within which it can be used (Black et al., 2016, p. 1). The practical guidelines, then form an "important tool" that can assist with "urban planning and design" (Black et al., 2016, p. 1). Therefore, amid the many overlaps and tensions between representations of physical nature, disciplinary approaches can lend themselves to working at different scales, where it becomes necessary to consider its implications.

Overlaps at the city scale

Before I move on to focus on the implications of different representations of physical nature-infrastructure at policy scales, it is important to draw attention to overlaps between all three of these approaches at the city scale. The *connected landscape*, *ecosystem services* and *engineered approaches* can all be used at the city scale as part of a range of strategic approaches for influencing urban development, where one or more representations of physical nature-infrastructure interactions can be in operation at any one time (Table 2-3). I have chosen to flag the overlap at the city scale here, as it will form the basis for the section to follow, where I describe how influential actors can influence the use of different disciplinary approaches at the city scale (Section 2.2.2). I return to the implications of drawing on one or more disciplinary approaches at different levels in Section 2.2.

Cascading representations

One way that different meanings of green infrastructure are represented at the city scale is through the ‘cascading effect’. The “cascading effect” describes the process through which the priorities and aims for using the concept become more clear and focused at finer scales (Mell, 2015a, p. 119). For example, at each policy level, meanings of green infrastructure can become “influenced by advocates and stakeholders” at that level according to specific needs (Mell, 2015a, p. 119). The finer the scale, the more ‘local’ narrative becomes, where it is easier to refine and pinpoint the exact focus on a particular policy setting or geographic context (Mell, 2015a, p. 119). Therefore, fracture points can exist within policy settings at the city scale, where actors and the local context serve to influence the meaning of green infrastructure concepts policy.

While green infrastructure concepts can be represented across a range of policy scales, they are often drawn on by more than one actor at the city scale.

Representations of green infrastructure at broad policy scales such as the national and regional scales can be adapted and refined to include a particular focus at increasingly finer scales. For example, should a *connected landscape approach* be used at the national and regional scale, a government official in an environmental department may choose to focus on biodiversity preservation as a key city level focus and develop a local by-law to support it. A researcher may conceptualise that urban stormwater management is a key area for intervention at a city level and may work within existing national and regional policy to support a *connected landscape approach,* which allows for a more targeted approach to manage existing parks and green space.

By implication, while each of these cascading meanings of green infrastructure is valid, they serve to create a range of divided representations of green infrastructure concepts at the city scale, where they are interpreted differently according to the actor's disciplinary background and/or physical nature-infrastructure interactions and the context. While the cascading effect enables me to describe the process through which different approaches are used at increasingly finer scales, it does not focus on how the different approaches to green infrastructure stack up. In other words, theories around the 'cascading effect' have not gone a step further to reflect on how a range of conflicting representations of physical nature-infrastructure interactions can be used in policy at the city scale. While it is relatively straightforward to conceptualise how green infrastructure concepts can gain meaning as it filters down to increasingly finer scales according to a particular policy setting, it becomes more complex to study how these meanings are drawn on in practice.

Narrowing the scope

I have shown how different disciplinary approaches lend themselves to a range of policy scales and how the cascading effect can lead to a range of representations of green infrastructure concepts at the city scale. I now focus on the implications of the cascading effect, where it can illuminate or omit certain aspects of physical nature-infrastructure interactions at increasingly finer scales. For example, by following an *engineered approach* at the city scale, the broader scope and focus associated with the *connected landscape approach* often used at the regional scale can be lost. Therefore, although still being framed as 'green infrastructure', representations can imply or omit aspects of broader or more general understandings of physical nature-infrastructure interactions that may be mutually exclusive.

The many representations of physical nature-infrastructure interactions across different policy scales can also create a range of narratives on green infrastructure. Policy actors can draw these different representations in a range of ways to respond to opportunities and challenges in their daily work. The many narratives around the "development of green infrastructure policy" can create "complexity", where it can represent such a broad range of narrative on green infrastructure that it can become difficult to navigate (Mell, 2014, p. 612). For example, the use of green infrastructure concepts in policy from a national to city scale can include narratives around managing water, conserving biodiversity and improving quality of life simultaneously (Mell, 2014, p. 612). The implication of having such a broad range of narratives at different policy scales means that representations of green infrastructure concepts at one level may not resemble it at another.

To follow on from my example above, I reveal where gaps can occur between the use of green infrastructure concepts at different scales. To start, a *connected landscape approach* does not emphasise whether or not native or non-native plants exist on a piece of land, while under an *ecosystem services approach* this may form a significant feature. For example, if a vacant piece of land is seen as green infrastructure at the national or regional scale *(connected landscape approach*), the same piece of land may not be deemed to be valuable under an *ecosystem services approach*, where the fact that it has native plant species may be the sole purpose of the project from the outset. Consequently, the use of multiple green infrastructure narratives across policy settings can lead to conflicts and gaps where they can support diverging representations of physical nature-infrastructure interactions according to their meaning.

Second, conflicts can also arise between different representations of green infrastructure across different policy scales. Working with my descriptions of the three disciplinary approaches I refer to above, it is commonplace for national and regional policy to draw on a *connected landscape approach*, city scale policy to draw on an *ecosystem services approach* and an *engineered approach* to be drawn on at the local scale. Depending on which approach comes before the other, the filtering down of representations of physical nature-infrastructure interactions can be lost. For example, by focusing on engineering rules and guidelines at a finer scale tends to detract from “understanding the balance and interlinking” characteristics of physical nature as defined under the landscape connectivity approach (Cameron and Blanuša, 2016, p. 377). The implications of focusing on function rather than the “interlinking” physical nature is that the overall strategic approach to green infrastructure can become confused. Instead of scoping possibilities for connecting existing physical nature, the focus is rather on responding to specific service-based needs. Therefore, the wider and more general aesthetic and quality of life benefits can be lost through the cascading effect.

Similarly, an *engineered approach* can also place less attention on the ecosystem services elements of physical nature. The *ecosystem services approach* encourages the development of existing and new services provided by nature, where they are developed within a particular setting according to specific native or non-native plants and trees. Under the *engineered approach*, the focus is about providing functions however they are ‘best’ provided. In this approach, the role of specific “plant communities”, supported by an *ecosystem services approach*, can be lost (Cameron and Blanuša, 2016, p. 377). Therefore, the use of the *engineered approach* alongside the *ecosystem services approach* can create conflicting narratives at different policy scales around which detail ought to be focused on to support a green infrastructure approach.

The implications of having a range of policy narratives that illuminate physical nature-infrastructure interactions in different ways is that can serve to divide interests and resources at each of the policy scales. As such, the intended, shared outcomes of green infrastructure concepts at each of the policy scales are not met. It also creates conflict between actors that are part of policy dialogue, where despite talking about green infrastructure as a common idea, they can all have vastly different understandings of green infrastructure, where they can work in different ways to use it in practice. Subsequently, it becomes necessary to consider how green infrastructure is conceptualised in light of its setting and context.

2.2.2 Whose meanings in policy?

I demonstrated green infrastructure concepts can be represented in different ways across policy scales, where they can have gaps or conflicting representations of physical nature-infrastructure interactions across scales. While this points to the complexity of green infrastructure concepts, where their multiplicity can create ambiguity around how green infrastructure concepts are understood and used in policy, it does include a focus on how particular representations of physical nature-infrastructure interactions are distilled across individual policy documents such as plans, guidelines and legislation at each of the levels. To consider whose understandings of green infrastructure concepts are used in policy and are significant, I consider how specific interpretations of physical nature-infrastructure interactions are used.

Plans, guidelines, and legislation that refer to green infrastructure tend to represent one dominant interpretation of physical nature-infrastructure interactions. Having only one representation of physical nature-infrastructure interactions tends to be favoured by policymakers as it can reduce uncertainty by orientating a range of actors toward a common policy goal or outcome. For example, distilling a core vision in infrastructure management guides a set of steps toward a collective goal across a range of government and non-government actors such as the private sector and members of civil society. Policy, such as guidelines, can also set out the steps and technical details for using green infrastructure concepts in practice to reduce uncertainty around how concepts are used. By implication, the specific interpretations of physical nature-infrastructure interactions in policy can influence how green infrastructure concepts are conceptualised.

To develop policy, a variety of actors are drawn together to develop which representations of physical nature-infrastructure interactions are used in policy. While the intention is to include inputs from a range of policy actors, in many cases, not all of the voices are translated into the final strategy document. For example, while distilling the “idea” of green infrastructure can imply a degree of “shared territory” has been reached (Wright, 2011, p. 1010), in reality, “interests compete for the dominance” and certain interpretations of physical nature-infrastructure interactions are then used rather than others (Wright, 2011, p. 1010). By implication, it becomes necessary to consider whose interpretations of physical nature-infrastructure interactions are represented in policy and which influential actors are involved as they can influence urban development.

Influential actors

Infrastructure is shaped by influential actors. While on the one hand infrastructure can be considered to be apolitical in administrative structures and policy, it is becoming increasingly necessary to consider the politics associated with infrastructure and why it is important for understanding the city. I have outlined the many meanings of green infrastructure in policy and how one dominant meaning can be incorporated into policy at a variety of scales that can lie in conflict with each other. While identifying the political aspects of infrastructure forms an important feature of understanding how concepts such as green infrastructure influence and how the city develops, it is necessary to consider the broader implications of its politics.

I mentioned at the start of the chapter, green infrastructure is viewed as a common term that can enable different actors to come together under a common objective to support the sustainable development of urban areas (Section 2.1). That said, the implications of actors activities tends not to be considered as part of the mainstream literature on green infrastructure. For example, while planners, engineers and architects aim to “integrate” urban space, where they “re-configure” the city in “specialised, privatised and customised” ways, they can connect and develop part of the city and “bypass others” (Luque-Ayala and Silver, 2016, p. 5). The “spatio-political dynamics” of the city influences “relations of control”, where it can serve to create and/or perpetuate inequalities”(Luque-Ayala and Silver, 2016, p. 4). Therefore, understanding how the city is shaped by actors as a process of control over urban space signals the need to consider who and how actors shape urban infrastructure and the city as a whole.

Much like infrastructure, green infrastructure can be viewed as being a mediating feature of social life. Infrastructure, albeit an apolitical construct in policy texts, shapes and is shaped by politics. For example, infrastructure such as electricity networks have been identified to play an integral part in “shaping” the “city’s spatial, social and political landscapes (Luque-Ayala and Silver, 2016, p. 1). By focusing on infrastructure one can “open up” political debates that underpin its development in the city, where it can “foreground [its] contested nature”, where green infrastructure can “mediate urban life whilst also opening up new possibilities” for exploring “urban autonomy” (Luque-Ayala and Silver, 2016, p. 3). By implication, follow on one meaning of green infrastructure can have implications for how it mediates social life and supports autonomy.

Distilling only one interpretation of physical nature-infrastructure interactions in policy documents can not only create contestation, but also shape the city in spatial, social, and political ways. Depending on whose meaning is followed it can play an integral role in where and how infrastructure development takes place. For example, much like infrastructure, green infrastructure can be “socially constructed by various interest group” that influence it through “an array of tensions, tactics and complexities” (Luque-Ayala and Silver, 2016, p. 5). The tensions, tactics and complexities have a much larger influence on how infrastructure is developed, where it can be "more problematic for (justice and equitable) infrastructure provision than technical issues" (Luque-Ayala and Silver, 2016, p. 5). Therefore, focusing on whose meaning shapes and influences the tensions, tactics and complexities form a noteworthy feature of exploring infrastructure, and green infrastructure, as a socio-political process.

Influential actors can influence how green infrastructure concepts are used in the city, including how development takes place. For example, in instances where green infrastructure has "not yet [been] explicitly 'defined'" as being part of a particular disciplinary approach, or having "different interests attach different environmental, social and economic meanings to it" the concept can become "corrupted" (Wright, 2011, p. 1004). Green infrastructure concepts can become corrupted where actors "compete for the dominance of […] the concept", where they put forward their understandings of physical nature-infrastructure interactions to achieve a personal or professional interest (Wright, 2011, p. 1010). As a consequence, green infrastructure concepts are not used in a vacuum and they are inherently political.

The politics associated with whose interests are met by policy visions that draw on green infrastructure is rooted in policy development and its application in practice. Certain interpretations of physical nature-infrastructure interactions can strengthen existing practices or activities around urban management or support the inclusion of certain types of actors over others. Dominant narratives already have meanings of physical nature-infrastructure interactions. For example, in a study by Finewood in Pittsburgh, the United States of America, it was found that meanings of physical nature resonated with existing rules that supported the use of “grey epistemologies” or *engineered approach* (Finewood, 2016, p. 1014). Grey epistemologies were supported by disciplines such as “hydrology, engineering, and planning” disciplines, where actors that were likely to “reform their language and practice to be commensurate with grey epistemologies are most likely to move their agenda forward” (Finewood, 2016, p. 1014). Therefore, dominant meanings of physical nature-infrastructure interactions in policy remain, where existing rules can draw on similar meanings of green infrastructure concepts, leaving the others behind.

Following an *engineered approach*, the policy development process in Pittsburgh acted to silence the other representations and understandings of physical nature. In other words, the engineered green infrastructure “veiled” the representations of physical nature under the other two disciplinary approaches (Finewood, 2016, p. 1016). Existing rules supported by an *engineered approach* contributed to green infrastructure as being the “same old process in new clothes” that did not bring about all the benefits of the green infrastructure approach as it was intended (Finewood, 2016, p. 1014). In this way, existing rules and policy settings can serve to legitimise disciplines and certain city level actors.

As explained in the introduction, while a focus on the urban political ecology of green infrastructure as urban governance forms a compelling study of actors and their influence over infrastructure development, the outcomes or findings often illuminate or highlight power and tend not to frame how it influences urban development going forward. In other words, while it highlights influential actors, power relations and decision-making processes, it tends not to include a reflexive lens for exploring the implications of influential actors going forward. As I explain in the conceptual framework (Chapter 3), I have chosen to explore these latter considerations in more detail, where I include a focus on the process and implications of actors on physical nature and infrastructure as a whole.

Limits to the promise of green infrastructure

Existing policy settings have already established groups of actors across a range of levels and ways of going about policy development, including rules such as guidelines. The use of approaches according to existing rules such as legislation and guidelines can draw on the interests and expertise of certain kinds of disciplines or actors. For instance, it is questionable as to whether meanings of green infrastructure concepts are used to “alter the objectives of economic development, or whether economic objectives remain unchanged under the label of green infrastructure” (Wright, 2011). Green infrastructure concepts can, therefore “permit political agendas” over others (Wright, 2011, p. 1004). Thus, used in settings where there is an established policy context, approaches can be drawn on to support existing rules that can legitimise or strengthen the influence of certain actors or disciplines.

In summary, the many disciplinary representations of physical nature-infrastructure interactions can be drawn on at different policy scales to support the green infrastructure concept. While I have outlined the disciplinary meanings of green infrastructure lend themselves to certain levels of policy, such as the national, regional, city and policy-level, the use of one dominant understanding of physical nature-infrastructure interactions can result in a contested concept. As representations are not used in a vacuum, the way they represent physical nature-infrastructure interactions has implications for how green infrastructure concepts are used by actors in policy and practice and who benefits from them. By implication, by understanding how green infrastructure concepts are conceptualised requires a focus on not only the context and setting, but also whose interpretations of physical nature-infrastructure interactions dominate.

2.3 Capacious meanings in practice

I have shown complexity around the many meanings of green infrastructure in disciplinary knowledge and policy, where there can be more than one understanding of physical nature in operation in any one time. I have also demonstrated how the use of green infrastructure concepts in policy and practice can create contestation around the coordination of a strategic vision, where despite drawing on one dominant approach in policy, there can be multiple conflicting meanings held among them at any one time. I focus on one further layer of complexity, where despite having a range of individual meanings of physical nature-infrastructure interactions, the green infrastructure concept can be capacious enough to include and/or draw together a range of meanings in practice.

Practice relates to the ‘doing’ elements of green infrastructure, where meanings of green infrastructure are interpreted into tangible outcomes to respond to a local setting or context. For example, an engineered solution such as a constructed wetland is designed and implemented to address specific urban needs. Actors from a range of sectors and disciplines come together to develop a green infrastructure intervention, which may accommodate a breadth of individual physical nature-infrastructure interactions. By implication, I move away from how green infrastructure concepts are represented in policy and focus on how they are used in practice.

In practice, a range of disciplinary understandings and policy representations can draw together city and project levels actors according to their interests and backgrounds. The use of one or more disciplinary approaches to green infrastructure at different levels points to the ‘fluidity’ of the concept, where despite having relatively fixed boundaries in meaning according to disciplinary knowledge and dominant policy interpretations, in practice it enables a range of disciplinary and policy actors to work together to ‘do’ green infrastructure. Accommodating a breadth of physical nature-infrastructure interactions under one concept points to “fluid boundaries” in its meaning (Horwood, 2020, p. 2). For example, meanings of green infrastructure concepts can be “subject to change and re-negotiation” depending on the “audiences, priorities and aims” that enable different green infrastructure meanings to be drawn on (Horwood, 2020, p. 8). Thus, understanding how green infrastructure is conceptualised in practice requires a focus on its capaciousness.

Another way of conceptualising fluidity and capaciousness in is the idea of 'comfortable meanings'. Although not conceptualised fully in the paper by Wright, the "comfortable meanings" of green infrastructure indicates that the concept comes to gain meaning through the way it is used in policy and practice (Wright, 2011, p. 1004). Comfortable meanings present a counter logic to the "resistance to [the green infrastructure concept's] ambiguity", which I demonstrated in the first section on disciplinary meanings, where disciplinary literature tends to contextualise the concept to have fixed boundaries (Wright, 2011, p. 1004), (Section 2.1). As a consequence, areas of overlap can exist between physical nature-infrastructure interactions that indicate how project level actors come to use the concept in practice despite complexity around its many meanings.

2.3.1 Finding comfortable meaning

Due to fluidity in the meanings of green infrastructure concepts, the concept itself can accommodate a range of physical nature-infrastructure interactions. While the literature on green infrastructure tends to focus on mainstreaming specific conceptualisations of physical nature-infrastructure, how they gain meaning in practice has not yet been fully researched. Consequently, it can demonstrate how policy level actors can come together in different ways to conceptualise green infrastructure concepts by working with and outside their existing understandings.

Toward setting up a study to explore how green infrastructure concepts are used in practice, I point to the complexity around the evolving meanings of green infrastructure concepts and how they can be constituted by a range of overlapping physical nature-infrastructure interactions.

Working outside of policy

Actors can draw on green infrastructure concepts in ways that do not follow overarching policy at a national, regional and city scale. Green infrastructure concepts can therefore come to gain meaning in unplanned or organic ways, where they can be influenced by the context and setting within which they are used. For example, in the Ruhr region in Germany, green infrastructure is considered an "indispensable element of the urban-regional fabric" at a regional policy scale[12], which was influenced by planning influences at the European level such as the Green Capital of Europe programme (Reimer and Rusche, 2019, p. 1556). In practice, however, green infrastructure was drawn on to address pollution in the Emsher river, where it served as a "rhetorical and practical frame" for addressing urban water concerns at the project scale (Reimer and Rusche, 2019, p. 1556). The implications of using green infrastructure in this way illustrated how instead of being influenced and incentivised by overarching policy, the concept was used as part of a "unique window of opportunity", which created the 'comfortable' setting and context for its use (Reimer and Rusche, 2019, p.

[12] Green infrastructure concepts used in regional plans most closely followed a *connected landscape approach*, where it supported general planning outcomes such as "making efforts to improve the urban environment and move towards healthier and sustainable living areas" (European Commission, n.d., p. n/p).

1556). By implication, green infrastructure concepts can be used outside policy representations in unplanned ways.

In a similar way to policy, green infrastructure is used by a range of project level actors in practice where despite approach, there can be multiple understandings of physical nature in operation at any one time. The same can be said for practice, where despite green infrastructure concepts being “constructed by a group of planning professionals, [according to] which mechanisms are important”, they can be drawn on in a variety of ways according to the local setting (Reimer and Rusche, 2019, p. 1545). Accordingly, the “basic world views manifest in the planning domain”[13] and can be adapted in practice to accommodate a range of interests and settings (Reimer and Rusche, 2019, p. 1545). As a consequence, it becomes important to consider how they are understood in disciplinary knowledge and represented in policy, including how they can gain meaning in unplanned ways.

Using green infrastructure in unplanned ways

I explained how green infrastructure concepts can be influenced according to existing rules and guidelines (Section 3.2.2), I now consider how they can gain meaning outside of existing rules and guidelines where they influence practice. While there are instances where existing rules and guidelines, such as those at a regional or city scale, do influence how green infrastructure concepts are drawn

[13] Scholars consider history and how policymakers frame green infrastructure concepts over time.

on, the converse may also be true. Using green infrastructure concepts as part of a window of opportunity demonstrates the “exemplary” ways green infrastructure concepts can be used in practice (Mell, 2020b, pp. 9–10). By exemplary in this instance, I refer to instances where practical meanings were drawn on outside of “normalised practice” such as policy at one or more levels, or existing plans and guidelines (Mell, 2020b, pp. 9–10). Accordingly, green infrastructure concepts were used in practice according to different understandings of physical nature, which existing outside policy.

One reason for the exemplary use of green infrastructure in practice is that it is often not legislated or included as mandatory features of existing rules or legislation. Not being legislated has implications for how meanings are interpreted and drawn on. For example, green infrastructure can be “a non-statutory service”, where there are no lines of legal accountability for project level actors that use them (Mell, 2020a, p. 3). In instances where there is no accountability, green infrastructure concepts can be drawn on as a “supplementary element in development objectives”, where they are used after “core investments in housing and other infrastructure are met” (Mell, 2020, p. 3). Therefore, without legally assigned roles and responsibilities, the green infrastructure concept is open to interpretation and can be used through voluntary activities, rather than established legal roles and responsibilities.

I explained exploring green infrastructure like infrastructure can ‘opens up’ social, spatial and political debates. In the same way that infrastructure can assert control over where and how development can take place, it can also demonstrate meaning from the ground up, where citizens use infrastructure, or in this case green infrastructure, to shape the city. For example, in addition to being identified as a social phenomenon of state control (Section 2.2), it can also illuminate “fiscal relations and judicial processes where “ethical and political” questions emerge through how infrastructure is “mediated [and] negotiated” (Von Schnitzler, 2016, p. 4). Exploring infrastructure, including green infrastructure, can therefore become an “entry point” for exploring how cities “take shape” outside of its “conventional location and mediators” such as those I outlined regarding state control (Von Schnitzler, 2016, p. 4) (Section 2.2). Exploring voluntary activities and how they ‘open up’ opportunities for exploring the spatial, social, and political features of the city provides an important step for decolonising understandings of the city, but also infrastructure networks as a whole.

Voluntary activities

The idea green infrastructure concepts mediate the city through a series of unplanned and/or voluntary activities deviates from much of the literature I have presented above on disciplinary knowledge and policy. Much of the literature on green infrastructure focuses on ‘how to’ support or mainstream the approach to bring about urban benefits such as those I have indicated by each of the approaches, including conservation, service provision or connected landscapes. Windows of opportunity demonstrate how green infrastructure concepts can be used in unplanned ways, which may draw differentially on disciplinary knowledge and policy. This introduces the need to consider how green infrastructure concepts are influenced or shaped by actors, including the context and setting.

I draw attention to one study that shows how green infrastructure concepts were used in unplanned ways to illustrate how green infrastructure concepts are used in practice. In addition to legislated functions on green infrastructure, best practice tends to call for a dedicated funding stream to encourage the use of green infrastructure in practice. The New York Green Infrastructure Plan and Chicago Cook County green infrastructure projects tend to be praised as “successful” examples of green infrastructure, but also where there were sufficient “transitions to funding structures” in support of green infrastructure concepts (Mell, 2020, p. 10). However, as Mell (2020) points out, other projects such as the Million Trees Project New York City, Particular Green Infrastructure in Paris, and Cheonggyecheon Stream Renaturalisation projects, point to the exemplary ways in which green infrastructure can be used where there are no legal requirements and where there is no fixed budget.

Voluntary activities comprise an understudied element of how green infrastructure concepts are used. The Million Trees Project New York City, Particular Green Infrastructure in Paris and Cheonggyecheon Stream Renaturalisation projects were implemented by a range of actors, where they were funded outside of solely state-led intervention and funds. In other words, unlike the New York Green Infrastructure Plan that was implemented through a dedicated government fund, they demonstrate the “role of communities in delivering” green infrastructure (Mell, 2020, p. 10). While I do not intend to focus on funding as a standalone theme, it does identify one element of voluntary activity that supported green infrastructure through “participatory budgeting” and through the “support of the business community” (Mell, 2020, p. 10). Consequently, green infrastructure can be used by a range of actors through hybrid or alternative funding streams, where meanings are drawn on and adapted in practice.

Windows of opportunity

Another study that touches on the unplanned ways green infrastructure concepts are drawn on in policy is Horwood (2020). While the study focuses on the use of green infrastructure in policy, the shared understandings of green infrastructure around a common interest served to unite policy actors to get the job done despite their differences. For example, in England’s North-West region, a “policy focus and associated funding opportunities” created a shared interest around green infrastructure concepts (Horwood, 2020, p. 14). Shared interests around economic development contributed to the “breadth” of green infrastructure concepts, where it supported a “bringing together of [actor] interests” where the roles and responsibilities between actors involved in policy can shift over time (Horwood, 2020, p. 14). Consequently, windows of opportunity, such as funding or economic development opportunities, can bring together project level actor interests around green infrastructure, where despite their different understandings of physical nature, they are united around a central focus.

Windows of opportunity, therefore, encompass one avenue that green infrastructure concepts are used in practice. Focusing on how these opportunities influence the meaning of green infrastructure concepts supports a study of green infrastructure gains comfortable meanings in policy and practice. Through voluntary activities, a “wider number of stakeholders” can become “involve[ed] [in] the decision-making process” and subsequently how understandings of green infrastructure are interpreted in practice (Mell, 2020b, p. 11). Exploring the “interest groups” or actors that influence the comfortable meanings of green infrastructure encouraged a study of actors that work within and outside existing “roles, responsibilities and legal requirements” (Mell, 2020, pp. 8 and 11). Therefore, the opportunistic ways in which green infrastructure is used at the project level offers one further level of ambiguity around green infrastructure, where it can be used in more open or flexible ways.

2.3.2 Momentary power and shared understandings

I have chosen to focus on the windows of opportunity and comfortable meanings of green infrastructure concepts as they point to the ‘momentary power’ of the concept. Momentary power sets up an idea that green infrastructure concepts come to exist and are used at particular points in time, across a range of project level actors, in accordance with the context and setting. Framing how green infrastructure is conceptualised in this way sets up a study to explore how green infrastructure concepts come to exist at any one point and continue to be used in unplanned ways. Rather than focusing on a particular disciplinary approach and how representations come to exist in policy, the momentary power of green infrastructure concepts enables a study on the many meanings of physical nature-infrastructure interactions and how they can be individual or shared, and how they can be evolving in relation to each other.

By establishing the momentary power, green infrastructure points to a further gap associated with how the concept is configured over time. Green infrastructure approaches can bring together a range of actors at the project level in practice that can contribute to the development of shared understandings. While actors can have a range of different understandings of physical nature-infrastructure interactions, they can also exhibit a degree of common ground, where the green infrastructure concept is capacious enough to allow for shared understandings to develop.

Room for shared understandings

Reflecting on meanings of green infrastructure as both dividing and uniting individual actors demonstrates the importance of considering how they are communicated in dialogue or written accounts. As Lennon (2019) points out, the green infrastructure concept is “like a language” (Lennon, 2019, p. 13). Rather than a fixed disciplinary account or single representation in policy, green infrastructure concepts are a “dynamic idea” that “borrows and seamlessly integrates […] other dialects in local expressions” (Lennon, 2019, p. 13). Therefore, while project level actors may hold specific understandings of green infrastructure background and experience, they can find a common language for ‘doing’ green infrastructure in practice if the meaning is broad enough.

While project level actors can hold a range of disciplinary ways that they draw on physical nature-infrastructure interactions, there is something that holds them together on projects. Project level actors can be “advocates of the concept”, where they are brought together under the general concept of green infrastructure (Lennon, 2019, p. 16). Being an advocate of green infrastructure enables them to “communicate” a broad approach “across contexts, boundaries and scales” (Lennon, 2019, p. 16). Green infrastructure can therefore create a common focus across actors on projects, where it manifests as a “common language for environmental planning”, that is driven by a collective interest in the concept’s basic principles or approach:

> …the desire to work collaboratively across disciplines and with natural processes, respect context, promote multifunctionality and foster connectivity, contour a shared understanding of what the green infrastructure concept represents.

(Lennon 2019, p. 16)

Therefore, despite the many meanings of physical nature-infrastructure interactions, the broader green infrastructure banner can bring together a wide range of project level actors to focus on a common theme or application in practice.

A second study that illuminates the shared meanings of green infrastructure in policy is Horwood (2019). The study identified discourse coalitions as instrumental to gain consensus around the priorities and aims of green infrastructure in policy. Discourse coalitions refer to “a group of actors who share a social construct”, where it forms part of “the political process” (Hajer (1993) in

Horwood, 2020, p. 9). Conceptualising the development of shared meanings of green infrastructure in policy using discourse coalition shows how "meaning-making" is "brought together [through] a coalition of organisations around a shared interest" such as "promoting green-space within an economic remit to secure investment" (Horwood, 2020, p. 10). While discourse coalitions are useful for conceptualising the meaning-making process, it does not focus on the implication of these shared meanings for project level actors going forward towards implementation.

Shifting from shared meanings to shared understandings

I make the shift from shared meanings to shared understandings to illuminate one further layer of complexity around green infrastructure concepts and how it can hold momentary power. While on the one hand, project level actors can have many different understandings of green infrastructure, where they can come together under a shared idea of green infrastructure, there is also room for shared understandings to evolve. For example, project actors come together on projects to implement green infrastructure concepts under a shared meaning and through this process, they come to know green infrastructure in new or different ways. In other words, their understandings of physical nature-infrastructure can change in relation to each other.

Illustrating how shared understandings develop through windows of opportunity points to an additional feature of green infrastructure concept and how they can gain meaning as an individual and shared or collective process. The idea of shared understandings presents a counter-narrative to disciplinary knowledge and applied policy understandings, which I have demonstrated in Sections 2.1 and 2.2 above. For example, individual project level actors with a background in engineering may initially interpret green infrastructure according to engineering disciplinary knowledge. While working on a project with planners and landscape architects they may evolve different meanings of physical nature-infrastructure interactions that can overlap with the *ecosystem service* and *connected landscape approach* (Section 2.1) to find solutions to address a material concern, such as flooding. Similar can be said for a landscape architect and environmental scientist. Therefore, the outcome of shared understandings is the evolution of understandings of physical nature-infrastructure interactions.

Therefore, despite holding multiple understanding of physical nature-infrastructure interactions at the individual level, the momentary power of green infrastructure illuminates where different understandings come together to support the use of green infrastructure concepts in practice. The literature on green infrastructure concepts focuses on how concepts gain meaning in policy, with less emphasis on how meanings come to exists in practice. Toward conceptualising how practical meanings of green infrastructure come to exist in practice, I draw on noteworthy moments in policy development that are likely to create a common vision around physical nature-infrastructure interactions to enable the use of green infrastructure concepts in practice. While my descriptions do not account for the exact ways practical meanings are (re)conceptualised, they do illuminate a starting point for considering how green infrastructure concepts are used among a range of project level actors that hold a variety of understandings of green infrastructure at any one time. Therefore, by establishing how shared policy meanings come to exist, I signal a gap in knowledge around the ways shared practical meanings evolve as an outcome of the unplanned, or opportunistic, use of green infrastructure concepts.

In summary, while green infrastructure concepts tend to be used in policy according to technical and scientific evidence and best practice, not enough is known about how they are used in practice. Existing studies on the meaning of green infrastructure policy points to the complexity associated with the use of green infrastructure concepts in policy, where it can be capacious enough to include a wide range of understandings and representations of physical nature-infrastructure interactions. In addition, studies also show green infrastructure concepts have fluid boundaries in their meaning that can enable its meaning to evolve. Toward understanding the capacious and evolutionary aspects, I identify momentary power as a conceptual device to explore the concept’s many individual and shared understandings and how actors come together on projects in practice to use green infrastructure.

2.4 Understanding green infrastructure in practice

In this chapter, I showed the complexity around green infrastructure concepts, or more specifically, the range of physical nature-infrastructure interactions that comprise them. I illuminated the tensions, overlaps and gaps around physical nature-infrastructure interactions that contribute toward its complexity. Pointing to these fracture points and overlaps enabled me to show there is a need to not only examine the range of project level actors involved in implementation, but also to focus on whose interpretation is dominant and how the concept can accommodate for a wide breadth of physical nature-infrastructure interactions to ‘do’ green infrastructure. I also identified momentary power as a conceptual device to focus on how actors negotiate the complexity of green infrastructure concepts on projects in practice, where they can draw on them in unplanned ways. To answer the research question, I now develop a conceptual framework to explore how green infrastructure concepts are conceptualised (Chapter 3).

Chapter 3 CONCEPTUALISING GREEN INFRASTRUCTURE AS PRACTICE

In this chapter, I adapt a practice theory approach to explore the momentary power of green infrastructure concepts. Currently, we do not know enough about how green infrastructure concepts are used in practice and where project actors can draw on one or more understandings or representations of the concept in unplanned ways. Toward exploring how green infrastructure concepts are conceptualised in practice, I develop Schatzki's practice theory approach to illuminate physical nature-infrastructure interactions and how they can shift across one or more social actors[14] at any one time. By using a practice theory approach, I illuminate how green infrastructure concepts gain meaning as an embedded feature of the social world and where it develops out of an individual or shared process that can evolve over time.

Practice theory, infrastructure and environmental management

While there are many ways to study how green infrastructure concepts are used in practice, one way is using practice theory. Practice theory is one strand of social theory that conceptualises how the social world is organised. While scholars use a range of definitions of practice, they all explore the social world through the bodily activities of social actors. I deliberately focus on Schatzki's

[14] I refer to social actors as a generic category for actors within a particular context or setting.

practice approach as it enables me to study how meaning evolves across one or more social actors at any one time in unplanned ways. Schatzki's practice theory also makes it possible to explore how meaning unfolds or develops as a situated and contextually bound concept, which I showed formed an important feature for how green infrastructure concepts are understood and represented in policy and practice in the literature review (Chapter 2).

Practice theory has been used to explore the social aspects of infrastructure. Studies by Shove focus on the hidden or concealed elements of infrastructure, which have come to comprise the daily lives of city actors. For example, the approach is used to consider how infrastructure "enable[s], sustain[s] or change[s] what people do" over time (Shove, 2016, p. 3). By exploring infrastructure as a mediating feature of social life, I illustrate how infrastructure enables social life in different ways such as "how car parking spaces facilitate driving" for example (Shove, 2016, p. 3). Therefore, by focusing on infrastructure as a mediating feature of the social world, it foregrounds the relationship between infrastructure and the daily practices of actors.

Shove and Spurling have also used a practice theory approach to study sustainability transitions by focusing on the behaviours of actors. They use practice theory to illuminate the "social, institutional and infrastructural conditions" and how they can create "much less resource-intensive ways […for how…] life might take hold" (Spurling and Shove, 2013, p. 1). Understanding the conditions of actors aims to illuminate how they embark on a "radical redefinition of what counts as normal social practice", including the "institutions and infrastructures on which these arrangements depend" (Spurling and Shove, 2013, p. 2). Therefore, by analysing practice and what people do, it enables a study of how new technologies or approaches can take hold.

Everett and Lamond follow a similar approach where they use practice theory to explore the attitudes of actors toward environmental approaches. Attitudes in this instance refer to the motivations of actors and how this translates to opportunities or barriers for using green infrastructure concepts. For example, Everett and Lamond explore cultural and social behaviours around 'blue-green infrastructure' for urban flood resilience, with the view to identifying the adapting behaviours around flood management going forward (See Everett et al., 2016 and Lamond and Everett, 2019). Practice theory is used to understand "the link between attitudes, behaviour and stewardship" around adopting and using 'blue-green infrastructure' as a way to identify a range of "motivations and barriers" (Everett et al., 2016, p. 101). Practice theory can therefore illuminate the characteristics of the social actors that lie behind practices.

While practice theory has been used to explore aspects of social life related to sustainability and the behaviours and attitudes of actors, they tend not to illuminate social meaning and how it is conceptualised over time. For example, while Shove and Spurling take a more detailed view of infrastructure by building on Schatzki's conceptualisation of materiality, it presumes infrastructure is 'hidden' and practices already exist in some way, shape or form, where links can be revealed by applying a practice theory approach. By foregrounding infrastructure in this way, it centres a study around infrastructure as the mediating feature of social life. As such, it has implications for how change is conceptualised were it emerged from a known starting point.

As Everett and Lamond point out, stewardship around blue-green infrastructure takes place where there is a willingness to carry out these practices. They identify a link between meaning, perception and attitude, which can amount to activities or practices around blue-green infrastructure. That said, they tend not to focus on how activities come to exist or evolve because of participant's interests. By implication, it does not focus on how meaning develops according to use, where I have indicated there is a strong interplay between understandings or 'know-how' and materiality (Section 2.3). Consequently, there is room to build on these approaches by exploring how the green infrastructure concept gains meaning as part an emergent process and where interests around physical-nature infrastructure interactions can develop and influence the use of the concept in unplanned ways.

A practice theory approach to physical nature-infrastructure interactions

I have developed a conceptual framework to foreground physical nature-infrastructure interactions held among one or more actors. To illuminate physical nature-infrastructure interactions and how they evolve, I focus on the interplay between *practical understandings*, *rules* and *general understandings*. Exploring how physical nature-infrastructure interactions evolve through the relationships between these three concepts enables me to draw out how green infrastructure concepts are (re)conceptualised among one or more social actors according to what they do. Hence, I explore meaning by focusing on how social actors understand physical nature-infrastructure interactions and how these meanings evolve.

Schatzki's practice theory offers two basic conceptual building blocks for exploring meanings of green infrastructure and how they evolve. These are 'activities' and 'practices'. 'Activities' refer to "doings and sayings" of social actors and how they take place in space and time (Schatzki, 1996, p. 26). An important feature of the doings and sayings of social actors is that they are "embodied", where they are comprised of "bodily doings and sayings" (Schatzki, 1996, p. 26). While doings and sayings may only be read as what is done or spoken about, it is also important to draw attention to the fact that it also includes how things are "written" about (Schatzki, 1996, p. 26). I refer back to activities when I describe continuing practice below (Section 3.2.2).

'Practice' is the outcome of activities. In other words, practice emerges out of a string of activities that can be carried out by one or more social actors at any one time. As such, practice is a collective process, which has a set of individual and shared "unfolding" activities (Lammi, 2018, p. 13). As a collectively constituted phenomenon, practices are the "site" where meaning or intelligibility can be derived (Schatzki, 1996, p. 12). Accordingly, practices offer a conceptual device for exploring how social phenomenon come to exist, where activities can be individual or shared, or where they come to exist in unplanned ways.

To show how I develop Schatzki's conceptual framework, I reflect on Schatzki's practice theory approach and why I have selected it for exploring how green infrastructure is conceptualised in practice (Section 3.1). In the second section, I develop a practice theory approach to foreground physical nature-infrastructure interactions as an individual and collective process (Section 3.2). In the last section, I focus on how meanings of physical nature-infrastructure interactions can be (re)conceptualised according to how they are used (Section 3.3).

3.1 Schatzki's practice theory approach

Schatzki's practice theory approach lends itself to a study of green infrastructure and how it is conceptualised in practice due to its focus on the 'doing' elements of the social world. The approach highlights practice as a collective outcome that can be influenced by actors and existing rules, where it defines how practice continues as a stable or evolving set of activities. Toward conceptualising green infrastructure using a practice theory approach, I first present the building blocks of Schatzki's practice theory approach (Section 3.1.1), before illustrating how they conceptualise physical nature-infrastructure interactions (Section 3.1.2). Presenting on the basics of practice theory enables me to show how I develop it to respond to the research question in the sections to follow (Sections 3.2 and 3.3).

3.1.1 Illuminating meaning

Practice theory is more of an approach than a theory in the sense that it is used and drawn on in a variety of ways by different scholars. Scholars can follow a strict approach as outlined by Schatzki, or a mix of practice theory scholars such as Schatzki and/or Giddens or Bourdieu. As such practice theory is described as a “toolbox” that can be drawn on differentially to explore how the social world is organised (Lammi, 2018, p. 18). To show how Schatzki’s practice theory has been used to explore different elements of practice, I illustrate studies that have drawn predominantly on Schatzki’s body of work.

Schatzki’s approach seeks to conceptualise how the social world is organised. The approach has been used widely within organisational management and consumption studies where it has been used as a standalone, or part of a toolbox approach to explore topics such as telemedicine (Nicolini, 2010), self-governance (Mattijssen et al., 2018), how sustainability practices evolve through institutional knowledge (Silva and Figueiredo, 2017) and how collective action supports achieving sustainability (Welch and Yates, 2018). The latter two on sustainability and infrastructure form a recent thrust of research that draws on Schatzki’s approach.

To explore sustainability and infrastructure Schatzki’s practice theory has tended to be used to focus on how practices evolve and how they are shared among social actors. For example, Nicolini’s (2010) study considers how knowledge is shared by focusing on the ‘sites’ of telemedicine practice. Mattijssen et al., (2018) explore how social actors self-organise, where they undertake activities to achieve a shared goal, to manage conservation areas. Silva and Figueiredo (2017) detail how institutional knowledge on sustainability is constructed and shared among social actors; and, Welch and Yates (2018) consider how practice evolves out of collective projects on sustainability. The abovementioned studies provide a basis to consider how sustainability practice arise through a collective and evolving process, but the approach has tended not to focus on how understandings can evolve at the individual and collective scale.

Building blocks of a practice approach

To study the social world, Schatzki sets out an approach that involves two key building blocks, ‘practices’ and ‘activities’. These are the two key features of practice theory that I will draw on in the thesis. Schatzki’s conceptualises the social world as a “nexus” or a “web” of practices (Schatzki et al., 2001, p. 56). Practices are the broader processes that are comprised of a set of “temporary unfolding” activities (Lammi, 2018, p. 13). While activities tend to be carried out by individual actors, practices can be shared between one or more actors. By implication, the social world is comprised of a series of interlinking sets of activities which can be individual or shared.

What social actors do and say articulates something about their understanding or conceptualisation of the social world. Acknowledging that social actors are neither neutral and do not exist in a vacuum, they perform activities according to “what makes sense to them” (Schatzki et al., 2001, p. 55). Attributing what makes sense to social actors to what they do therefore situates practice as the "site where understanding is structured and intelligibility is articulated" (Schatzki, 1996, p. 12). Therefore, exploring activities can illuminate understanding and how it is configured among social actors at any time.

Before I continue with a description of meaning and how it can be explored under a practice theory approach, I must pause for a moment to include a feature of activities that I draw on in more detail on physical nature-infrastructure interactions (Section 3.1.2). In addition to being bodily or embodied, activities are also associated with materiality or tangible constituents of the social world that exist in time and space, where they are "materially interwoven" with the practices and activities of social actors (Schatzki et al., 2001, p. 3). Materiality refers to the "stuff" that makes up social life, including physical nature-infrastructure interactions (Schatzki, 2000, p. 125). I return to materiality below to explain how it is characterised in the social world (Section 3.1.2).

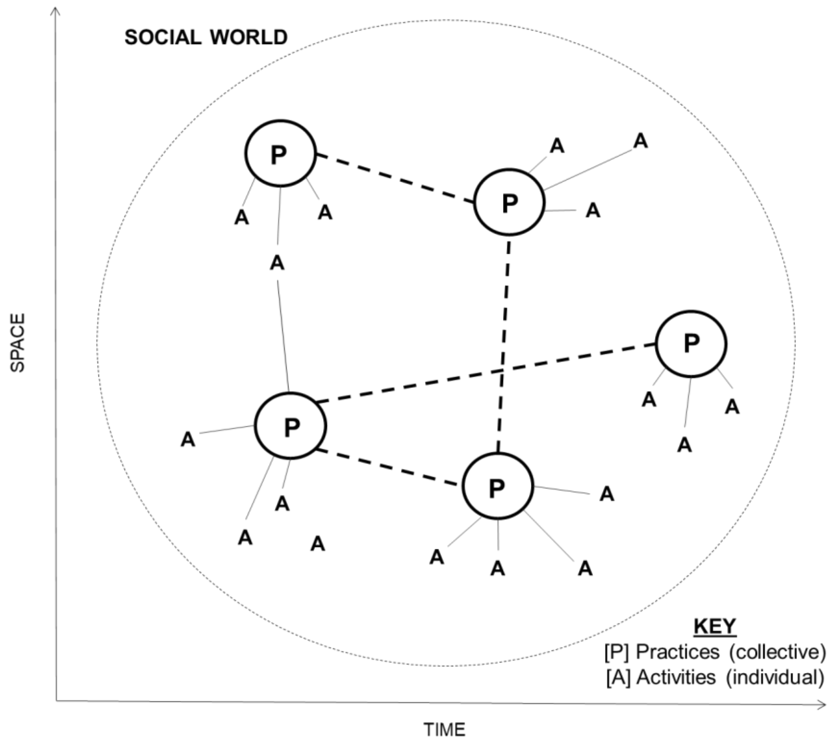

Figure 3-1: Overview of the basic building blocks of Schatzki's practice theory.

As I mentioned in the Introduction (Chapter 1), materiality can be conceptualised in more than one way. While materiality is typically considered to be the backdrop of social life, authors in social sciences view it as being integrally linked to how social life is constituted (Latour, 1996; Schatzki, 1996). Focusing on materiality along this vein enables me to explore how many individual and collection meanings can evolve in relation to tangible or physical aspects of the social world and how they help to constitute practice over time. Therefore, by making this choice enables me to consider how these meanings emerge and develop in more detail.

Following Schatzki, doing ‘what makes sense for social actors to do’ forms an important component of a practice approach. To understand why actors ‘do’ things, I delve a little bit deeper into the ‘intelligibility’ of social actors and how they make sense of the social world. A string of activities form practice if “its members [referring to actors] express an array of understanding, roles and structure” (Schatzki, 1996, p. 106). According to this, understanding can be used to determine meaning, where “people share an understanding of a word or action” only when they “use the word or carry out action” (Schatzki, 1996, p. 110). By implication, practice as an organising feature of activities can be used to explore meaning.

As indicated in Figure 3-1, practices operate on a broader hierarchical scale than activities. Practices are defined as the “open-ended [15], spatially-temporally dispersed nexus of doings and sayings” (Schatzki, 2012, p. 13). Another way of articulating this is that the “effects of […] different people’s activities” become part of an “organised constellation” that can be described as practice (Caldwell, 2012, p. 286; Schatzki, 2012, p. 14). By implication, practice forms a way of doing things that can be shared among social actors.

Considered side-by-side, activities and practice can demonstrate slightly different things about the social world. I explained at the start of the section that activities and practices operate on two different hierarchical scales. Activities can be

[15] Open-ended refers to practice as being “composed of any particular number of activities” (Schatzki, 2012, p. 14).

defined as what individual actors say and do, or the "events" that can "happen" through "intentional and voluntary" acts (Schatzki, 2012, p. 18). Practices, on the other hand, are broader "meaning-making, identity-forming, and order-producing activities" that illuminate more than "just […] what people [say and] do" (Nicolini, 2010, p. 602). The interplay between activities and practice provides an interesting conceptual approach to illuminate different elements of the social world.

Organising components of practice

Schatzki identifies four components of practice that can influence what makes sense for social actors to do. The four components that organise practice are *practical understandings, rules, general understandings* and *teleoaffective structure*[16] (Figure 3-2). Each of these features of practice can influence how social actors do things at the activity level, that amount or add up to evolutions at the practice scale. Therefore, they precede activities, as they influence how social actors 'do' things. I return to the procedural elements of practice in the next section (Section 3.2.2).

I begin by explaining *practical understandings*. Practical understandings refer to what social actors know and how it organises their activities (Figure 3-2). Knowing how to do something precedes activities, where they influence the activities of

[16] The four organising components of practice theory have not always been part of Schatzki's practice theory. Early accounts of the theory only draw on three components – practical understandings, rules and teleoaffective structure (Schatzki et al., 2001). More recent studies describe a fourth component – general understandings (Schatzki, 2012).

other actors. For example, practical understanding is defined as "knowing how to X, knowing how to identify X-ings, and knowing how to prompt as well as respond to X-ings" (Schatzki, 2002, p. 78). Practical understandings are a central feature of practice, where it "underwrites the proposition that the maintenance of practices" that support the "persistence and transformation of social life" (Schatzki et al., 2001, p. 12). As I demonstrate later on in the chapter, practical understandings also evolve through how social actors carry out their activities (Section 3.2.2).

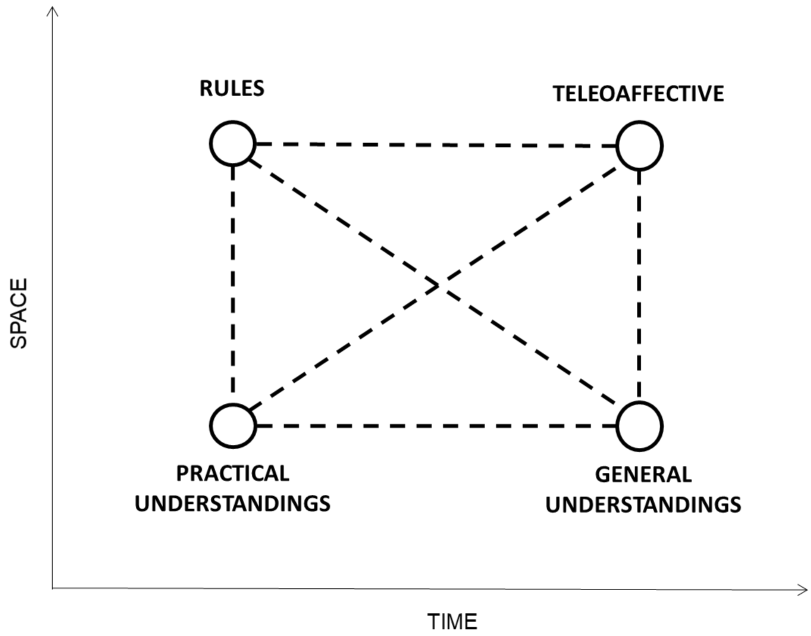

Figure 3-2: Organising components of activities and practice.

Rules guide social actor activities by influencing their pathways for action. Rules influence what green infrastructure actors can do through their activities. For example, rules are "methodically applied generalisable procedure[s] of action implicated in the practical activities of daily life" (Schatzki, 1996, p. 156). By following rules, actors have a sense of “knowing how to go on’", where it orientates social actors by “qualifying” a “colloquial intercourse” (Schatzki, 1996, p. 96 and Schatzki, 2002, p. 226). Consequently, rules can support the repeatability of activities, having a defined way of doing things makes carrying our activities ‘easier’ and ‘safer’.

As a third step, I refer to *teleoaffective structure* which refers to the set of organised activities required to carry out practice (Figure 3-2). Practices require that actors carry out a “correct” set of tasks “for the sake of” achieving specific “ends” (Schatzki et al., 2001, p. 61). For example, green infrastructure concepts in policy may represent a particular outcome such as a constructed wetland to manage urban water. A specific representation of constructed wetland may guide social actors toward using certain kinds of materials so that can achieve a particular look or feel. Therefore, the type of practice determines the structure of activities and how they ought to be carried out.

As the last step, I describe *general understandings* which is a common sense of things that are held across social actors. General understandings are not necessarily shared or common knowledge, rather it is a tacit quality held among actors (Figure 3-2). For example, general understandings are not the “ends for which people strive”, but they are rather senses of “worth, value, nature, or place of things, which infuse and are expressed in people’s doings and sayings“ (Schatzki, 2012, p. 16). By defining general understandings across aesthetic values allows me to position how green infrastructure as practice evolves, where the activities of social actors evolve, where activities are influenced by "components of wider discursive formations that intersect practices, and may exhibit pre-reflexive, tacit or affective aspects" (Welch and Yates, 2018, p. 5). As I demonstrate below, general understandings can illuminate how practice can evolve among social actors that carry out activities on green infrastructure projects (Section 3.3.1).

Before I move on to the next section, I must specify one further characteristic of practice, namely that it occurs in time and space (Figure 3-1 and Figure 3-2). "Time-space" locates practice as something that is spatially and contextually bound, where it forms an "essential feature of activity and exists only when, and in so far as, activity happens" (Schatzki, 2012, p. 18). That said, to "determine what people do" it becomes important to consider the temporal and spatial aspects of practice (Schatzki, 2012, p. 19). Establishing the temporal and spatial dimensions of practice has implications for practice and their constitutive activities, namely that can evolve at different speeds at different times.

As practice is situated and contextually bound, one or more practices can exist at any one time. Practices can interact with each other in unplanned ways. As such, practices can be described as "unfolding of social phenomena" that can "arise, persist, and dissolve…principally through human activity" (Schatzki, 2012, p. 21). By implication, practices can "burst forth anytime", where they can "set social affairs in new directions" (Schatzki, 2012, p. 22). Therefore, practices can evolve at different speeds at different times, where they can find a state of equilibrium or be in constant evolution.

3.1.2 Physical nature-infrastructure interactions and materiality

I develop Schatzki's practice theory to foreground physical nature. To explain how I foreground nature-infrastructure interactions, I explain how Schatzki conceptualises physical nature, or 'nature' as Schatzki calls it, and infrastructure. In Schatzki's view, physical nature and infrastructure are the material features of the social world[17]. Materiality refers to the "physicality", which includes non-human entities such as "humans, artefacts, organisms, and things of nature" (Schatzki, 2000, p. 125). In other words, physical nature and infrastructure are both considered to be the "stuff" that makes up social life and it is the social actors that derive its meaning.

I have already highlighted scholarship on the social construction of nature and why I have chosen to focus on 'physical nature' (Chapter 1). My focus on materiality or the 'physicality' of green infrastructure forms an important component of my contribution to knowledge. In other words, by being more specific about which green infrastructure I explore, it enables me to delve deeper into the process for how meaning develops and evolves. As materiality forms a key component of how I explore green infrastructure in the thesis, I feel it is

[17] I build on Schatzki's conceptualisations of 'nature' in two of his writings, *Materiality and the Social Life* and *The Social Bearing of Nature*.

necessary to make explicit how I have adapted a practice theory approach to support a study of physical-nature infrastructure interactions.

Schatzki's framing of physical nature and infrastructure as the homogenous 'stuff' of the social world creates a starting point for me to explore understandings of physical nature-infrastructure interactions. For example, if the social world is comprised of a series of 'things', it is then the social actor's intelligibility of materiality that separates them as physical nature and infrastructure. Understanding can, therefore "bleed into […] physicality", where meaning is derived according to characteristics of the social world (Schatzki, 2000, p. 125). A noteworthy conceptualisation of materiality as the "stuff" of the social world is that it has "physical constituents and properties" that can become familiar to individual and groups of actors (Schatzki, 2000, p. 125). Consequently, the constituents and properties of material features become understood as being physical nature-infrastructure interactions in their various forms.

Therefore, meanings of physical nature-infrastructure interactions are derived from their physicality, where their properties can be understood in different ways. Toward showing how social actors understand physical nature-infrastructure interactions, I first present on Schatzki's account of 'nature' as a material phenomenon and how it can influence actor activities over time, before explaining how they conceptualise infrastructure. As such it resonates with my conceptualisation of physical nature-infrastructure interactions (Chapter 1). I return to my description Schatzki's framings below when I draw on them to explain how social actors understand physical nature-infrastructure interactions (Section 3.2).

Linking materiality and meaning

To begin, physical nature can influence activities through their temporal and spatial presence, where social actors are required to engage in activities to manage them. For example, physical nature such as land, stream beds or dirt can “qualify” practice, where they “come to have bearing” on social life (Schatzki, 2000, p. 136). While there is a range of ways physical nature comes to bear on social life, Schatzki’s provides where “a dam needs to be built to accommodate it” can illustrate the need to carry out activities around water management to address the problem (Schatzki, 2000, p. 136). In this way, the occurrence of physical nature bears significance on activities, where they can serve to qualify how and why things are said or done.

Second, the properties of physical nature can also influence how activities are carried out. One such example of this is their physical composition. The “physical-chemical composition” such as shape, colour and texture determines which material entities are available for social actors to draw on and how they carry out their daily activities (Schatzki, 2010a, p. 136). For example, the properties of wood determine how “barns, fences, and carts can be built, how they are best painted, how trees can be felled, and the dangers trees can pose to horses roaming in their paddocks” (Schatzki, 2010a, pp. 136 and 137). Thus, the materiality of nature can influence how actors carry out their activities.

A third way the properties of physical nature can influence activities is through biological flows. The flows of physical nature can influence where and how social actors carry out their activities. Where what happens up or downstream of the flow can have bearing on what social actors do in time and space. For example, activities can "capture or embrace moments of biological flows", where social actors do and say things to the management of "matter-energy flows" (Schatzki, 2010a, p. 137). Flows influence social actor activities such as "cooking, eating, heating, […] constructing […] mowing [and] planting", where their activities are defined by how flows manifest at spatial or temporal scales (Schatzki, 2010a, p. 137). This is significant because it means that practice and their constitutive activities can be orientated around managing flows of physical nature such as stormwater management.

While physical nature is referred to on at least two occasions by Schatzki (see Schatzki, 2010a, 2000), infrastructure does not form a prominent feature of his work. Infrastructure falls under a general classification of materiality that is conceptualised as a tangible "social phenomenon" that occurs in time and space (Schatzki, 2019, p. 2). Schatzki does mention 'infrastructure' in his writings such as the paper on *Materiality and the Social Life*, but he does define infrastructure in the same way that I have here. For example, Schatzki tends to refer to infrastructure as the structure or organisation of 'temporal-spatial' phenomenon that can provide services in urban settings, but does not go much further to consider how they influence practice as I have explained for physical nature (Schatzki, 2010). Thus, although infrastructure is not explicitly discussed, as a material feature it bears significance on social life in a similar way to physical nature.

Due to their temporal and spatial characteristics, the materiality of infrastructure is important for how it is conceptualised. Materiality can “compose or bear on people’s lives” through their physicality (Schatzki, 2019, p. 2). The link between materiality and what social actors do forms an important feature of practice, where they are “are subject to change[18]”, contributing to the “emergence, development, persistence, and dissolution” of practices (Schatzki, 2019, p. 19). Consequently, there is a mutually constitutive relationship between materiality and activities, where they bear significance on social life.

In sum, developing Schatzki’s practice theory to explore physical nature-infrastructure interactions sets up a starting point for understanding the capaciousness of green infrastructure concepts, including the many understandings of physical nature-infrastructure interactions. Focusing on materiality, which can be understood as physical nature-infrastructure interactions, creates a more flexible and open approach for understanding how green infrastructure concepts are conceptualised. For example, instead of starting with a fixed or static idea of what green infrastructure is among one or more actors, it enables a study on how green infrastructure concepts come to

[18] Further qualified as the “interpersonal relations, personal networks, employment, governmental policy, taxation, health care, the provision of food and water, personal safety, communication and infrastructure, workplace politics, sports teams, affairs of neighbourhood, community, and country, even family matters, assuming families qualify as social phenomena” (Schatzki, 2019, p. 2).

gain meaning through their material attributes such as its physicality, physical-chemical composition and biological flows. Foregrounding meanings of physical nature-infrastructure interactions in this way, and how they come to gain meaning creates a more open starting point for studying a range of physical nature-infrastructure interactions and how they can be drawn on in unplanned ways.

3.2 Foregrounding physical nature-infrastructure interactions

I pointed to the fact that physical nature-infrastructure interactions form the basis for my analysis of green infrastructure concepts, where multiple meanings of physical nature and infrastructure can be in operation at any one time. In this section, I demonstrate how I develop a practice theory approach to explore these interactions (Section 3.2.1). I adapt Schatzki's practice theory by developing his descriptions of materiality, where social actors come to identify elements of the social world according to properties they come to know as physical nature-infrastructure interactions. By foregrounding physical nature-infrastructure interactions I show how they can shift in relation to one another or be in evolution.

3.2.1 Developing practice theory to study nature-infrastructure interactions

To develop a practice approach to explore nature-infrastructure interactions, I draw on three of the organising components of practice namely practical understandings, rules and general understandings. I have chosen not to draw on the fourth component, teleoaffective, as my intention is not to illuminate the structured set of tangible or known activities that are required to achieve a specific end goal, which is fixed by rules or practical understandings. Rather, I focus on the intangible elements that influence how social actors carry out their daily activities. I feel this omission is justified as I intend to explore how practice develops tangentially to rules and existing practical understandings. I explain how I use the three organising components of practice theory to foreground physical nature-infrastructure interactions. I have developed a conceptual diagram to aid my descriptions (Figure 3-3). I refer back to the diagram in the sections when I explain the interactions between the concepts in more detail (Section 3.2.2 and 3.3.1).

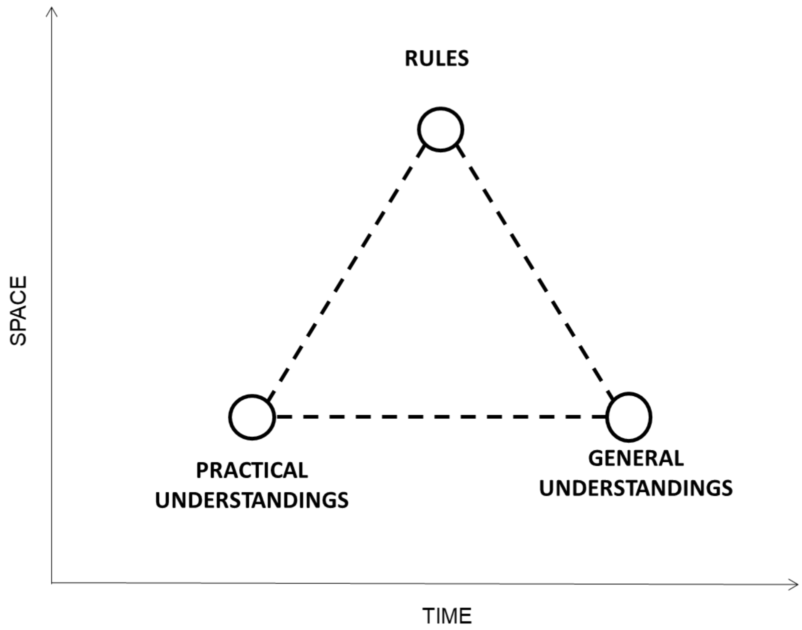

Figure 3-3: A practice theory approach to conceptualising physical nature-infrastructure interactions

As a starting point, social actors already have practical understandings of physical nature-infrastructure interactions according to their different disciplinary approaches. Their understanding of physical nature-infrastructure interactions also includes ‘know-how’ they have gained from engaging with physical nature and infrastructure in the past. For example, after working on a project where a constructed wetland was used to manage urban water, the actors that worked on that project would have an understanding of physical nature, where they conceptualise it as providing a functional service. Project level actors, therefore, have already have a preconceived idea of what physical nature and infrastructure is and how they ought to perform activities to design, plan and implement projects.

Activities can also be guided by rules. Rules can include legislation, professional guidelines or ways of doing things. Rules organise practice by defining which project level actors ought to carry out activities to achieve their agendas and goals. For example, government actors are legally responsible for maintaining stormwater and parks according to statutory law. Government actors are then bound to carrying out certain kinds of activities to ensure culvert and canals are maintained and to ensure the grass is cut and trees are pruned. Another example is the roles and responsibilities associated with the municipal legal procedure to carry out infrastructure projects. Roles and responsibilities identify which government and/or municipal actors ought to carry out activities across specific departments and professionals such as municipal infrastructure departments, engineers and environmental scientists to create accountability.

General understandings are not necessarily shared or common knowledge. It is rather a tacit quality that is held among actors. For example, general understandings are not the “ends for which people strive”, but they are rather senses of “worth, value, nature, or place of things, which infuse and are expressed in people’s doings and sayings“ (Schatzki, 2012, p. 16), (Figure 3-2). By defining general understandings across aesthetic values allows me to position how green infrastructure as practice evolves, where the activities of actors evolve over time, where activities are shaped by “components of wider discursive formations that intersect practices, and may exhibit pre-reflexive, tacit or affective aspects” (Welch and Yates, 2018, p. 5). As I demonstrate below in the section on evolving practice, general understandings help me to show how practice evolves among actors who carry out activities that form part of green infrastructure as practice (Section 3.3.1).

3.2.2 Physical nature-infrastructure interactions and continued practice

Understandings of physical nature-infrastructure interactions support continued practice. In other words, practice continues through repeated activities that have similar, or the same, conceptualisations of physical nature-infrastructure interactions. In the section on Schatzki’s practice theory, I noted that practices can continue over time, where practical understandings, rules and general understandings can allow practices to persist or evolve (Section 3.1). I now consider how practices persist over time, where they organise activities according to practical understandings and representations of physical nature-infrastructure interactions in rules.

Practical understandings: 'Know-how'

Practical understandings play an integral role in organising practice. Not only do practical understandings, or know-how, influence how activities ought to be carried out, they also serve to support a way of doing things according to familiar rules and general knowledge. Practical understandings set out a known way that project level actors, such as engineers, go about their activities. For example, the provision of an infrastructure intervention, such as a concrete channel to manage stormwater, forms part of a tried and tested approach that has an established set of administrative and professional guidelines, and a commonly held belief. By implication, the use of such an approach is considered to be less risky due to its repeatability.

Over time, engineers working on a project develop a practical understanding of how to draw on professional guidelines in different ways to adapt and implement a stormwater solution. This understanding, in turn, serves to qualify practice that responds to material context such as the amount of water entering the channel (see *biological flows* in Section 3.2.1), the choice of materials such as concrete and steel inserts to support its strength (*physical-chemical composition*). Therefore, engineers can approach, design and implement a concrete canal to manage stormwater according to a pre-existing practical understanding of how to carry out that practice.

Practical understanding precedes activities carried out by the engineer in my example above. Practical understanding can precede activities as they can organise practice according to what is already known (Section 3.1.1). For example, project level actors come to know the properties of material features as being physical nature and/or infrastructure, where they can also “carry understandings of the meanings of those humans and nonhumans [referring to materiality like physical nature]” (Schatzki et al., 2001, p. 63). Practical understandings of physical nature and infrastructure form part of “practice and its arrangement” (Schatzki et al., 2001, p. 63). Consequently, practice implies an inherent understanding of physical nature-infrastructure interactions and the social world.

Rules and their bearing on activities

A second way practice can be organised is around rules. When I outlined Schatzki’s practice theory approach, I explained that rules refer to explicit prescriptions on how activities proceed (Section 3.1). While I elaborate on rules below, I need to refer to one key feature of rules that I draw on in more detail in my explanations in the section to follow. Rules is a broad organising component and it can include things such as administrative planning or project management processes, policy or legislated guidelines and presents a way about doing things. Rules tend to be held among project level actors such as engineers, environmental scientists, or landscape architects. By working together on projects, these actors can also gain a practical understanding of the rules they draw on to perform their activities, where it creates certainty around what to ‘do’ and ‘say’, for example, to build the concrete channel in my example above.

Rules is a broad organising component that can influence practice according to its practical understandings or representations of physical nature-infrastructure interactions. I focus on institutional rules and professional guidelines as two forms of rules that can organise an actor's practices on projects. Institutional rules and professional guidelines define legislated roles and responsibilities of project level actors and draw on existing administrative processes to plan, design and implement projects. They can also be constituted by disciplinary approaches, where they define a way of undertaking activities within professional communities.

To start, institutional rules influence practice by setting out the process or protocols for organising activities. By institutional in this instance, I refer to formal social organisations such as government departments or academic institutions that have standard procedures such as environmental law, professional standards and administrative procedures[19] that influence the way project level actors carry out their activities. Rules can be in written or spoken form and organise activities through their "explicit agendas or goals, strategies" (Welch and Yates, 2018, p. 7). The agendas, goals or strategies define how activities are "pursued" (Welch and Yates, 2018, p. 7). By implication, institutional rules organise activities by setting out how activities should be carried out to meet particular agendas or goals.

[19] Defined as "standards, uses, rules, and maxims of good and bad conduct", which guide what actors do (Schatzki, 1996, p. 96).

To illustrate how the activities are influenced by institutional rules I provide an example of environmental law. Environmental law tends to be a legislated institutional rule that has specific roles and responsibilities for environmental professionals on a project. For example, to conduct a baseline study to determine whether or not a constructed canal can be developed, an environmental practitioner who is qualified to carry out the study will need to identify whether or not there are endangered plants or a wetland at the site. The practitioner will refer to a checklist for determining what can or cannot be allowed according to what physical nature is present at the site. Therefore, the environmental practitioner is the only project level actor legally allowed to perform the role of conducting an environmental baseline study, where they draw on institutional rules to identify what to look for and how to carry out the baseline.

Practice can also be influenced by institutional rules such as environmental law. Environmental law can represent physical nature-infrastructure interactions that translate to different types of material features. For example, environmental law can set out the descriptions and plans for managing endangered fora and fauna. It can also set out goals or outcomes, such as teleoaffective above, that can enable actors to protect them through their daily activities on projects. The inclusion of specific representations of physical nature-infrastructure interactions where there are set goals or outcomes services to reduce uncertainty. In other words, the material features become known.

A second way institutional rules organise practice is through professional guidelines. Professional guidelines outline a commonly held way of doing things among a group of project level actors such as engineers, environmental scientists, or landscape architects. For example, under the *engineered approach* (section 2.2), engineers rely on existing guidelines and standards to reduce uncertainty in the design. Professional rules drawn on by engineers could be tried and tested engineering standards, municipal stormwater guidelines or international best practice that influence how actors carry out their activities to achieve a certain goal on a project.

To illustrate how professional guidelines influence activities, I elaborate on my previous example of an engineer building a concrete channel for managing urban water. An engineer will draw on engineering standards and best practice to design a concrete canal. Drawing on standard and best practice enables the engineer to design the channel, where known properties of the water flow (*biological flows* in Section 3.2.1) and which material can be used (*physical-chemical composition* in Section 3.2.1). Professional guidelines, therefore, create certainty, where known dimensions of the water can be used to determine the width of the canal and how many years it will last.

Institutional rules and professional guidelines also support certain representations of physical nature-infrastructure interactions. Representations of physical nature-infrastructure interactions organise practice by influencing how activities are carried out. As part of continued practice, all three organising components, namely practical understandings, rules and general understandings are in a kind of ‘equilibrium’. In other words, representations and understandings of physical nature-infrastructure are stable, where they serve to repeat the same kinds of activities with the same kinds of outcomes. For example, while building a canal to manage stormwater may differ according to the location, flow of water and rainfall pattern that can vary from place to place, the idea and how it is used to respond to stormwater concerns remains relatively the same across different projects.

3.3 Evolving nature-infrastructure interactions through practical understandings, rules and general understandings

Foregrounding nature-infrastructure interactions in practice theory enables me to explore how conceptualisations of physical nature-infrastructure interactions either persist or evolve over time. Toward conceptualising how understandings of physical nature-infrastructure interactions are configured, I draw attention to noteworthy relationships between practical understandings, rules and general understandings I introduced in Section 3.1 above (Figure 3-3). By outlining the different relationships between the organising components of practices, I demonstrate how practice can organise actor activities, where they can either continue to use existing understandings of physical nature-infrastructure interactions (Section 3.2.2) or where understandings evolve according to how concepts are used (Section 3.3.1).

3.3.1 (Re)conceptualised physical nature-infrastructure interactions and evolving practice

Practice can evolve, where different representations or understandings of physical nature-infrastructure influence how actors carry out their activities on projects. I showed how actors and rules can hold or represent pre-existing understandings or representations of physical nature-infrastructure interactions (Section 3.1.2). Practice evolves where one or more of the organising components influence the activities carried out by actors on projects according to the different understandings of physical nature-infrastructure interactions. I now explain how different configurations of physical nature-infrastructure interactions can develop as part of a collective or shared understanding, which can organise practice over time among a group of actors working on a project.

General understandings and doings and sayings

General understandings can develop around understandings of physical nature-infrastructure interactions, where they can serve to create a shared sense of how activities should be carried out. General understandings can bring together a range of actors on projects under one broad understanding of green infrastructure. As general understandings refer to the broad values and beliefs of actors, it can create a “collective identity” around the “pursuit of collective objectives” such a shared environmental ethic or approach to urban development projects (Welch and Yates, 2018, p. 9). While project actors can hold different understandings of physical nature-infrastructure interactions, they “align their different commitments, beliefs and values towards shared activity” (Welch and

Yates, 2018, p. 10). Consequently, general understandings can organise practice around a shared activity that draws on different understandings of physical nature-infrastructure interactions.

General understandings can therefore prescribe collective objectives among project level actors, where they can counter the influence of rules on activities. The ability for groups of actors to orientate their values, interest or beliefs around a common identity that exists outside of institutional rules or professional guidelines, points to one way that different conceptualisations of physical nature-infrastructure interactions can evolve. While on the one hand, there is a “firmness” associated with institutions, there can also be a degree of “plasticity” (Schatzki, 1996, p. 98). Plasticity can enable “more complex practices” to evolve, where they can “overlap, form hierarchies, and join” with former versions (Schatzki, 1996, p. 98).

Plasticity presents opportunities for understanding the momentary power of green infrastructure and how different conceptualisations of physical nature-infrastructure interactions evolve. To go back a step, I showed in the literature review that green infrastructure concepts tend to not be legislated in policy, where specific roles and responsibilities are not assigned to activities associated with green infrastructure. In other words, “bureaucratic organisations [do not have the] professionalised roles ensuring this takes place” (Welch and Yates, 2018, p. 10). As such, the activities attached to statutory stormwater management functions, for example, may not explicitly reference green infrastructure and how it ought to be carried out by actors on projects. General understandings offer an alternative organising principle, where it can evolve through informal spoken or unspoken rules that hold these actors together.

To create a collective activity, project actors can draw on existing institutional rules and professional guidelines or work outside of them. By doing so, actors are required to test their practical understandings on projects, where they must experiment with physical nature-infrastructure in new ways so that their properties can be better understood as practical understandings. Testing the properties of physical nature-infrastructure allows actors, such as engineers, to draw on other material entities that are not represented by existing rules. For example, working outside of engineering standards can draw engineers to a boulder instead of a concrete slab. Although a boulder can provide the same functions as a concrete slab, selecting a boulder requires that actors carry out different activities and interact with physical nature and infrastructure in different ways. This can also encourage them to use different materials that may not fall under existing engineering standards. Therefore, working outside of existing rules requires testing and experimentation.

Testing and experimentation form an integral part of how practice evolves. Without experimentation, actors may not know how to carry out their activities to achieve a collective objective on projects. “Pockets of experimentation” can evolve an actor’s practical understanding or know-how over time, which can organise practice going forward (Schatzki, 2013, p. 39). In other words, the engineer that used a boulder to perform the functional values of a concrete slab may now use it in the design and development of other activities going forward. Hence, testing and experimentation encourage evolution in meanings of physical-infrastructure interactions.

Experimentation and 'know-how'

Experimentation forms part of evolving practical understandings on the properties of physical nature-infrastructure interactions. In other words, to carry out activities to test out the physical-chemical properties of physical nature and infrastructure (Section 3.1.2). Experimentation can support the "gradual evolution" of practice, where new links can develop between an actor's practical understanding and the material world (Schatzki, 2013, p. 39). Therefore, general understandings and the activities to achieve collective objectives outside of rules facilitates the (re)conceptualisation of physical nature-infrastructure interactions among actors working on projects.

The (re)conceptualisation of physical nature-infrastructure interactions can destabilise the equilibrium (Section 3.2.2). While rules may represent physical nature-infrastructure interactions in specific ways, practical understandings support different activities to what is outlined by existing rules, such as environmental legislation and professional engineered standards. Destabilising or disturbing the equilibrium across the three organising principles - practical understandings, rules and general understandings – can lead to an evolution in the meaning of physical nature-infrastructure interactions and shift toward a new equilibrium.

3.3.2 Finding equilibrium through shared practical understandings and rules

Shared activities imply that actors not only work together to test or experiment with the material properties of physical nature and infrastructure on projects, but also that shared practical understandings can arise among them. When actors work to test out the properties of material entities, they involve other actors in their activities. For example, the engineer can draw disciplinary knowledge from other project level actors such as planners or environmental scientists. Another way the engineer may include others is by communicating how the experiment works and whether it is successful or not. Regardless of which actors are involved in the experimentation process, a collective objective draws actors together to support the evolution of shared understandings.

The evolution of the shared practical understandings influences how practice is carried out going forward, where the practical understandings of material features can be (re)conceptualised under a new or different shared understanding. Due to a new shared understanding, project actors such engineers, planners and environmental scientists can “react to material properties of entities or events” in different ways going forward (Schatzki, 2010a, p. 139). These evolved and different understandings can support the “altering, creating, or rearranging [of] material entities“, where the entities may not resemble the representation in existing rules (Schatzki, 2010a, p. 139). By implication, the evolution of shared meanings of physical nature-infrastructure interactions may create challenges, where there may be unfamiliar to other actors, legislation or professional guidelines.

Exploring general understandings and how they support shared understandings demonstrates how physical nature-infrastructure interactions can evolve. (Re)conceptualised meanings of physical nature-infrastructure interactions can serve to “transform” practices, where they “henceforth evolve differently” to include different understandings of green infrastructure concepts (Schatzki, 2013, p. 38). Understandings of physical nature-infrastructure held among actors involved in the project with similar general understandings, therefore, differ “from the versions of the practices that did not migrate” (Schatzki, 2013, p. 38). Consequently, new understandings of physical nature-infrastructure interactions can produce entirely different outcomes. The implications of this are that existing rules are not configured to provide the necessary supporting processes and protocols for their long-term maintenance.

Over time, persistent (re)conceptualised understandings of physical nature-infrastructure interactions can influence rules such as legislation, professional guidelines and best practice. Shared practical understandings can influence how actors carrying out their activities on projects going forward. By adapting and modifying rules according to know-how, project level actors support continued practice, where the evolutionary features of its meaning can fall into equilibrium again. Therefore, practice enters a new equilibrium, where meanings are in agreement across practical understandings, rules and general understandings.

To go back to the start of the chapter, I outlined practice as a broad process that is both meaning-making and identity-forming, where it can define an equilibrium state. As practice can "delimit what people are generally able to do", it plays a role in shaping the activities of other actors in the city or working on other projects, where they draw on (re)conceptualised meanings of physical nature-infrastructure interactions (Schatzki, 1996, p. 161). By participating in activities actors can develop shared practical understandings through the way they "acquire knowledge and abilities, become cognisant of rules, build and alter the physical environment" (Schatzki, 1996, p. 161). Therefore, practice is in a never-ending process of continuation and renewal through evolution.

3.4 Practice and the (re)conceptualised meanings of green infrastructure

In this chapter, I developed Schatzki's practice theory approach to explore how green infrastructure concepts are conceptualised as a situated and contextually bound phenomenon. I chose to focus on the relationship between *practical understandings*, *rules* and *general understandings* to foreground physical nature-infrastructure interactions that are held among one or more actors and how they evolve over time. A benefit of this approach is the ability to foreground the many meanings of green infrastructure concepts, which enables a study of how project level actors come together to negotiate its complexity.

By foregrounding physical nature-infrastructure interactions, I showed how practice can be in a state of equilibrium, or be destabilised over time. General understandings, or commonly held ideas or values among project level actors, can influence how they carry out their activities, where they may find the need to work outside of rules and experiment with new understandings of physical nature-infrastructure interactions. Where experimentations take place, understandings of physical nature-infrastructure interactions can be (re)conceptualised as an individual or collective process that constitutes new shared understandings about the social world. Therefore, practice evolves through the activities of project level actors and influences how they carry out their activities into the future according to their understandings of the social world.

Chapter 4 GENERATING DATA ON GREEN INFRASTRUCTURE AS PRACTICE

In this chapter, I explain how I gathered and analysed data to explore how green infrastructure concepts are conceptualised. To gather data on an actor's understandings of physical nature-infrastructure interactions in Johannesburg, I chose an abductive research design. I selected in-depth interviews to gather participant accounts of their 'temporal journeys' (Schatzki, 2012, p. 25). Gathering data on participant's temporal journeys illuminated the activities they carried out, including the activities of other actors working on 'environment and infrastructure' projects, which facilitated exploring how green infrastructure concepts were conceptualised in practice. In-depth interviews also supported data generation on individual and shared practical understandings of physical nature-infrastructure interactions and how were developed outside rules in unplanned ways.

I presented on my use of physical nature-infrastructure interactions as a conceptual device to explore the many meanings of green infrastructure concept among actors that use them in practice. To explore participant's understandings of green infrastructure concepts, I have chosen to structure the in-depth interviews around participants understandings of physical nature-infrastructure interactions. By asking about 'environment and infrastructure' projects enabled me to explore participants individual and shared understandings, which is what I set out to explore in the conceptual framework.

I gathered in-depth interviews on the use of physical nature-infrastructure interactions at both the city and project scale. Gathering data at two levels enabled me to use an explorative approach to data collection. I began conducting interviews at the city scale to gain an understanding of how participants across government, private sector and civil society understood green infrastructure concepts or ‘environment and infrastructure’ projects in practice. By focusing on ‘environment and infrastructure’ projects as an overarching focus of the interviews, I drew on a wider range of participant understandings of green infrastructure concepts and what it meant to them. In other words, by exploring what participants understood as ‘environment and infrastructure’ projects, I explored particular physical nature-infrastructure interactions held by one or more participants (Figure 4-1).

While I could have asked participants about physical nature-infrastructure interactions, I felt it may detract from my intention to gather a wide range of conceptualisations of physical nature-infrastructure interactions. As the concept of ‘nature’ is broad and can easily become contested due to its many conceptual and material meanings, I chose to avoid this by focusing on ‘environment’, which is a commonly understood term that would likely receive less contestation. The term ‘environment’ tends to be defined as the physical natural world and/or an approach for addressing development. Consequently, I felt the use of the term ‘environment’ did not have the same sensitivities as ‘nature’ among actors (and participants) and would, therefore, enable me to engage around a relatively fixed idea across a range of participants with different backgrounds.

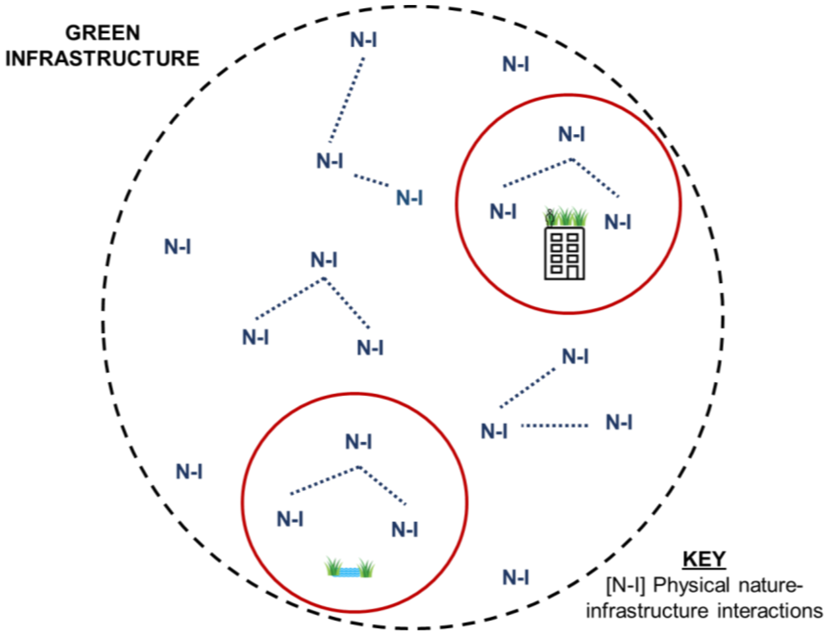

Figure 4-1: Focus on 'environment and infrastructure' projects to draw out specific meanings of physical nature-infrastructure interactions held by participants. Red circles represent how refering to 'environment and infrastructure' projects enabled me to focus on certain understandings of physical nature-infrastructure interactions held by participants.

After identifying ‘environment and infrastructure’ projects, I then zoomed into two ‘environment and infrastructure’ projects identified by city level participants, namely at Bruma Lake and Paterson Park. Gathering data using an ampliative approach not only enabled me to generate data on multiple social worlds, but also facilitated a more detailed study of critical cases, where I gathered data on the temporal journeys of participants who have in-depth knowledge or experience on a particular issue. By focusing on Bruma Lake and Paterson Park, this enabled me to add to what was already known, by pursuing participant accounts further.

To focus on the use of green infrastructure concepts in a more detailed way, it became necessary to focus on a particular context and setting. By implication, it detracted from the procedural elements of practice and how it is in a continuous state of evolution. That said, given the focus of the study around how green infrastructure is conceptualised and (re)conceptualised over time, I felt this decision was justified.

To explain how I gathered data on multiple physical nature-infrastructure interactions I have broken the chapter into five sections. To begin, I explain why I selected a qualitative approach to explore how green infrastructure concepts were conceptualised (Section 4.1). I then present the geographic setting of the study (Section 4.2), before explaining how I gathered data at the city and project levels (Section 4.3). After describing the way I gathered data across these two scales, I explain how I analysed data using a hybrid grounded theory-thematic analysis approach to draw out key themes from participant accounts (Section 4.4). Last, I set out the ethical considerations for the study (Section 4.5).

4.1 A qualitative study on green infrastructure concepts

Abductive research aims to engage with multiple social actor realities at any one time. A study of the multiple realities of actors lends itself to social constructivism where reality, or the social world, exists through the individual and shared interpretations. Generating data on the social realities of actors is beneficial to the study as it supported an understanding of the many evolving physical nature-infrastructure interactions over time. I demonstrated physical nature-infrastructure interactions are situated and contextually bound and can be individual or shared (Section 3.1 and 3.3). Therefore, by generating data that acknowledges multiple social actor realities, it enabled a study of multiple physical nature-infrastructure interactions that are held among participants at any one time.

To analyse the multiple physical nature-infrastructure interactions and how they evolve to have shared understandings, I gathered data on how project level actors carried out their activities over time. Focusing on what actors 'did' enabled me to explore the "temporal journey" of participants[20]. Gathering data on the temporal journeys of actors enabled me to focus "contemporaneous conditions" that influence how actors practiced green infrastructure (Schatzki, 2012, p. 25). Therefore, as part of gathering data, I explored the embedded contextual understandings of physical nature-infrastructure interactions over time.

I took on the role of dialogic facilitator to gather data on the temporal journeys of actors working on green infrastructure projects. A dialogic facilitator supports a study of green infrastructure as practice, by generating data on how multiple actors come to know green infrastructure concepts on projects. In my role, I created dialogue "between the researcher and the researched" by reducing my authority in the research process (Blaikie, 2000, p. 54). Reducing my authority supported a "variety of 'voices' to be expressed" (Blaikie, 2000, p. 54). Taking this

[20] Another way to gather this information is ethnography, where "interaction-observations" allows for data to be generated to explore how practices unfold over time and space (Schatzki, 2012, p. 25).

approach gathered “people’s words for activities and practices” and accounts of their temporal journeys, rather than using my own (Schatzki, 2012, p. 24). By taking on a dialogic facilitator role, therefore, facilitated the collection of multiple evolving physical nature-infrastructure interactions.

To ensure I gathered the experiences of green infrastructure actors on projects, I needed to understand participants’ “way of life” (Blaikie, 2000, p. 54). I did this by allowing them to “speak for themselves” on their experiences of green infrastructure concepts in practice (Blaikie, 2000, p. 54). I used “verstehen”[21], or “thick descriptions”, where I generated data by “grasping the subjective meanings used by the social actors” (Blaikie, 2000, p. 54). By taking this approach, I gathered information about the participant (race, age and language), study site and actor context (history, individual interests, geography and professional knowledge). This supplementary information supported my analysis of data in Chapter 6 and Chapter 7 and strengthened the validity and reliability of the study findings (Section 4.5).

In-depth interviews made it possible to gather participant accounts to understand their activities and how they comprised practice. I used in-depth interviews as a way to engage in “a conversation with a purpose” and to gather thick descriptions (Hennink et al., 2011, p. 109). In general, in-depth interviews are used for the “purpose of gaining a detailed insight into the research issues from the

[21] Or the need to capture participant’s actions, framings or experiences from their point of view.

perspective of the study participants themselves” (Hennink et al., 2011, p. 109). As I reflected on in the qualitative research encounter, gathering the experiences of participants formed an important part of exploring practice where I drew out the many understandings of physical nature-infrastructure interactions, including participant’s words for them.

Studying how social actors come to know their world through their actions and experiences situates knowledge production as an iterative process. Findings were not obvious at the start of the research project, rather they evolved throughout the data generation and analysis process. This kind of knowledge production is known as “ampliative”, where the conclusion is “not already present in the premises” (Hammersley, 2005, p. 5). As such, “abduction leads the way into the next task”, where it enabled me to develop knowledge in ways that supported an understanding of how green infrastructure was conceptualised according to a particular context and setting (Hammersley, 2005, p. 5). As I mentioned earlier, the green infrastructure concept is used in relation to a particular context or setting, where it can influence how concepts evolve.

4.2 Geographic setting

The geographic location of the study is the Johannesburg Metropolitan Municipality (now referred to as *Johannesburg Municipality*), which is demarcated by the administrative boundary. Toward exploring how the context and setting influence how project level actors carry out their activities, including rules that apply to geographic settings, I provide general background information related to the geographic setting, which forms the basis for my analysis chapters (Chapter 6 and Chapter 7). As the setting and context form such an integral component for how practices unfold, I return to the geographic setting to build on the administrative process and state of infrastructure in the section to follow (Chapter 5).

Figure 4-2: Johannesburg Municipality located in the Gauteng Province, South Africa (Source: Author).

The Johannesburg Municipality is in the north-eastern part of South Africa. Johannesburg Municipality is located with the smallest of South Africa's 9 provinces[22] and it has the largest population in the country, with an estimated 4.4 million people (Statistics South Africa, 2011), (Figure 4-2). Similarly to many other South African cities, Johannesburg is “spatially disfigured” due to its Apartheid history which saw resources and investments being made in white areas of the city (Abrahams and Everatt, 2019, p. 255). These investments have left a legacy in the city, where “highways, light industrial plants, rivers and streams” lie at odds with each other, where they are interspersed across different parts of the city in fractured arrangements (Abrahams and Everatt, 2019, p. 255). Consequently, while the demand for resources and services is high, they are dealt with across a fundamentally divided and spatially disfigured landscape.

Physical nature in Johannesburg

Physical nature in Johannesburg takes many different forms. Physical nature is dotted in and among residential areas, where large expansive open areas are found on the periphery of the urban centre. The physical nature of Johannesburg is significant for conceptualising green infrastructure, where it has not only formed part of the history of the city, but also presents a solution to water pollution (Bruma Lake) and flooding (Paterson Park). The latter point will become more apparent when I describe how green infrastructure was practiced in Johannesburg in Chapter 6 and Chapter 7.

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[22] The total area of Johannesburg Municipality is 1 645 km^2 (Statistics South Africa, 2011).

Johannesburg Municipality is located in the *highveld region* of South Africa. The *highveld* is an area of South Africa that is characterised by a high lying plateau. The significance of which is its set of expansive grasslands, which are considered to be the native vegetation of the city. In addition to grasslands, it has a wide array of other kinds of physical nature such as an expansive set of ridges and a large planted urban forest, with over “10-million trees”, cemeteries and a collection of urban streams (Mail and Guardian, 2012, p. n/p). Although not being native to the city, the extensive forest represents a rich cultural history that has served to shape Johannesburg over time.

Physical nature and history

To begin, the planted urban forest is a noteworthy feature of Johannesburg’s settler history. In the chapter to follow, I illuminate how the city’s early beginnings are rooted in gold mining (Section 5.1). Gold mining brought an influx of people of European decent to the city to prospect on the gold mines. Trees such as *Eucalypts*, or “blue and red gum trees” as props to support the cavernous “underground tunnels” (Mail and Guardian, 2012, p. n/p). Trees were also planted in early European settlements, such as “*Oaks, Pines* and *Wattles*”, which later formed the formerly white suburbs of the Apartheid period. Orange Grove, which I refer to in more detail when I describe the study sites (Section 5.3.2), is one such example.

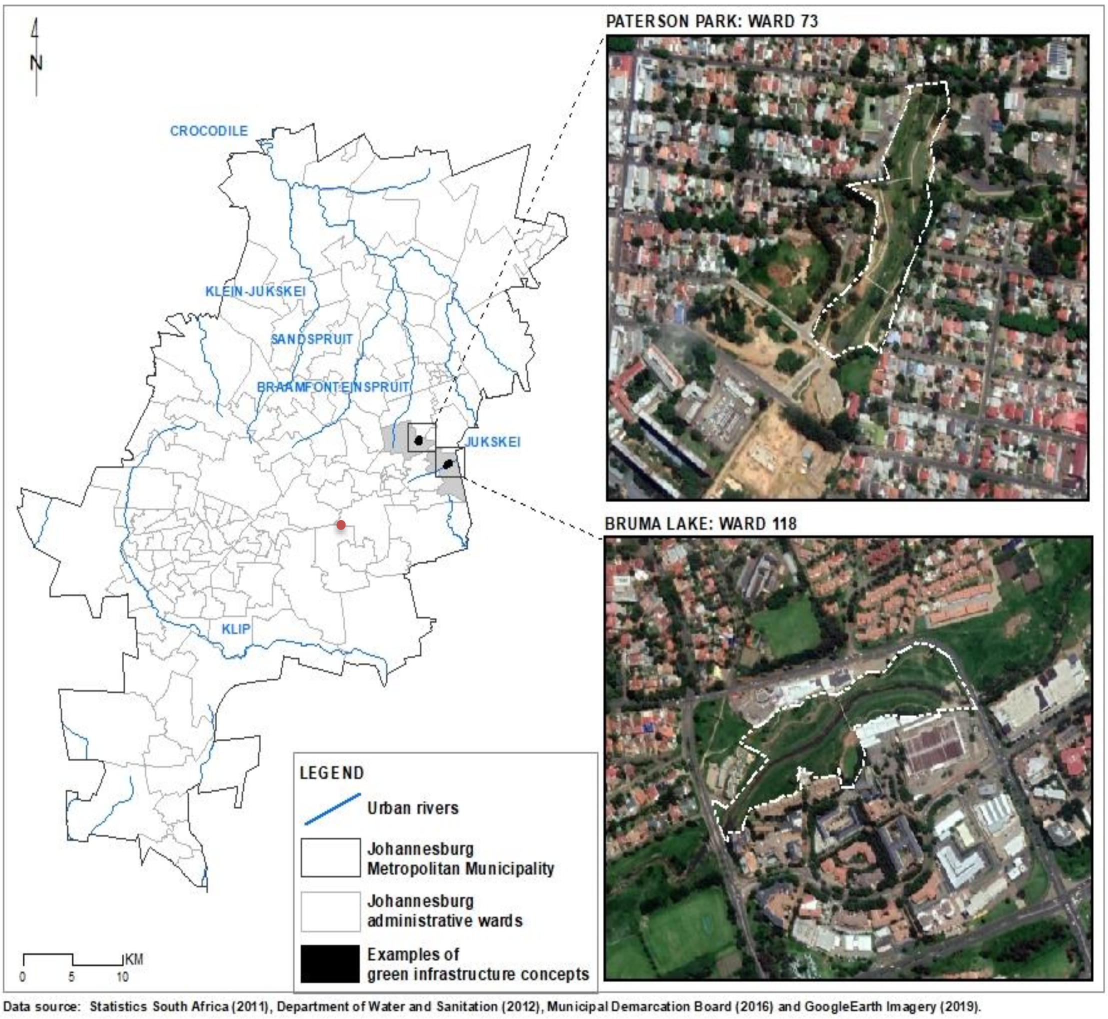

Figure 4-3: Location of Bruma Lake and Paterson Park projects in Johannesburg, South Africa. The centre of Johannesburg is indicated by a red dot (Source: Author).

Johannesburg also has a range of public and private green spaces that include parks, parklands, abandoned Johannesburg Municipality land and empty plots. A noteworthy type of physical nature that relate to the thesis are parks. Parks were first created in the city as part of early developments around gold mining, such as Joubert Park in the central part of Johannesburg (indicated by the red dot in Figure 4-3) resembled an English “Victorian parkland” (Mail and Guardian, 2012).

The park portion of the Paterson Park site was originally a farm that was later developed into a park after it was inherited by Johannesburg Municipality (Section 5.3).

Urban water flows

The city is fed by an intricate web of small conduits and streams or *spruits*[23]. Despite its web of urban water conduits, Johannesburg has been afforded its development by importing its water from Lesotho as part of the *Lesotho Highlands Project.* While Johannesburg is the most densely populated urban centre in South Africa, it was not developed around a sustainable water supply. While importing water does not form the basis for the thesis, it is important to mention that managing urban water flows as physical nature forms an important part of the daily legal responsibilities of Johannesburg Municipality (Figure 4-3). The significance of which becomes apparent when I explain the Bruma Lake project in more detail (Section 5.3).

The current state of water conduits and spruits is poor, with high instances of water pollution and erosion. One such river that I refer to in the thesis at the Bruma Lake site is the Jukskei River that is “infamously polluted” (Christie, 2014, p. n/p), (Section 5.3). Water pollution emanates from failing buildings in the central business district (indicated by the red dot in Figure 4-3), where the effluent from poorly managing buildings enters into water conduits and spruits. Another

[23] Afrikaans term for a seasonal stream.

reason for pollution is through illegal dumping that introduces debris and litter into the urban water system, including its mining waste. While I do not delve into mining waste in detail as it has a limited impact on the study sites, it is noteworthy to flag as it demonstrates broader pressures on urban water flows in the city.

4.3 Gathering data on 'environment and infrastructure' at the city and project levels

I gathered participant accounts during 71 in-depth interviews with 74 [24] participants that cut across a range of participant groups (48 city level and 26 project level participants) that enabled me to understand physical nature-infrastructure interactions at the policy and project levels. I supported these interviews with other methods including meeting key informants, observing actor activities at events, and appraising policy documents[25] (Section 4.3). Using more than one method increased the reliability of project findings as it allowed for the triangulation of information that I gathered during the interviews by cross-checking findings using document analysis[26].

I gathered data on the use of green infrastructure concepts at two scales. The systemic, or city-wide scale, and the project level. Gathering data at two scales enabled me to explore green infrastructure as a situated and contextually bound

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[24] To collect valid accounts of participant meanings and their activities, I found it necessary to schedule follow up interviews where there was not enough time to cover all the interview themes (city and/or projects) during the participant interviews. I also conducted follow up interviews where other participants indicated the participants were 'champions', or the most important actor in the understanding and use of green infrastructure concepts at the city or project level.

[25] Participants shared these with me, or they referred to them in their interviews.

[26] Triangulation is a way to cross-check data, where it is "the practice of employing several tools within the same research design", where it allows for "the researcher to view a particular point in research from more than one perspective and hence to enrich knowledge and/or test validity" (Sarantakos, 2013, p. 159).

phenomenon, where the use city level accounts facilitated an understanding at the project level. I present on the process I used to collect city level accounts of green infrastructure and related projects (Section 4.3.1) before I demonstrate how I refined my approach at the project level by selecting two projects using a critical cases sampling method (Section 4.3.2). I order the section in this way as it allows me to show how and why I selected the projects I used as the focal point of the study.

4.3.1 City level accounts of 'environment and infrastructure' projects

I began conducting interviews with actors involved in the use of green infrastructure concepts in the city. I defined 'use' according to the actor's existing involvement in the doings and sayings of green infrastructure concepts in practice from my knowledge and experience. I identified participants that were involved in initiating or supporting dialogue on green infrastructure concepts or were directly involved in their conceptualisation, development and implementation. By defining 'use' in this way, I selected participants from a range of backgrounds. Participants included officials from municipal departments and municipally-owned entities; officials, private sector professionals and members of civil society involved in environment and infrastructure applications in the city; and officials, private sector professionals and members of civil society involved in activities linked to institutional rules such as statutory law, legal roles and responsibilities[27] and municipal administrative processes for managing environment and infrastructure.

The institutional rules I used to select participants included: (1) the Johannesburg Spatial Development Framework 2040 that outlines the spatial vision for the city and strategies to achieve this vision; and, (2) the Integrated Development Plan[28], a central document for laying out the agreed development priorities for actors in the city. Using both policy documents enabled me to select participants who were involved in the systemic, or city level policy activities around the use of green infrastructure concepts. I also selected professional and civil society groups based on reports in the media and participants recommended to me by stakeholders I met or other study participants[29].

Sampling for those interested or involved in 'environment and infrastructure'

Following this approach, I selected participants with institutional roles and responsibilities associated with the management of physical environment and infrastructure, but also those who did not. As I later show in the analysis chapters, this latter point was significant as it revealed a range of civil society participants that also influenced the management of environment and infrastructure in the city

[27] Outline in the Constitution of The Republic of South Africa 1996 Section 155(6)(a) and (7). Includes functions such as management functions attached to air quality, stormwater management, water and sanitation, parks and recreation and refuse removal.

[28] A legally binding 5-year strategic plan that guides the social and economic development in Johannesburg.

[29] I approached most of the participants using a snowballing sampling technique. Some participants did not respond to being contacted (15 participants) and some participants avoided interviews (on three occasions). My standard approach was to follow up with participants three times each. In cases where participants were identified as playing a significant role in the use of green infrastructure concepts in practice, I followed up a further time via WhatsApp or in-person by sending them a message or calling them on their mobile phones.

(Chapter 6 and Chapter 7). Their activities did not necessarily form part of institutional or professional rules. The implications of gathering data from a range of stakeholders with institutional and other responsibilities around the use of environment and infrastructure approaches was that I could consider how green infrastructure concepts are influenced by a variety of actors in practice.

I used purposive sampling to select participants involved or interested in 'environment and infrastructure' projects in Johannesburg. Purposive sampling implies that I selected a sub-set of participants around the parameters I presented above. To select participants who met the abovementioned criteria, it was necessary to conduct research beforehand to identify them. To do this, I developed a database using online research and information shared with me by key informants. To contact and schedule interviews, I used the database as a living document to manage the process[30]. Over time, I added to the database through snowballing, where I identified other participants within the study population.

Using the database, I sampled for typical cases. In other words, I sampled for common features or attributes across the participants. Sampling for typical cases made it possible to collect data from a range of disciplines, roles and personal activities. It also afforded me the opportunity to gather data from participants involved in activities influenced by institutional rules and general understandings.

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[30] Database included the names, affiliations and contact details of participants. I also used the database to record the number of times I contacted participants.

I contacted participants over the email and telephone. The email was my preferred mode of contact as it allowed participants to freely decide to participate in the study. I only used the telephone in instances where only telephonic information was available or where other participants indicated this was the only way to contact them[31]. I also used the telephone to confirm whether participants received interview requests and to follow up on interview details.

In-depth interviews

I scheduled interviews at a suitable time in a location where the participant felt comfortable[32]. I also scheduled interviews with more than one participant[33] or met them at project sites. In most cases, the participant's time constraints limited their availability and interest for meeting me on-site. I recorded the interview on an audio device and recorded the route taken concerning feature of interest at the sites such as the renaturalised river and park. I also recorded participant activities such as pointing or engagement with other actors at the project sites, such as maintenance workers, including references to key elements of the project, points or features of contention, contestation or agreement based on spatial phenomenon.

[31] Over time, it became apparent many participants communicated using text messaging or platforms including WhatsApp rather than the email. I used this mode of contact where the participant preferred it or where participants explained it was the only mode of communication.
[32] I held interviews in a public location such as the participant's place of work or at a café for example. Arranging interviews in public settings ensured the safety of the participant and me.
[33] Where the participant showed a preference or arranged this themselves.

Interviews lasted between 1 – 1.5 hours and I spoke with participants for as long as they indicated they wanted to. I conducted all my interviews in English and recorded them on a handheld audio device. I considered this common procedure unless participants requested otherwise. At least five participants requested to talk off the record. During these times, I stopped the audio and did not record field notes. After the participant indicated it was okay, I resumed the audio recording. I treated the interviews as a conversation by probing participants around themes related to the topic of the study. I developed an interview guide to cover topics related to the research question, which I used to probe participants to explore physical nature-infrastructure interactions (Table 4.1).

I used probing to support an abductive research approach. Probing allowed me to engage in "a conversation with a purpose", where I was able to draw out noteworthy topics or themes according to a pre-prepared interview guide (Blaikie, 2010; Hennink et al., 2011, p. 109). To develop the interview guide, I used a conceptual framework, where I showed the links between practical understandings, rules and general understandings (Figure 3-2). The interview guide engaged with the following broad themes to generate data on participants. Themes included:

- Participant's background such as their role, activities related to environment and infrastructure interventions and understanding of physical nature-infrastructure interactions;
- Their approach and use of environment and infrastructure policies, plans and standards in general;
- Their focus and activities on green infrastructure projects or applications (if any); and,

- Activities and interactions with other actors concerning policies on environment and infrastructure, plans and standards and green infrastructure projects or applications where applicable.

I piloted the interview guide on five participants to gauge its effectiveness. After the pilot, I refined[34] the interview guide and my approach to conducting the interviews (see the final guide in Table 4.1).

Table 4-1: Research themes used to guide in-depth interviews at the city level

CITY LEVEL INTERVIEW THEMES
Role and background
Explain projects/work
Rationale for projects/work*
Approach used*
Process for conceptualising, developing and implementing approach/projects/work*
Use of any plans, policies, standards etc.*
Actors work most closely with*
Most influential actors*
Actors not worked with*
People to contact

*Applicable in instances where green infrastructure or related projects were being pursued at the time or had been completed.

[34] I refined how I probed participants when they went off topic, included introductory questions to support verstehen and to build rapport and re-ordered interview themes. I reflected on the pilot to refine participant information sheets and consent forms which explained the ethical and data security concerns.

During the interviews, I was careful not to use the term ‘green infrastructure’, or any related concepts that fell under the general thrust of green infrastructure concepts that support environment and infrastructure interventions. Similar concepts included nature-based solutions, ecological infrastructure and sustainable urban drainage systems (Table 2-1). As understandings of green infrastructure, where there are differences in the way participants could conceptualise the concept, I referred to the project as being a study of ‘environment, infrastructure and urban management’, rather than ‘green infrastructure’. By not directing the conversation with participants toward a predefined understanding I feel it allowed me to identify the range of physical nature-infrastructure interactions rather than one understanding of green infrastructure. As I describe in more detail in the section on project level accounts, it also enabled me to gather data on how green infrastructure was conceptualised. I continued to interview participants until I realised that I had achieved saturation when data began to repeat itself[35].

While conducting the interviews, I took down notes in a field notebook. I was careful to record key points of interest, my observations, routes I took on any site visits and interesting remarks or participant emotions. After returning from the field each day, I typed the notes and added to them where possible. I believe this step was important to capture the time I spent with participants – my feelings,

[35] I identified saturation is the point where “no additional data […was…] found” (Glasser and Strauss, 1973, p. 61). In other words, I knew I had achieved saturation when accounts were “similar” and were repeated over and over again” (Glasser and Strauss, 1973, p. 61).

thoughts and ideas. By doing so, I also captured other kinds of data that I could not record on the audio device[36]. In addition, every two weeks I also conducted what I call a 'brain dump', or the writing down of my reflections. The information was useful for consolidating preliminary findings and for selecting projects and the actors involved in them.

4.3.2 Focusing on two 'environment and infrastructure' projects to explore (re)conceptualised physical nature-infrastructure interactions

I interviewed participants that were involved in 26 different green infrastructure projects in Johannesburg. I have provided an overview of these projects in the Appendix (Appendix 1). Participants identified a range of environmental and infrastructure projects such as urban water management, mixed-use housing, or retail developments and environmental preservation. Projects were funded and managed by a range of participants such as Johannesburg Municipality and private sector entities such as developers or non-profit organisations. Participants described projects according to their use or benefit to them or the city, where they identified successful projects if completed, or where a different or innovative approach was followed or used. To explore how participants and other actors used an environment and infrastructure approach at these sites, I selected two projects to investigate physical nature-infrastructure interactions and the activities of actors in more detail.

[36] Included disruptions or where participants did not talk to certain topics.

I used the terminology ‘environment and infrastructure’ instead of green infrastructure when talking to participants about the study. I believe using this terminology enabled me to focus on particular physical nature-infrastructure interactions that are held by one or more participants at any one time. I felt that making this choice encouraged a broader focus on green infrastructure concepts and how they are conceptualised, but also enabled me to focus, or zoom in, on two shared understandings of ‘environment and infrastructure’ (Figure 4-1). By implication, I explored green infrastructure, where it came to have similar meanings or connotations across a range of participants, including the many individual or shared meanings of physical nature-infrastructure interactions

I will draw attention to noteworthy groupings of projects identified by participants before I move on to explaining the projects I chose for the study. Describing these groupings enabled me to set the scene, or broader context, of green infrastructure projects. For example, municipal projects tended to relate to an urban water-related infrastructural problem such as flooding, stormwater management or where poor infrastructure design made it technically impossible for actors to intervene due to cost or risk, or where there were insufficient funds to address infrastructure concerns across the entire infrastructure network (Appendix 1). Projects included an *engineered approach* called a river renaturalisation at Bruma Lake, Paterson Park and Bosmont (Section 2.1). In all three of these projects, a green infrastructure approach was drawn on to address failing urban water management infrastructure that was affecting the local community. Addressing these concerns at the project level also demonstrated broader infrastructural concerns at the city level, where ageing and failing infrastructure served to create concerns over the provision of reliable services or where flooding created concerns for residents. Projects to address urban water management and flooding tended to be explained using references to an *engineered* or hybrid *engineered-ecosystem services approach*.

Other municipal projects where green infrastructure concepts were referenced included creating or restoring wetlands at Moroka Dam, Kelland wetland and Queens Street, Bruma. Projects formed part of a broader wetland restoration initiative across South Africa, where wetlands were used to purify water, therefore, reducing the need for other kinds of water purification on-site or downstream. All the listed wetland projects had been completed at least 5 years before the fieldwork took place and there were one or more actors – municipal officials and private sector professionals – working on these projects. Participants who worked on these projects explained that they had reflected and developed their activities to refine their efforts on these projects. These projects tended to be explained using an *ecosystem service approach*.

Municipal officials also used environment and infrastructure interventions as a form of planning development control. One municipal official at the Environment and Infrastructure Services Department explained that they chose to use existing rules such as planning development control to influence the use of green infrastructure concepts in practice. Cedar Lofts is one example, where participants from the Environment and Infrastructure Services Department set guidelines for private developers to use green infrastructure concepts. A private developer applied to the municipality to develop housing on a site where there was an existing wetland. Under South African law, developing over a wetland is illegal. Instead of declining the development, municipal officials at the Environment and Infrastructure Services Department chose to use existing rules such as stormwater management bylaws to set conditions on the kind of development that could take place. Conditions included preserving the wetland and developing the site into a residential complex. Listed conditions on the project became legally binding in the implementation of the project. Projects were described as a hybrid of landscape planning approach, with features of the *ecosystem service* and *engineered approaches*.

A further way green infrastructure concepts were used was by non-profit organisations. An example of this was site-level interventions at Diepsloot, where community-led bioswales were implemented through a partnership between non-profit Sticky Situations, Water and Sanitation for the Urban Poor[37] and the University of Witwatersrand. A site-level bioswale was developed with the local community and tested to manage runoff from communal taps which were undermining land and flooding housing[38]. The bioswale formed the basis of

[37] Also known as 'WSUP', an international non-profit organisation that aims to improve sanitation services by working together with local community members and service providers.
[38] The bioswale was constructed from discarded materials that could be readily found in a South African informal settlement such as broken or 'half' bricks and discarded building materials, including broken concrete slabs.

student projects at the University of the Witwatersrand, which aimed to develop the approach further from a technical perspective.

Selecting Bruma Lake and Paterson Park

As my research design relied heavily on the accounts of participants to understand their temporal journeys on physical nature-infrastructure interactions, I needed to be able to find and interview participants involved in the projects. This meant that I was not able to explore all the 'environment and infrastructure' projects identified by participants in detail. For example, other municipal projects such as Moroka Dam, Kelland wetland and Queens Street (Bruma) took place at least 5 years before the fieldwork period. Given the lapse in time, it would have presented a fundamental barrier to understanding how green infrastructure concepts were used as influential participants may have taken on other roles or left the vicinity of the project. In addition, practice was likely to have evolved during this time.

Another reason I did not select Moroka Dam, Kelland wetland and Queens Street (Bruma) for further investigation was because it would have created concerns given the institutional rules and politics. As many of the city's policy and plans are changed and updated according to a political tenure period of 5 years, institutional rules and their representations of physical nature-infrastructure interactions would likely have changed. As understanding how participants worked within existing institutional rules and outside them forms a noteworthy feature of my conceptual approach, this would also present a barrier to gathering timely and rigorous data (Section 3.1). Therefore, given the strong conceptual focus on rules and how they influence practice, I felt selecting more recent projects was justified.

Bruma Lake and Paterson Park were identified by participants as two recent examples of ‘environment and infrastructure’ projects. Bruma Lake and Paterson Park were explained to be a striking example of where an ‘environment and infrastructure’ intervention had been used to manage urban water flows. The intervention used at the sites was river renaturalisation, which is an example of the *engineered approach* I presented in Chapter 1. The *engineered approach* focuses on the use of physical nature as a way to solve urban problems by working with physical nature and not against it (Section 2.1). At the two sites, the use of river renaturalisation meant that water flows were managed in such a way where instead of building a concrete or synthesis conduit, it was developed to resemble a river system. As I illustrate in the chapter to follow, elements of physical nature such as boulders and plants were used to provide functional value, rather than relying only on conventional materials with well-understood physical-chemical properties (Section 3.1), (Figure 4-4 and Figure 4-5).

Figure 4-4: Photographs of the renaturalised river and park at Bruma Lake. (A) and (B) show the renaturalised stream, boulders and surrounding vegetation from a west-facing direction. (C) and (D) show the park with recreational equipment and open green space from a north- and east-facing direction (Photographs taken by the author on 10 and 24 April 2018).

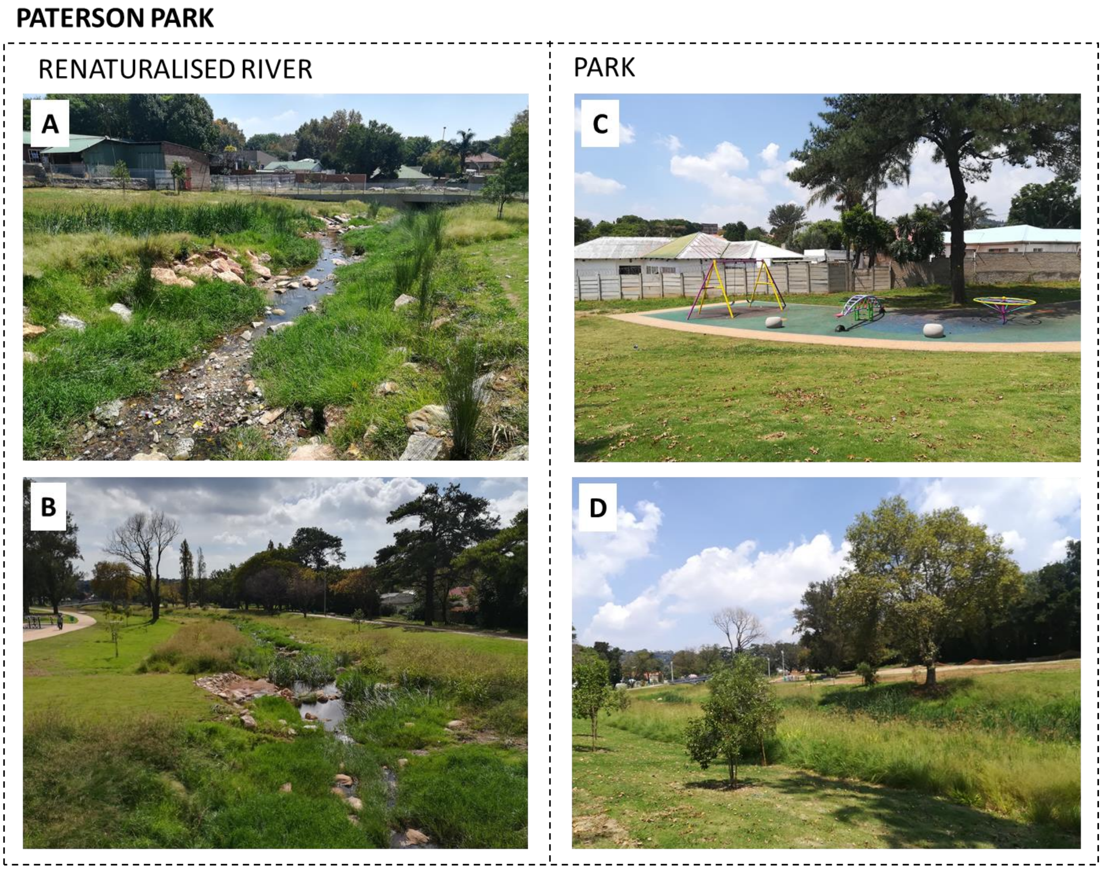

Figure 4-5: Photographs of the renaturalised river and park at Paterson Park. (A) and (B) show the renaturalised stream bed, banks and surrounding vegetation from a northern and south-facing direction. (C) shows the park created as part of the project with recreational equipment and open green space; and, (D) shows the park and renaturalised stream from a west- and south-facing direction (Photographs taken by the author on 14 March and 10 April 2018).

After selecting Bruma Lake and Paterson Park it became clear that the two projects shared the same design engineer. That said, while projects followed a similar approach with the same design engineer, they were used in slightly different ways. As I explain in Chapter 6 and Chapter 7, a form of green infrastructure called river renaturalisation was used at the sites in different ways. Selecting Bruma Lake and Paterson Park allowed me to explore one type of green infrastructure practice in the city, where river renaturalisation was used in practice (Section 8.3). By exploring how green infrastructure is practiced as a process, I was able to understand how physical nature-infrastructure interactions evolve or shift over time.

Sampling participants involved in the projects

To select participants for in-depth interviews at the project level, I used critical cases. Critical cases is a sampling strategy used to interview participants that have in-depth knowledge or experience on a particular issue. Selecting critical cases enabled me to gather data on actor activities at Bruma Lake and Paterson Park, where I was able to explore their activities in more detail. Selecting critical cases enabled me to illuminate the individual and shared activities of actors and how they amounted to the use of river renaturalisation, or green infrastructure practice. Therefore, by focusing on actors at the project level, I was able to explore how practice evolved as a process.

Identifying participants for in-depth interviews

To identify participants involved in the projects, I developed a stakeholder diagram for each project where I mapped out all actors involved in the projects according to their roles and responsibilities at various stages. Participants included, but were not limited to, government officials (municipal), researchers and academics, private sector, non-governmental organisations (international, national, provincial) and national/international institutions. I added actors to the diagrams based on participants' accounts of who was involved in the use of green infrastructure concepts at both projects. I treated it as a live diagram, adding to it and amending it over time. It is worth noting participants had a range of roles and responsibilities on the project around knowledge creation, administration, policymaking, service provision and construction and included community activists and project champions. The latter point formed a noteworthy feature I refer back to in Chapter 6 and Chapter 7 as the concept was used across a range of actors that spanned a variety of institutional and other roles and responsibilities.

Gathering data across a wide range of participants contributed to the rigour of the research methodology. By interviewing a wide range of participants, I was able to explore the multiplicity of green infrastructure, while also reducing the subjectivity of the data. Ensuring rigour was important as there is a "potential for subjectivity" in social science research (Cypress, 2017, p. 254). By creating rigour I ensured the data was not "worthless" or that it "loses its use" (Cypress, 2017, p.

254). Therefore, by gathering data from a variety of participants enabled me to explore the complexity of green infrastructure more rigorously.

Table 4-2: Research themes used to guide interviews at the project level. I have included an overview of city level interviews themes to show how I adapted and refined themes at the project level.

CITY LEVEL INTERVIEW THEMES
Role and background
Explain projects/work
Rationale for projects/work*
Approach used*
Process for conceptualising, developing and implementing approach/projects/work*
Use of any plans, policies, standards etc.*
Actors work most closely with*
Most influential actors*
Actors not worked with*
People to contact

PROJECT LEVEL INTERVIEW THEMES
Role and background
Explain projects/work
Involvement
Rationale for projects/work
Contributions
Approach used*
Approach origins*
Striking features or outcomes of project/work*
Different from other projects worked on*
Changes in process for conceptualising, developing and implementing projects/work*
Changes in use of any plans, policies, standards etc.*
Actors worked most closely and in what ways
Most influential actors in supporting approach

Actors not worked with
Changes in engagement/relationship with other actors*
Translation of technical concepts in practice †
Key moment/activities/people
Interdisciplinary working †
Communication †
People to contact

*Applicable in the cases where green infrastructure or related projects were being pursued or had been completed.
† Themes added to the list of themes based on key discussion points identified in the previous phase.

I conducted project level interviews in the same way I did for city level interviews. This involved contacting participants over the email and telephone and conducting interviews[39] in person[40]. Interviews ranged between 1 – 1.5 hours in length[41]. Again, I treated the interview as a conversation with a purpose and probed participants using key themes contained in the interview guide, although I did this sparingly to allow participants to draw on aspects of physical nature-infrastructure interaction they felt were important to the topic of discussion. I adapted and refined the key themes for the project level interviews according to the preliminary findings I gathered in the city level interviews above.

[39] As for city level interviews, I also met participants on-site where I followed the same process for collecting experiences, routes and activities.
[40] I conducted interviews in English and recorded them on a hand-held audio device for transcription.
[41] Interviewing participants on-site sometimes went over this time estimation and lasted up to 3 hours.

Toward understanding the use of green infrastructure concepts at the project level I needed to ask questions such as who, where, when and why and how the projects unfolded. Given the nature of the conceptual framework, focused on actors and their activities I paid attention to the activities or the 'doings' and 'sayings' of individual and groups of actors undertook activities that supported the use of green infrastructure concepts in practice. I provide an overview of the themes I included in the project level interviews in comparison with the city level interviews (Table 4-2). Toward refining the themes, I use to guide project level interviews, I adapted the city level themes in the following ways:

- Included a focus on participant activities and actor interactions at the project level;
- Asked participants about the approach they used (which actors, where and why), origins of their ideas and striking features of the project;
- Focused on how concepts influenced participant activities, practices or approach to infrastructure management;
- Asked about the use of plans, policies and standards, including interactions with other actors and associated activities; and
- Probed around the translation of technical concepts in practice, interdisciplinary working and avenues for communication.

I achieved saturation after data began to repeat itself[42]. Reflecting on my full list of participants, I was able to interview at least 85-90% of the participants I identified across the two projects. Instead of focusing on accounting for the activities of all actors at Bruma Lake and Paterson Park across the two projects, I chose to focus on achieving saturation across responses from each of the

[42] I identified saturation is the point where "no additional data […was…] found" (Glasser and Strauss, 1973, p. 61). In other words, I knew I had achieved saturation when accounts were "similar" and were repeated over and over again" (Glasser and Strauss, 1973, p. 61).

participant groups – such as municipal officials, private sector professionals and across different civil society groupings. For example, I achieved saturation where participants descriptions of projects, actor activities and outcomes began to repeat themselves among participants in each group.

The implications of achieving saturation across the participant groups made it possible to focus on creating a robust account of the activities of actors both within their sectoral group, but also with other actors. Taking this approach enabled me to verify the data gathered in the 'doings' and 'sayings' of actors and gather data on shared understandings and how they evolved within and across participant groups. In this instance, I acknowledge an outlier response may have shifted the findings of the study. Nevertheless, as I intended to gather shared understandings and knowledge among participants, I felt taking a risk was justified as it enabled me to gather data to respond to the research question, while also creating rigour.

Supporting data

During the fieldwork period, I also attended public sessions on topics related to the use of green infrastructure concepts in Johannesburg and at the two project sites. I attended public lectures and municipal public participation sessions such as the session scheduled by Johannesburg Roads Agency on the Stormwater Masterplan in the vicinity of Paterson Park. I felt attending these sessions enabled me to gain a good sense of the context and setting for the projects. I recorded sessions on an audio device and wrote up general notes on what I saw and thought in my field notebook.

4.4 Analysing data to explore how green infrastructure concepts are conceptualised

After I gathered data for the study, I transcribed participant interviews verbatim to ensure participant's exact words and phrases were preserved. I transcribed 60% of the total interviews[43] (Table 4-3 and Table 4-4). I decided which interviews were most relevant by discerning which were most descriptive. To discern which projects were most relevant, I used participant interviews that were richer in context and detailed issues in more depth. I selected interviews where participants described each stage of the project, the activities they carried out, how their activities drew on institutional rules or general understandings and how this contributed to overall green infrastructure practice. I did not transcribe interviews where participants shared information that did not relate directly to the research question. As with the interviews, I transcribed enough city and project level interviews to gain saturation (Section 4.3).

Selecting to analyse data by dividing interviews into actor groups enabled me to further ensure rigour. First, it ensured I had gathered the accounts of a range of participants to include their understandings of physical nature-infrastructure interaction to enable a study of the use of green infrastructure concepts by a

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[43] I transcribed 43 of the 71 of the interviews I conducted.

variety of institutional or other actors. Second, it created rigour by verifying participant descriptions of tensions and overlaps between physical nature-infrastructure interactions across and within groups in a more focused and detailed way. Nevertheless, as I intended to gather shared understandings and knowledge among participants, dividing the interviews according to the group made it possible to respond to the research question.

Table 4-3: Total number of participants interviewed per sector

PARTICIPANTS PER SECTOR	NUMBER
Government (GOV)	24
Private sector (CONS)	19
Academics and researchers (ACA)	17
Civil society (CISCO)	13
Multi-lateral development finance institution	1
TOTAL	**74**

Table 4-4: Total number of city and project level participants interviewed

PARTICIPANT OVERVIEW	NUMBER
City level	48
Project level Bruma Lake	10
Project level Paterson Park	15
Both equally	1
TOTAL	**74**

While it might have been beneficial to transcribe all 71 interviews, it is unlikely more than 60% of these interviews would have added any new information to the analysis. In cases where I did not transcribe interviews, the notes I had typed up after the interview took place served as a guide as to whether they contained any data of interest or relevance to the study. In the case of any data of interest, I listened over and/or subsequently transcribed 2 further interviews. I have included a summary of transcribed participant interviews in the appendix, including the identification codes I used to reference participants (Appendix 3).

Analysing city and project level data

I began analysing the transcriptions in coding software called *NVivo* using a grounded theory approach. Grounded theory afforded an analysis of individual actor accounts, including thick descriptions, by drawing on the context and settings of participants. Grounded theory enables themes to emerge through the data analysis process, where it "begins with the empirical world and builds an inductive understanding of it as events unfold and knowledge accrues" (Charmaz, 2008, p. 155). Collecting data as part of an emergent process is "well suited […to…] studying uncharted, contingent, or dynamic phenomena" (Charmaz, 2008, p. 155). To collect participant accounts and create themes I developed a codebook that acted as a living document for data analysis, where I added codes as necessary. To understand how I coded data, I need to explain how I developed the codebook.

To create the codebook I followed guidelines by Hennink et al., (2011) and Guest et al., (2012). First, I developed deductive codes using topics I covered in the literature review, interview guide and researcher experience of the field. Examples included the 'ACTORS' involved, the 'ORIGIN' of the approach, ‘SCALE’ and its implications, ‘RESPONSIBILITY’ of each actor and ‘CREATIVITY’ undertaken by actors. During the coding process, I also created inductive codes based on the key issues, topics and themes discussed in the data. I used these codes to label blocks and lines of texts according to key topics or themes of interest. I have included an example of my completed codebook in the appendix (Appendix 3).

After I created deductive codes, I began coding transcribed interviews. I broke the coding process into three phases. In each phase, I coded 12 interviews, creating inductive codes as I went. I used Guest et al., (2006) to guide this process, where 12 interviews of a relatively homogenous group in a thematic analysis would yield saturation. As this study interviewed a variety of participants across scales and sectors, I repeated this process to ensure I reached saturation across these groups too. After I coded the first 12 interviews, I refined codes further by sorting through them to define the boundaries and key issues discussed. After the first 12 were complete, I then moved on the second set, then the third. Through this process, I began noting less additional data and themes during the coding of each set of interviews, and I made very few changes to the codebook. I took this as a sign that I was approaching a reasonable level of saturation.

Throughout the process of creating codes and coding the data, I took down notes about any thoughts, ideas and data of interest. I tried as far as possible to make connections and links between links and consolidating themes as I went. Memos made it possible to match concepts and theory to data by "exploring, checking and developing ideas" (Charmaz, 2008, p. 166). In particular, it enabled me to "learn" the data through the evolution or ampliative knowledge creation, where my ideas evolved as I made further discoveries from the data (Charmaz, 2008, p. 166). This process of notetaking created a framework to draw out key themes or topics of interest.

Thematic analysis to distil analytical themes

After I coded data, I then switched from grounded theory to thematic analysis. I made this switch to identify main themes associated with the thick descriptions and memos I had already coded. A thematic analysis made it possible for me to make sense of the data and thick descriptions by allowing me to arrange codes and actor accounts according to topics participants believed to be of interest. Under the grounded theory approach this would not have been possible since technically the approach aims to value each description as valid and not necessarily related to a broader theme. The thematic analysis also allowed me to visualise data, including its relations so that I could make sense of actor accounts as part of a 'big picture'. This is the term I use to describe the overall findings of the study, where participant data formed a 'picture' of how they used green infrastructure concepts in Johannesburg and how it manifested as a social construct. I found this more useful than a grounded theory approach that would have drawn more on a comparison of participant accounts.

Using thematic analysis, I then picked out key issues discussed in the transcribed interviews and notes, grouping similar, or related codes, and then aggregated findings under broader headings. During this process, I allocated data under three headings that became progressively higher in hierarchy, or organisation. I formed themes and topics of increasing commonality. I did this according to the 'basic themes', "organising themes" and "global themes" (Attride-Stirling, 2001, p. 385). I created "web-like illustrations that summarize the main themes constituting a piece of text" (Attride-Stirling, 2001, p. 385). I developed the approach to include an even larger hierarchical theme, called a 'universal theme', to bring together data where there were too many global themes. Developing a universal theme made it possible to manage the volume of data I had coded. Locating data around a set of hierarchical themes allowed relationships to be visualised, and to identify gaps in the data.

After I sorted and reworked data according to relationships between topics and themes, I visualised them using *FreeMind*[44]. *FreeMind* facilitated the visual construction of relationships between themes and enabled me to develop the 'bigger picture' of the data I had coded, which identified a "central story that accounts for the issues in the data" (Hennink et al., 2011, p. 248). Developing a bigger picture was the first step toward conceptualising my data, where it provided "a detailed understanding of individual components of the data and the

[44] *FreeMind* is a free mind mapping software package.

linkages between these” (Hennink et al., 2011, p. 248). I organised themes into universal, global, organising and basic themes to identify and explore links. I found mapping the data was beneficial for grasping themes discussed in the data and the links between them.

Conceptualising themes and their linkages

I then conceptualised the data using ‘telescoping’. Telescoping enabled me to analyse how green infrastructure was used as an evolving process by “moving from a broad overview of the data to a close examination of the detail” (Hennink et al., 2011, p. 248). I conducted “two analytic tasks simultaneously”, where I switched from “’zooming-in’ to ‘zooming-out’”, which make it possible to summarize the data and refine data analysis (Hennink et al., 2011, p. 249). Toward conceptualising data through telescoping, I took direction from the overarching research question of the thesis and gaps in the literature. I probed data through telescoping using the following questions:

- What historical and contextual factors influenced the use of green infrastructure concepts in practice?
- Which examples of green infrastructure projects or applications were referred to by city level participants?
- Which themes or codes were key to the use of green infrastructure concepts at the city and project levels?
- Which participants framed the use of green infrastructure concepts in practice?
- What were the backgrounds of participants and how did this influence the way they understood and used green infrastructure concepts in practice?
- Where were green infrastructure projects located in the city?
- Why were green infrastructure concepts used in practice (reasons/rationale)?
- Which participants’ activities were more influential than others?
- What kinds of city level outcomes evolved from project level findings?

- Why did participants carry out activities, or what was the context or setting of these actions?
- How were green infrastructure concepts understood by participants?
- How did the use of green infrastructure concepts at the city and project level influence development in Johannesburg?

Taking this step allowed me to interrogate data, where it enabled me to gain an understanding of specific themes and codes according to the overall research question. Themes that evolved out of the telescoping process enabled me to identify noteworthy features that influence the activities of actors on projects, including supporting information about how practice evolved.

4.4.1 Selecting two analytical themes: Ownership and uncertainty

Issues of *ownership* and *uncertainty* stood out as common themes among participant accounts from all groups. Although most of the participants from across sectors did not explicitly use the terms 'owner'[45] or 'ownership'[46] during the in-depth interviews, they did explain how ownership, or taking possession through their activities, influenced how the Bruma Lake and Paterson Park projects proceeded. Examples of ownership included understanding activities to lobby against Johannesburg Municipality, widening the scope of municipal projects, or working longer than was necessary to ensure projects added value

[45] Eighteen study participants used the term 'owner' 32 times in the transcribed interviews. A wide variety of actors in the city used this term. I found this split evenly across participants from civil society, private sectors and academia, with most of the references to the term being made by government officials. Study participants used this term to refer only to the legal ownership of land, buildings or companies.

[46] The term 'ownership' on the other hand is used fewer times, 16 references, by fewer study participants. The results however proved interesting for the study as it highlighted not only the legal ownership of land, but also the need for actors in the city to take ownership of projects through their actions. Government officials, private sector professionals and one interviewed participant from civil society used the term 'ownership' widely.

in more than one way. By *claiming ownership* through their activities, participants described the process through which green infrastructure concepts were conceptualised and where they took ownership of how they used the concept at the sites. Claiming ownership, therefore, emerged as a noteworthy theme.

Similarly, while participants also did not refer directly to the terms ‘uncertain’[47] or ‘uncertainty’[48], they did describe unpredictability or situations where there was an unknown. Instances of unpredictability were identified by participants as driving ownership, where participants explained it was necessary for them to not only claim ownership through their activities to respond to uncertainties, but also where they needed to claim ownership in response to uncertainty that resulted from their activities. For example, uncertainty developed around the future of the project sites, manifested as technical or geographic uncertainty or uncertainty around the future of the project sites. Participant descriptions of their activities to *manage uncertainty*, therefore, described how green infrastructure concepts were conceptualised in practice.

Ownership and uncertainty were mutually constitutive. Participants explained that claiming ownership enabled project actors to manage uncertainty at Bruma Lake and Paterson Park. That said, by claiming ownership, participants explained that further instances of uncertainty emerged on the project. Telescoping into the

[47] The term ‘uncertain’ was used in two instances by two participants from research institutes.
[48] The term ‘uncertainty’ was used in five instances by five participants. This included three participants from research institutes and two participants from the private sector.

mutually constitutive relationship between these themes enabled me to focus on the ways that participants negotiated physical nature-infrastructure interactions in practice. By zooming into this relationship in more detail, I did not focus on other themes that could have also been used to explain the use of green infrastructure in practice that may have brought about other research findings. Nevertheless, given the focus of the study on understanding shared understanding and practices as they evolved as a process, I felt it was beneficial to define the understanding and use of green infrastructure concepts through the shared process of claiming ownership to manage uncertainties.

4.5 Ethical considerations

To describe the ethical considerations for the study I divide the section into two components. First, I cover the steps I took to account for my positionality as I was already a member of the green infrastructure community of practice in Johannesburg when I began the study. Second, I considered the wider ethical considerations of researching Johannesburg green infrastructure conceptualisation in a highly variable and racialised context. Last, by considering the ethical considerations, I was able to reflect on my bias and how it influenced the study. In other words, how my research question led to data generation on self-selecting participants (Section 1.2).

To begin, I took steps to ensure I generated the data ethically. I drafted a project information sheet and consent form (Appendix 4 and Appendix 5). The project information sheet and consent form detailed how I would use participant data in the thesis and any related academic research outputs, including information on data protection. Before I began my interviews with participants, I asked them for their written consent to participate in the study by way of signing the consent form[49]. The signing of this consent form also bound me to the ethical use of their data. One participant amended the consent form[50], where they included things such as contacting them before the publishing of the thesis with any direct quotes I had used. Out of respect to the participant, I agreed to this. I also respected participant requests to speak off the record. I made clear that participants were able to withdraw from the study at any point.

Throughout the research process, I concealed the identity of all the participants. I assigned a unique identification number and I used this to identify them in the notes, transcripts, and data analysis. I saved personal information on participants in one spreadsheet, which included the participant's name and their unique identification number (Appendix 2). I separated the participant's identification number from their data. I saved all data on the University College London student storage drive, which is a secure, password-restricted platform. The abovementioned measures conform to General Data Protection Regulation 2016/679, which was the overarching policy governing data generation, analysis and storage at the time of research.

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[49] Participants gave verbal consent. One participant was not able to sign the data consent form and one participant agreed to proceed based on a verbal agreement after going through the information sheet and consent form.
[50] One participant adapted the consent form to include a clause to ensure I checked their final quote in the thesis. I do not quote this participant in the thesis, so I did not need to gain their consent under this clause.

I took steps to ensure the ethical nature of my research given my positionality. I explained I had been involved in research on green infrastructure concepts in Johannesburg before undertaking a PhD. To ensure I ethically generated data, I chose not to be based at Gauteng City-Region Observatory when I returned to conduct my fieldwork. I also took steps to ensure I gathered accounts from a wide range of participants from a variety of groups. While conducting interviews I chose to centre my interviews around physical nature-infrastructure interactions using 'environment and infrastructure' rather than green infrastructure concepts. Focusing on and probing participants on the use of 'environment and infrastructure' concepts in practice enabled me to gather a wide range of understandings of physical nature-infrastructure interactions and how they shifted over time. Using a more general term for green infrastructure facilitated the gathering of a range of participants accounts on physical nature-infrastructure interactions and not necessarily how I understood it based on my involvement in the green infrastructure community. My role as a dialogic facilitator made it possible to strike up a conversation, where my authority over participants and their accounts was limited.

One noteworthy ethical implication of my selected methods is that it supported a self-selecting group of participants from government, the private sectors and civil society that wanted to talk about the successes of Bruma Lake and Paterson Park. Interest in participating would have been less should I have selected projects that were not considered a 'success' by participants such as Queen's wetland in Bruma for example, which was not popular among the government officials and private sector professionals I interviewed (Section 7.3). Consequently, while my exploration of the range of green infrastructure interventions and how they were used by a range of city and project level actors was limited, I believed it was justified as it facilitated a stronger investigation of the understanding and use of green infrastructure concepts in Johannesburg. Focusing a very detailed study on one particular type of green infrastructure intervention, river renaturalisation, enabled me to address noteworthy gaps in the literature on green infrastructure, where it is largely unknown as to exactly how general understandings and meanings of the concepts are distilled from systemic policy contexts and translated into practice.

Next, generating data on Bruma Lake and Paterson Park also had ethical implications for my research study in terms of Johannesburg's highly racialised and unequal social context and spatial setting. As I already mentioned in the Prologue, as a white South African, I had grown up and lived in formerly white suburbs under Apartheid my whole life. The 26 'environment and infrastructure' projects identified by participants were located across a range of settings in South Africa such as municipally funded projects, private sector developments and local non-profit organisation site-level interventions in informal settlements (Appendix 1). Therefore, by selecting Bruma Lake and Paterson Park to gain more detailed insights on the use of green infrastructure concepts highlighted a choice that I made to focus on Bruma Lake and Paterson Park over others. By making these selections, I excluded a focus on other green infrastructure projects.

By implication, I only illuminated some of the actors, avenues and activities used to influence the understanding and use of green infrastructure concepts in the city, which represents a snapshot of broader racial and social diversity in the city. For example, active members of civil society were likely to be empowered through having the academic and professional backgrounds related to the lobbying tasks they undertook such as drafting legal letters, assessing the architectural foundations of public buildings, or assessing the environmental status of a particular site. Therefore, while the study illuminates the nuances of urban development in formerly white suburbs, the participants and interest in participating in such a study in an informal settlement or solely privately funded venture may have been different, where participants would not have had as much influence over the use of green infrastructure concepts due to their background, or where it may not have been necessary to create a strong civil society presence due to their financial influence. As such the study does not focus on many of the other dynamics that may evolve around informal settlements where new infrastructure is being built or extended.

I should note one further feature of my positionality – how participants responded to me. I have already acknowledged that the engineering field and supporting professionals of the participants I interviewed tended to be male-dominated and thus may have had implications for the kind of data shared with me by my participants. In addition to this, I do feel my nationality also influenced what participants shared with me. For example, when I attended many of my interviews, my participants were often surprised that I was South African and not

English. In some cases, they appeared to be thrown off by this and in some cases may not have wanted to meet with me had they known this previously. On the other side of the coin, my familiarity with South Africa and Johannesburg and its socio-political history encouraged some participants to share more in-depth and nuanced perspectives that they may not have done so for researchers of a different nationality.

4.6 Bruma Lake and Paterson Park as two ‘environment and infrastructure’ projects

In this chapter, I outlined the research design and methodological approach I used to generate data on how green infrastructure concepts are conceptualised. Municipal officials, private sector professionals and members of civil society such as academics and researchers identified Bruma Lake and Paterson Park as two sites where green infrastructure concepts had been used to manage urban water. Gathering more detailed data on the participant’s temporal journeys at each of the project sites made it possible to illuminate how participants carried out their activities to respond to water pollution (Bruma Lake) and flooding (Paterson Park) as a situated and contextually bound phenomenon. More importantly, gathering data through in-depth interviews afforded me the opportunity to explore multiple practical understandings of physical nature-infrastructure interactions and how they evolved as part of individual or shared understandings.

Using a hybrid grounded theory-thematic analysis approach, I illuminated two analytical themes to explain how participants at the sites conceptualised green infrastructure concept. *Ownership* and *uncertainty* were two mutually constitutive themes that described the temporal journey of participants, where they felt it necessary to claim ownership of the project sites through their activities to leave a legacy. A common value to leave a legacy among participants such as municipal official, private sector professionals and members of civil society, influenced how actors carried out their activities, where it became necessary to manage uncertainty at the start of the project, including uncertainties that emerged during the implementation of the projects (Chapter 6 and Chapter 7).

Chapter 5 GREEN INFRASTRUCTURE IN JOHANNESBURG

In this chapter, I present on the background of the two green infrastructure studies I chose to explore how green infrastructure is practiced in Johannesburg. Toward providing the background on Bruma Lake and Paterson Park, I feel it is necessary to illuminate two features of the Johannesburg context. First, to provide the setting for infrastructure in Johannesburg as a socio-political process by describing its history and administrative and operational structure. Second, to provide the socio-political context for the study sites, where they serve as two examples of mediating features of social life in Johannesburg. Covering these two features on the background of the study sites enables me to present on how green infrastructure concepts are practiced in Johannesburg (Chapter 6 and Chapter 7), where it enables me to illuminate how it is used in a situated and contextually bound way.

Setting up the context chapter in such a way enables me to explore how green infrastructure is practiced within and outside of existing rules around environment and infrastructure rules and ways of doing things in the city. I mentioned these two elements form an important part of my conceptualisation of green infrastructure and how it mediates social life in Johannesburg (Chapter 2). As the central feature of my conceptual framework was ‘physical nature-infrastructure interactions’ it is therefore necessary for me to contextualise both the infrastructural and environmental features of the city and how they are constituted by rules and practices in urban development as they have come to exist in the Johannesburg context.

By acknowledging power and culture associated with theories of planning and development in Johannesburg, I consider how Johannesburg has evolved as a socio-political process over time. Under this framing green infrastructure at the two study sites, which I will describe toward the end of the chapter, has come to evolve out of an “incessantly flexible, mobile and provisional intersection” of actors and material phenomenon, that tends to “operate without clearly delineated notions of how the city is inhabited and used” (Simone, 2004, p. 407). Understanding how Johannesburg is made through green infrastructure, therefore, requires using other ways of “seeing and acting” in the city that can reveal the “multiple rationalities” and “spatially extensive and shifting” interactions (Harrison, 2006, p. 320). Toward supporting such an understanding of Johannesburg using the methods I described in the preceding chapter (Chapter 4), I provide the context for the study sites in such a way as to reveal the more ‘lively’ aspects of infrastructure and the social world (1.3).

To describe the lively aspects of Johannesburg, I have chosen to divide the thesis into four sections. In the first section, I provide a general background of infrastructure challenges in Johannesburg, with an emphasis on water infrastructure, to illuminate how interest in green infrastructure concepts have evolved out of socio-political challenges associated with upgrading and maintaining infrastructure in the city (Section 5.1). I then explain the administrative and operational structure of Johannesburg Municipality to highlight the roles and responsibilities of municipal actors under instructional rules and how physical nature-infrastructure interactions are understood are managed in the city (Section 5.2). Last, I present a background of the project sites, where I explain noteworthy events that took place at Bruma Lake and Paterson Park, which sets the scene for the use of river renaturalisation in practice (Section 5.3).

5.1 Urban infrastructure in Johannesburg

Viewing infrastructure in Johannesburg as a socio-political process illuminates its many contestations and meanings in policy and practice. While the city itself has transcended the Apartheid period, it was and is still characterised by significant inequalities, which have become further entrenches over time. For example, despite its many political and social initiative since the Apartheid period, infrastructure networks "still bears the enduring imprint of the apartheid spatial order" (Murray, 2008, p. 1). Infrastructural networks and their services across transport, energy and water remain spatially located in formerly white suburbs and prevail beyond "racially codified rules, regulations, and restrictions" that "no longer apply" (Murray, 2008, p. 1). Johannesburg's infrastructure, therefore, remains a lasting reminder of its past and creates a foremost challenge for achieving a more equitable future.

Post-Apartheid Johannesburg is in a constant state of flux. While on the one hand marked change on the access and provision to infrastructure and services in the city demonstrates its flexibility and progress to re-dressing the fragmented and racialised aspects of infrastructure provision, the overall figures and averages do not do justice to the growing inequalities that are visible in the city. For example, as the “economic and commercial heartland” of South Africa, Johannesburg has become home to some of the most educated and high-earning members of the population (Beall, 2002, p. 14). Part of its success is the city’s “comparably high standard” of infrastructure and services that have made impactful steps to redressing inequalities rooted in the Apartheid era (Beall, 2002, p. 14). That said, the city remains constrained by fiscal resources, which limit wide-spread and rapid change to ensure equal access to infrastructure and services.

Infrastructure forms the basis for many of Johannesburg Municipalities efforts to redress its vastly unequal and fragmented urban landscape. Political objectives to redress historic inequalities in infrastructure access and development has drawn political and research interest to overcome the challenges associated with extending existing networks to former non-white areas in Johannesburg. For example, extending infrastructure network formed an important approach for ensuring all residents have access to infrastructure services such as potable water, sanitation and electricity, where the aim continues to be integrating “low-income citizens within a network of infrastructure and service” that have previously only been enjoyed by the “better-off residents of the city” (Beall, 2002, p. 151). Redress in the true sense of the term, has guided a set of political interventions to develop infrastructure and services in formerly non-white areas, which has tended to follow similar trends in urban development across a range of South African cities (Beavon, 2004). By implication, fiscal resources tend to be directed away from historically advantaged areas, the significance of which will become apparent at Bruma Lake and Paterson Park 5.3).

Non-payment for infrastructure and services in the city also plays a role in how infrastructure is shaped and developed in the city. While in the present day, it has been attributed to politics around affordability and access, it forms part of a “legacy” in the city, where it has roots in the unequal provision to inferior services during Apartheid that have transcended into the post-Apartheid era (Abrahams and Everatt, 2019, p. 267). While for the most part service delivery boycotts have been noted due to high increases in service tariffs by state-owned services such as water and electricity[51], it tends to “exacerbate the problem of non-payment”, where price hikes have resulted in an inability to pay for services (Abrahams and Everatt, 2019, p. 267). An inability to pay for services has also led to an increase in the number of “dangerous illegal connections”, where existing access to services tend to be shared through precarious means (Abrahams and Everatt, 2019, p. 267). Therefore, at a household level, infrastructure and its mediating role in social life creates a highly divided and complex landscape

Civil society, municipal official and private sector professional concerns over water pollution and flooding at Bruma Lake and Paterson Park are rooted in the deeply political past and present of infrastructure and environmental management in Johannesburg. While infrastructure needs in parts of the city that

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[51] Boycotts included payment for rent and service charges. It also including protesting activities where there were invasions of surrounding land (Smith, 2006, p. 4).

did not enjoy access to reliable services at equal standards dominate the political agenda, limits on fiscal resources have resulted in a growing number of infrastructure failures across the city. As I explain in greater detail below, they tend to “lose their capacity” to provide services as anticipated (Murray, 2008, p. 51). As parts of the city that are considered to provide reliable services, formerly white areas tend to attract a large influx of migrants from within and outside the Gauteng province, and this places “a massive strain on the physical infrastructure” in these areas, where subletting and overcrowding can contribute to “increased densities and placed excessive demands on public infrastructure” (Harrison et al., 2014, p. 236). Formerly white areas, therefore, present an opportunity to explore some of the contested features of Johannesburg’s urban infrastructure network.

By selecting Bruma Lake and Paterson Park, I delve deeper into understanding the socio-political aspects of infrastructure in post-Apartheid Johannesburg, where infrastructure acts as a bridge between its highly fragmented and racialised past and its future. As I demonstrate below, by focusing on two formerly white suburbs I reveal the politics of social transformation in these areas, where despite being associated with highly racialised Apartheid city, fledging social change and transformation has taken place. I also identify where material or mundane phenomenon such as parks intercept areas can illustrate changes in historic divides due to their social aspects and spatial locations. The latter of which becomes of interest where it illuminates the politics of infrastructure systems in decline, where its failures can illustrate where social and spatial change where post-Apartheid Johannesburg has seen marked social change over the last 27 years, where large influxes of migrants and non-white residents have moved into formerly white areas and urban centres.

A divided infrastructure landscape

In a similar way to other South African cities, Johannesburg has been designed according to programmes of spatial segregation under Apartheid. Apartheid was a legislated social and political system that enforced racial separation between white and non-white residents from 1948 until the early 1990s. I showed in the research methodology chapter, racial segregation and discrimination are deeply rooted in the very origins of the city from as early as 1886 when it first emerged as a tented mining camp (Beavon, 2004). The early inhabitants and workers on the mines were divided by race and class and these early divisions were strengthened through legal means during the Apartheid period (Beavon, 2004).

The unbalanced aspects of infrastructure were formalised through policy and legal structures. Addressing the divisions in society and space that were deeply embedded during the Apartheid period was a mammoth task. For example, government, at the national and city levels, was expected to extend infrastructure services into new areas, but also upgrade and maintain the existing network to service more densely populated areas. After the end of Apartheid, resources were insufficient to address challenges with the activities necessary to ensure all those living in Johannesburg receive the same kind access to services.

Infrastructure concerns at Bruma Lake and Paterson Park were, therefore, an outcome of political imperatives in the city.

After Apartheid ended, the African National Congress, the political party which won nationally in 1994, also governed Johannesburg after the first democratic municipal elections were held in 1995. The African National Congress inherited a spatially uneven and infrastructurally disjointed Johannesburg. Redressing unequal access to infrastructure service provision, such as urban water services, became their core political project (Smith, 2006). To facilitate redress, the Constitution of the Republic of South Africa was developed as a guiding document for change (South African National Government, 1996). The Constitution states all South Africans have the legal right to safe and sufficient infrastructure such as tapped potable water, sanitation services and electricity of an equal standard (Clause 27 – see below). The development of the Constitution marked a turning point in Johannesburg where equal rights to infrastructure became enforceable.

Guided by the Constitution, reforms in infrastructure access and management involved large capital investments to grow and spread infrastructure across the city. For example, an excerpt of the South African Constitution outlines:

> 27 Health care, food, water and social security
>
> (1) Everyone has the right to have access to—
>
> (a) health care services, including reproductive health care;
>
> (b) sufficient food and water; and

> (c) social security, including, if they are unable to support themselves and their dependents, appropriate social assistance.
>
> (2) The state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of each of these rights.

(South African National Government, 1996, p. 16)

While in principle, this forward-thinking reform held the government accountable for providing infrastructure to ensure 'sufficient' needs were met, in practice achieving this vision was difficult in the context of limited resources and entrenched inequalities.

Despite the African National Congress' political decision to invest in areas that did not have access to infrastructure services to redress access, it served to create further fractions in the infrastructure network. While focusing on growing and extending infrastructure into new areas, over time the existing infrastructure network began to deteriorate. For example, Murray (2008, p. 51) draws attention to "self-sufficient luxury enclaves" that began to develop, where infrastructure became "disjointed and disarticulated" (Murray, 2008, p. 51). The implication was that systemic networks such as water infrastructure "lose their capacity to generate the kinds of services they were designed to provide" (Murray, 2008, p. 64). Consequently, the fragmented and disconnected characteristics of infrastructure could not be easily adapted using a single infrastructural approach.

Restructuring municipal administration

The Johannesburg Municipality, then called the Greater Johannesburg Metropolitan Council[52], was responsible for initiating post-apartheid programmes to build and knit together the city's infrastructure networks. The Greater Johannesburg Metropolitan Council generated revenue through billable services and this was used to support initiatives for redress in the infrastructure sector. Municipal revenue generation was "focused on finding capital" to ensure historic inequalities were addressed (Beall, 2002, p. 152). When revenues were generated through billable services they were used to "provide new services to all of those that were deprived under Apartheid" (Beall, 2002, p. 152). Due to the need to generate revenue, a key focus of municipality was dedicated to finding ways to generate revenue to fund redress. Consequently, managing infrastructure as a system was not the main priority and necessary upgrading and maintenance work on existing parts of the network were not completed.

In the mid-1990s, growing pressure on the City of Johannesburg to provide equitable infrastructure access took its toll on city governance administrative structures. The situation was worsened by national budget cuts applied in the early years of post-Apartheid South Africa. Amid these economic constraints, municipalities found it challenging to finance progressive policy outcomes[53] (Tomlinson et al., 2003). By 1997, the Greater Johannesburg Metropolitan

[52] The Greater Johannesburg Metropolitan Council was created in 1995.
[53] As outlined by the Municipal Finance Management Act 56 of 2003.

Council reported a severe deficit of funds and other resources and action needed to be taken (Beall, 2002). Johannesburg Municipality's answer to their budgetary concerns was to develop a new strategic vision for the city in the form of the *iGoli 2002* strategy document.

The *iGoli 2002*[54] strategy document was drawn up by Greater Johannesburg Metropolitan Council 2001 to reform the Council's administrative functions and finances. A key focus of *iGoli 2002* was the economic decentralisation of service provision through the ring-fencing of Greater Johannesburg Metropolitan Council's businesses into stand-alone entities using the corporatisation model. At the time, one-quarter of all black residents in the city lived in informal dwellings and there were high levels of no access to basic services.

> iGoli 2002 had to address a situation in which, by the late 1990s, 24 per cent of African residents lived in informal dwellings, 17 per cent had no access to electricity, 15 per cent were without flush toilets and 13 per cent were without tapped water.
>
> (Smith, 2006, p. iv)

To ramp up efforts to deliver infrastructure services, Greater Johannesburg Metropolitan Council set up a collection of municipal-owned entities to manage the provision and allocation of infrastructure services. As I discuss in detail in the next section on the administrative structure of Johannesburg Municipality, these

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[54] *iGoli 2002* was introduced to encourage more effective and efficient governance and investment in socio-economic imperatives (Beall, 2002).

entities were set up as standalone companies reporting directly to Greater Johannesburg Metropolitan Council's departments (Section 5.2).

While *iGoli 2002* was developed to restructure infrastructure services, inequalities, backlogs, and funding concerns limited the way it was used. A key challenge remained revenue generation, or at least the ability of Johannesburg Municipality to raise funds for infrastructure services. While there was a significant effort made by the Johannesburg Municipally to increase municipal revenues over the period 2011 to 2016, where the city's gross value add grew by 88%, it struggled to generate enough funds to build new infrastructure, while also repairing and maintaining existing infrastructure networks (Harrison et al., 2014). This growth was a remarkable feat given a comparatively low gross value add over the same period across South Africa, at 62% (Harrison et al., 2014). In 2016, the municipality found the need to re-visit their political programme, where they found it necessary to conduct an internal review of finances, assets and infrastructure goals that started a new wave of activity for trying to address persistent fiscal concerns in the city.

Renewed priorities for infrastructure management

The Spatial Development Framework 2040, promulgated in 2016, laid out the planning blueprint for the city. The idea behind the internal review was to start from the 'bottom-up' by re-evaluating the city's existing infrastructure assets, assess their condition and then develop a masterplan in the next 10 years. To overcome the constrained environment for infrastructure improvement, the city began to explore alternative opportunities for engaging multifunctional infrastructure. One opportunity identified for doing this is using physical nature, or green infrastructure, as outlined in the Spatial Development Framework 2040. The shift in focus to include natural systems, or physical nature, as part of infrastructure management, was supported by international and provincial non-profit organisations such as C40 Cities, World Wildlife Fund, South African Cities Network, Gauteng City-Region Observatory and African Centre for Cities. As I reflect on green infrastructure concepts in policy and practice, these organisations contributed toward the solidifying a common understanding and momentum for evolution within infrastructure management, which aimed to create the case and identify opportunities for using green infrastructure concepts in policy (Section 1.1).

5.2 Administrative structure and operation of Johannesburg Municipality

The Johannesburg Municipality is located at the local level of three tiers of government [55] in South Africa. Identifying these three tiers is important for describing how green infrastructure concepts are used in practice as they highlight the legal roles and responsibilities of government around physical nature and infrastructure. The three tiers of government are "distinctive, interdependent and interrelated" (South African National Government, 1996, p. n/p). By law,

[55] Johannesburg is one of eleven metropolitan municipalities in South Africa. Metropolitan municipalities can enact all local government functions under The Constitution of The Republic of South Africa. They therefore have more administrative power and influence than municipalities over infrastructure and service provision.

municipalities such as Johannesburg are self-regulating where they have "the right to govern, on their initiative, the local government affairs of its community, subject to national and provincial legislation, as provided for in the Constitution (The Constitution of The Republic of South Africa, 1996, n/p). Accordingly, "national or a provincial government may not compromise or impede a municipality's ability or right to exercise its powers or carry out its functions" (The Constitution of The Republic of South Africa, 1996, n/p). Johannesburg is therefore autonomous in the way it carries outs functions outlined by national and provincial government policy.

To draw attention to a key feature of the Johannesburg Municipality administrative structure that is relevant to the argument, it is first necessary to identify the general legislated roles and responsibilities of South African government concerning infrastructure and environmental management. Setting out the roles and responsibilities provides background for my more detailed explanations of core departments and their functions in Johannesburg Municipality below. To aid my explanation of noteworthy roles and responsibilities I draw attention to an overview diagram that sets out the general functional competencies of national, regional and local government in South Africa that applies to the geographical institutional boundaries I referred to in the previous chapter (Section 4.2). At this stage, while the overview does provide contexts for the general functions, special arrangements are made between different levels of government to provide functions. Johannesburg Municipality has far more legislative power and roles and responsibilities over infrastructure and the environment than other kinds of municipalities.

Legislated roles and responsibilities

Different levels of government in South Africa have slightly different roles and responsibilities in terms of their legislative power. In the conceptual framework, I identified institutional rules of which legislated roles and responsibilities form a key component of how green infrastructure concepts are used (Section 3.1). For example, while at a national and regional level, the government is tasked with urban planning, which can include the planning and development of infrastructure; at the local level, municipal government is tasked with its management such as potable water supply and wastewater treatment (Figure 5-1). Given the centrality of legislative roles and responsibilities for understanding physical nature-infrastructure interactions and how project level actors practice green infrastructure, I refer back to the roles and responsibilities of national and municipal government in respect to infrastructure and the environment to aid my analysis of the understanding and use of green infrastructure concepts as practice.

The municipal system in South Africa is divided into three categories (A to C) that define slightly different municipal roles and responsibilities at the local level. Johannesburg Municipality is a metropolitan municipality and therefore has more roles and responsibilities around managing infrastructure and the environment (Figure 5-1). As such, Johannesburg Municipality is solely responsible for the provision and maintenance of all infrastructure services such as stormwater and electricity for example.

NATIONAL AND PROVINCIAL SHARED COMPETENCES

- Agriculture and administration of forests
- Disaster management
- Environment
- Nature conservation (excluding national parks, national botanical gardens and marine resources).
- Soil conservation
- Pollution control
- Urban and rural development (of which water infrastructure is a component)
- Regional planning and development (of which water infrastructure is a component)

MUNICIPAL COMPETENCES

- Air pollution
- Municipal planning
- Stormwater management systems in built-up areas
- Water and sanitation services limited to potable water supply systems and domestic waste-water and sewage disposal systems
- Municipal public works (needs of municipalities in terms of their responsibilities under the Constitution or other laws).

Figure 5-1: Summary of competences of the South African government divided into national, regional and local government. General functions listed are selected from schedule 4 of the South African Constitution (South African National Government, 2020).

I showed the burden that the legal roles and responsibilities for redress and the management of infrastructure placed on the limited financial resources of the city, where it was necessary to modify and adapt to new budget streams and administrative structures to enable redress under the current municipal model in

Johannesburg. To build on my accounts above, the challenge of generating enough budget to support the maintenance and upgrading of all services in the city places pressure on existing decision-making processes related to physical nature and the environment, where cost-efficiency tends to be a driving factor. I reflect on pressures associated with providing multiple services such as stormwater management in the analysis chapters, where I describe the roles of other actors such as members of civil society and how they supported the use of river renaturalisation in practice.

Now that I have described the legislated roles and responsibilities of Johannesburg Municipality, I can now turn to the administrative structures in place to ensure legal obligations are met. The Johannesburg Municipality is organised into ten core departments and twelve municipal-owned entities[56] (Figure 5-3). Departments and municipal-owned entities carry out functions as outlined by The Constitution of The Republic of South Africa (1996) (see Sections 155(6)(a) and (7), South African Municipal Systems Management Act (Act 32 of 2000) and a range of legally and non-legally binding internal policies and guidelines (City of Johannesburg Metropolitan Municipality, 2019; Parliament of the Republic of South Africa, 2000). Municipal departments work with a range of municipally-owned entities to carry out maintenance on infrastructure in the city, where roles and responsibilities are split between strategic oversight at the

[56] The intention of *iGoli 2002* was to reform the municipality's operations and finances. Reform was actioned through the setting up of 13 municipal-owned entities to manage the decentralisation of services. Johannesburg's services and technical expertise were unbundled to streamline services provision and maintenance in the city.

department level, with technical management and billing being performed by the municipally-owned entities (Figure 5-3).

Infrastructure management

Policy and strategic oversight of around infrastructure such as urban water management fall within the jurisdiction of two municipal departments. The Environment and Infrastructure Services and Development Planning departments. These two departments carry out necessary physical environmental and infrastructural service-related competencies[57]. Competencies include the regulation of air pollution, stormwater management, provision and maintenance of water, and sanitation. Unless a separate agreement exists between Environmental and Infrastructure Services and Development Planning departments and municipal-owned entities, such as for individual development projects, the Johannesburg Development Agency is responsible for implementing development projects, where it reports directly to the Development Planning Department. Johannesburg Water provides water supply and management services and reports to the Environmental and Infrastructure Services Department. Johannesburg City Parks and Zoo are responsible for maintaining all municipal owned open space, including parks and roadside verges, and reported to Environmental and Infrastructure Services until a recent change in 2016, where it now reports to the Community Development Department.

[57] These are a select list of competencies attached to local government in South Africa.

Municipally-owned entities are registered as self-funded companies and generate revenue from the billable services they provide such as water and sanitation, waste removal, and electricity. Municipally-owed entities also undertake individual development projects funded by the municipality, such as Bruma Lake and Paterson Park. The municipal-owned entities I refer to most frequently are Johannesburg Development Agency, Johannesburg Roads Agency, Johannesburg Water and Johannesburg City Parks and Zoo as they are the entities legally responsible for providing maintenance of infrastructure services and green space at Bruma Lake and Paterson Park. The activities of departments and municipally-owned entities are guided by the South African Constitution. In addition to their legal responsibilities, the abovementioned municipally-owned entities were also involved in the development of Bruma Lake and Paterson Park as standalone projects. While municipal departments and municipal-owned entities are legally tasked with carrying out infrastructure management functions, a range of other city or project level actors also plays a role in the management and maintenance of physical nature and infrastructure in the city. Involvement from the private sector, members of civil society[58] and non-profit organisations are common among municipal infrastructure projects.

[58] Includes academics, researchers and the public.

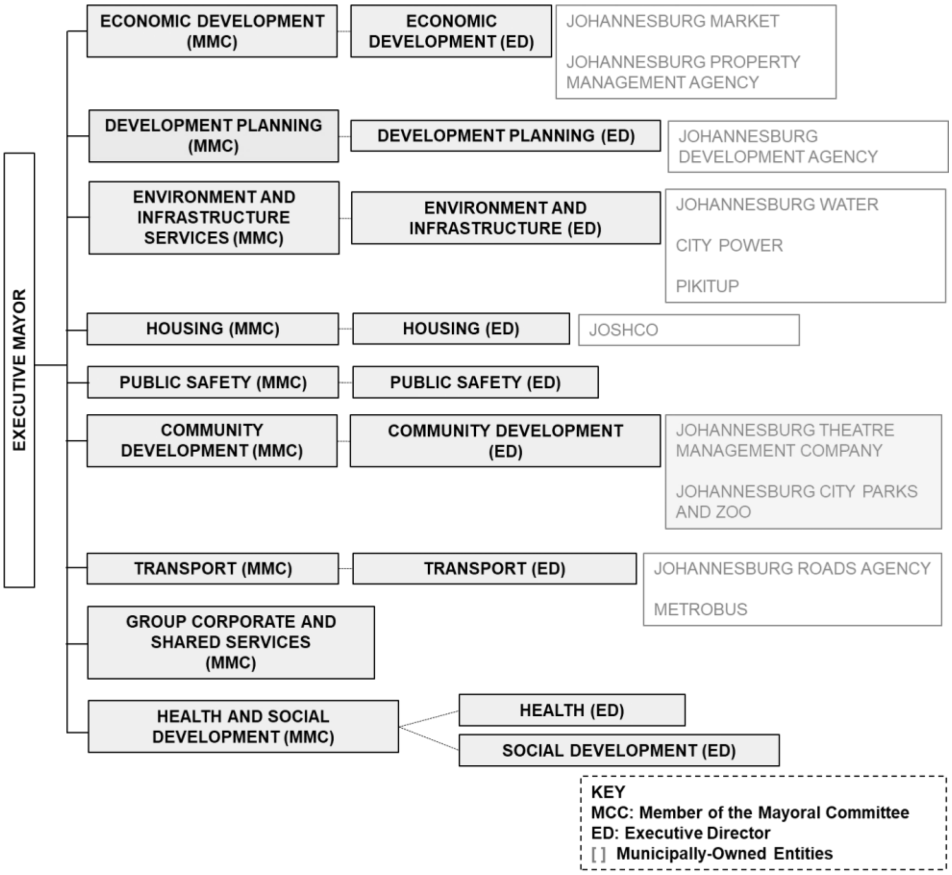

Figure 5-2: Organogram of the City of Johannesburg's executive structure and its oversight of departments and entities during the fieldwork period in 2018 (City of Johannesburg Metropolitan Municipality, 2017).

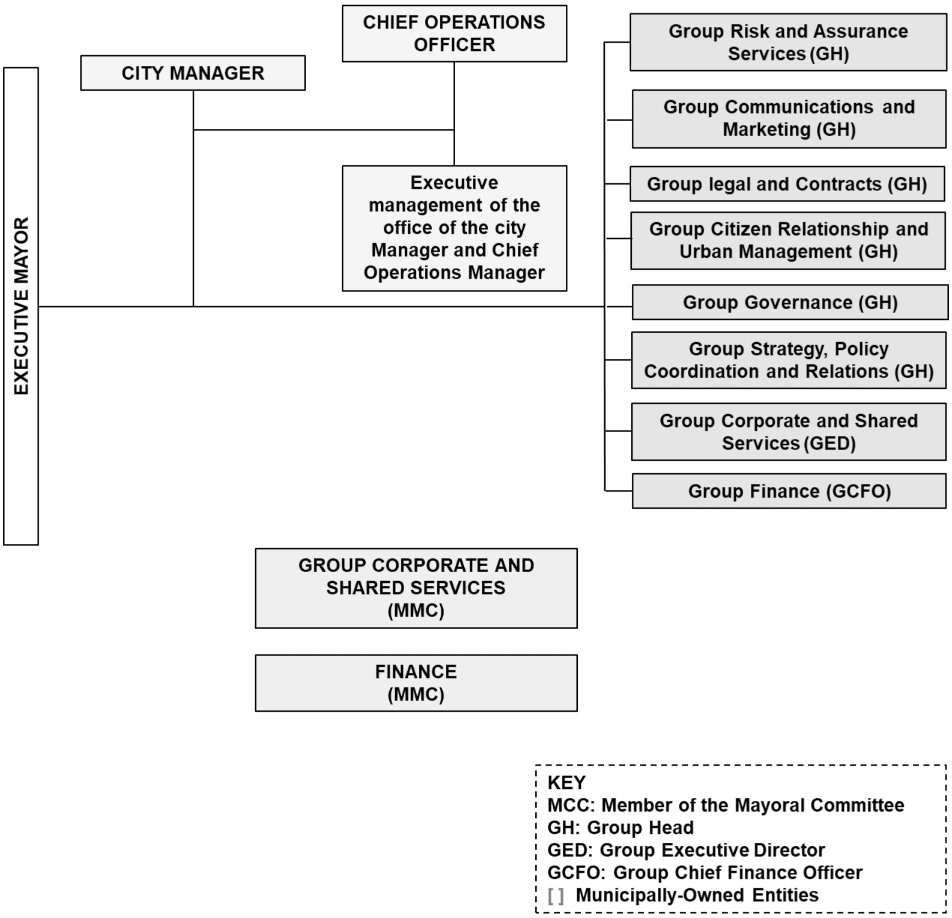

Figure 5-3: Overview of Johannesburg Municipality group functions during the fieldwork period in 2018. Group functions support executive management and municipally-owned entities to ensure consistency in their overall strategic approach to environment and infrastructure management (City of Johannesburg Metropolitan Municipality, 2017).

5.3 River renaturalisation at Bruma Lake and Paterson Park

In this section, I identify the actors at Bruma Lake and Paterson Park projects, including the activities and outcomes of a river renaturalisation approach. I selected Bruma Lake and Paterson Park projects because they were identified by city level participants as being noteworthy 'environment and infrastructure' projects that enabled me to investigate the multiple meanings of green infrastructure or physical nature-infrastructure interactions. I now provide the context on the project sites to contextualise key moments in its infrastructural, social and political history. The need to engage an 'environment and infrastructure' intervention is rooted in ageing and/or failing infrastructure manifested at the project sites (Section 5.1).

Before I move on, it is important to draw attention to local politics and the significance of Johannesburg Municipality dedicating capital budget to address infrastructure concerns at the project sites. For example, as I demonstrated in the analysis chapters, it was only after tension was created between Johannesburg Municipality and members of civil society such as the Bruma Business Owners Association that Johannesburg Municipality allocated capital budget as part of the 2011/2012 financial year to address infrastructure concerns (van Schie, 2012). Paterson Park was granted capital funds under the Corridors of Freedom Project capital project, which were intended for the development of transport, mixed-use housing and associated public amenities (City of Johannesburg, 2014). Drawing attention to the significance of how Bruma Lake and Paterson

Park projects were granted funds enables me to draw attention to how river renaturalisation was used Bruma Lake and Paterson Park.

I indicated earlier that formerly white suburbs saw a decline in the allocation of municipal funds to maintain and upgrade infrastructure, such as stormwater infrastructure, according to the political objectives of African National Congress. While carrying out the fieldwork, city level participants explained the underfunding of infrastructure maintenance and upgrading sparked tension over municipal spending. To present how tensions influenced the use of green infrastructure concepts at Bruma Lake and Paterson Park in the analysis chapters, I explain the context for local politics over the spending of municipal budgets in formerly white areas.

In South Africa, municipalities are comprised of administrative areas called wards[59], where Ward Councillors are voted in by members of the ward constituency. At both sites, wards were managed by the Democratic Alliance, an opposition political party to the African National Congress that was the political party in power at the level of city governance. Tensions arose between opposition parties at the ward and city level, where it would not work to the African National Congress' favour to fund infrastructure maintenance and upgrading at Bruma Lake and Paterson Park. Despite local politics, Bruma Lake and Paterson Park are two examples of where the Johannesburg Municipality spent the capital

[59] Wards are geopolitical divisions created by the Municipal Demarcation Board for elections. Wards elect a representative councillor that plays an intermediary role between residents and the Johannesburg Municipality.

budget on infrastructure in two former white areas. The implications of local politics for the use of green infrastructure is that it represents two cases that would be considered outliers to the way that projects would have been funded under the current political model.

5.3.1 Polluted water at Bruma Lake

Bruma Lake is situated in the suburb of Bruma, Johannesburg. It is located on the eastern border of Johannesburg administrative boundary and is considered the Eastern Gateway to the city [60] (see Figure 4-3). Before the lake was developed, the site was historically a sewage disposal site[61]. Bruma Lake was developed in the 1980s by a developer as a commercial venture. The lake was originally developed as a waterfront development with shops, restaurants and leisure facilities. The style of development was replicated by the developer in Randburg and Centurion which are two other areas within the Gauteng Province.

While Bruma Lake was developed, an agreement was made between the developer and the municipality. After its construction, it was agreed the lake would be donated to the city as a public amenity. As the city was not able to receive gifts, it was reported to have been sold to the municipality for a nominal sum (One South African Rand). This ‘donation’ however did not come without

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[60] One of the first landmarks you see when you enter Johannesburg Municipality when travelling by car from the airport. The location of Bruma Lake therefore had implications for local politics, where the lake was considered an eyesore or embarrassment for tourists and visitors (Chapter 6 and Chapter 7).
[61] 1946 and 1951 versions of the City Council of Johannesburg’s Road Map show a disposal works called ‘Bruma Disposal Works’ was located at the site. I viewed these maps at the Museum Africa Archives in Johannesburg, South Africa, during the fieldwork period.

responsibility. The city would inherit the operational and maintenance requirements of the site. I now explore the context of Bruma Lake in more detail. To aid my explanation of the events that took place at Bruma Lake, I have created a timeline of key events that I refer back to throughout the section (Figure 5-4).

Damming the Jukskei River

Bruma Lake is technically a dam[62]. It was built by developers along an existing part of the Jukskei River that flows from a spring in Johannesburg City Centre, or inner city. It is also fed through stormwater drainage[63]. The dam was built to collect these water flows, containing it in the vicinity of the commercial development. The lake created the 'attractive' focal point of the waterside development, which was used for boating and recreation. However, pollution and its knock-on impacts on the local economy created social and health concerns soon after it was developed. Pollution at Bruma Lake eventually led to the downturn of many businesses beside the lake, which deterred patrons due to its hazard it posed to their health. Over time, the buildings were abandoned and car parks around the lake became the site for informal and illegal activities. These changes acted as a catalyst for action among members of civil society.

Bruma Lake was originally built with a pump house that stored machinery to aerate water in the lake. The lake was originally fitted with a pump to prevent

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[62] A dam is an engineered water body where a barrier (typically a concrete structure) contains water in situ. In the case of Bruma Lake it was a concrete lined dam.
[63] The Jukskei River and engineered drainage systems such as stormwater runoff fed the lake.

water from becoming stagnant, which would allow bacteria to grow and debris to accumulate. As a result of poor maintenance over time, causing failing infrastructure, the water began to stagnate in the dam. The situation was worsened by substantial amounts of litter and debris washed into the lake from the inner city and upstream. The source of the problem was attributed to the source of the river and the socio-political situation in the inner city.

The decline of the lake and the rise of water pollution

Over time, a layer of sludge began to develop at the bottom of the lake due to the accumulation of debris. The lake developed a foul-smell, high *E. coli* counts and toxic levels of magnesium, along with litter and other debris. Debris accumulation together with the polluted water created an unpleasant and unsafe environment for people and local businesses. Consequently, businesses began to leave or find alternative premises[64]. For example, the well-known Africa curios flea market closed in 2012 due to the poor environmental conditions at the lake, which up until that point was described as a successful market since its conception in the early 1990s.

[64] China Mall was one business that opened in the vicinity of the lake after the onset of water pollution concerns. The general trend however was that businesses in the area were in decline due to economic and health reasons.

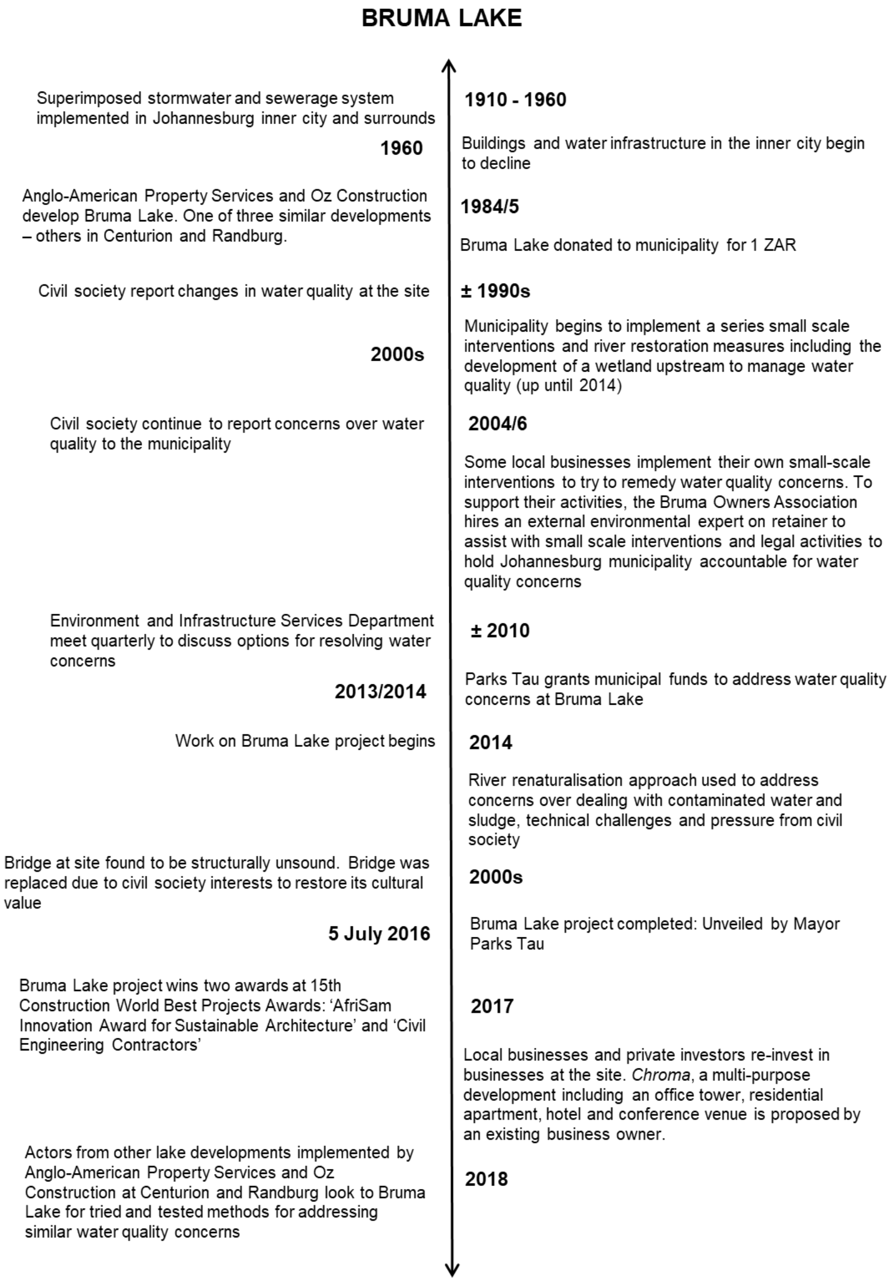

Figure 5-4: Timeline of key activities at the Bruma Lake site. The timeline presents the historical events and activities that influenced the use of green infrastructure concepts.

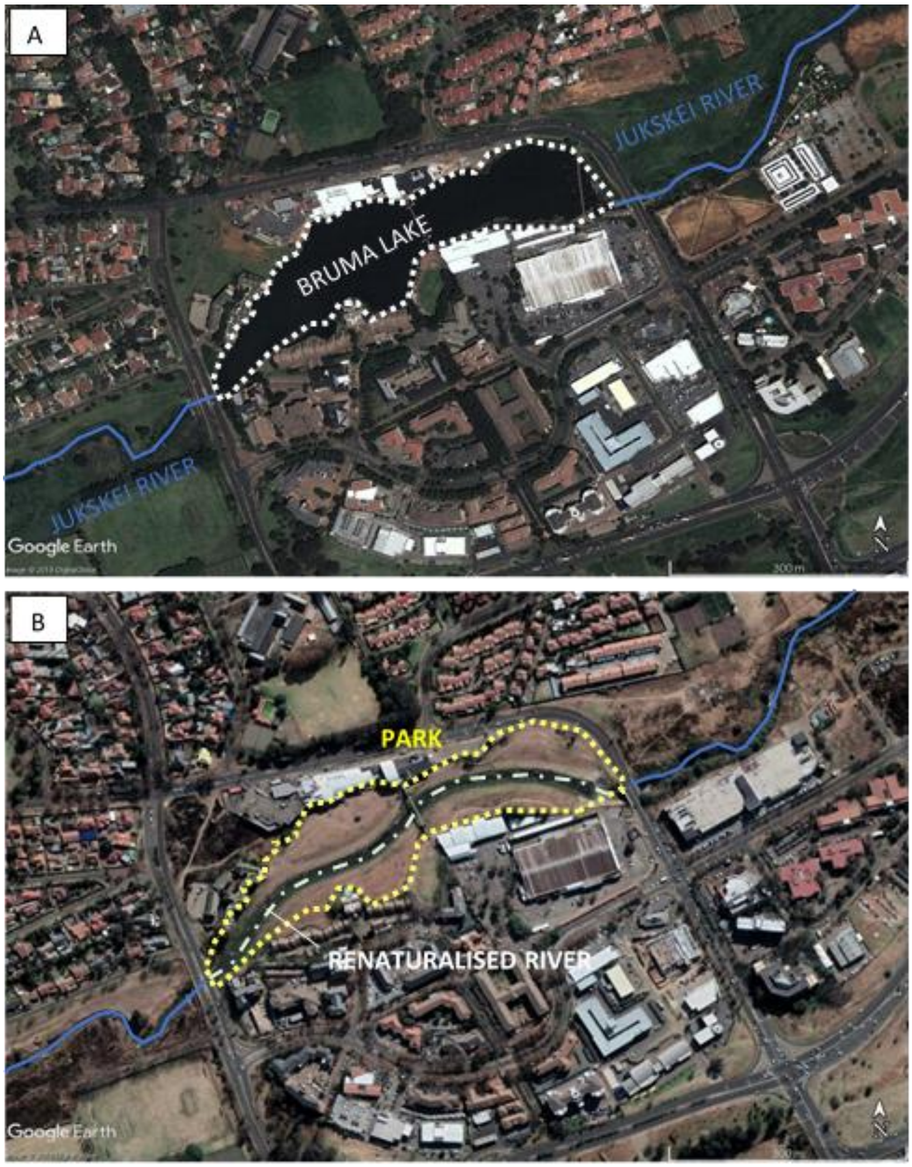

Figure 5-5: Before and after aerial photographs of river renaturalisation works at Bruma Lake. Aerial imagery sourced from Google Earth for years (A) 2011 and (B) 2018. The area covered by Bruma Lake in (A), was redesigned to include a renaturalised river and park (B). See the appendix for technical drawings (Appendix 6).

In response to environmental concerns, local officials applied for funding to alleviate the problem. Municipal officials at the Environment and Infrastructure Services Department tried many avenues for obtaining funds to address water quality concerns at Bruma Lake. The department tried small-scale purification options, including chemical treatment and bioremediation. Members of the Bruma Business Owners Association also paid toward the treatment of the lake through other means, this included a floating wetland. These interventions were superficial as in reality small scale interventions did not address the root cause of the problem, which remained the continuous supply of contaminated water from upstream and the dam that had become an infrastructural concern. Attempts by the municipality and private sector to address the problem were unsuccessful up until 2013/14.

Solving water pollution associated with the damming the Jukskei River

The approach that was followed included the 'renaturalisation' of a portion of the Jukskei River where the Bruma Lake was located. This involved the removal of the dam and the creation of a river channel (Figure 5-5). The channel used was unlike conventional concrete channels. It was modified to encourage connectivity with groundwater, which would take place since the implementation of the dam. The flow of water encouraged the aeration of water and allowed it to flow freely downstream. Instead of being trapped by the dam, the new channel was more mobile, where it interacted with groundwater, including other features of physical nature such as plants and sediment. The natural flow of water prevented the deposition of litter and debris from upstream.

The remaining parts of the lake, not used as part of the renaturalised stream, were converted into parkland using treated sludge material (Figure 5-5). This feature was believed to 'add value' to the site as it served to create public amenity. The project was completed in 2016, with a public unveiling ceremony by former Mayor Parks Tau. A public unveiling signified the intervention as a victory in terms of what was considered an environmental hazard but signalled its value as a political project. Considered a success at the site-level, the intervention has received increasing interest from the two other waterside developments that continue to encounter similar challenges. After the river renaturalisation project was completed, municipal officials believed Bruma Lake and its surrounds would be able to be a profitable economic area where more businesses could re-establish.

Bruma Lake formed part of a string of restoration efforts that had been carried out by the Environment and Infrastructure Services Department over the same period. For example, prior projects involved river restoration under the *ecosystem services approach* (Section 6.1), such as restoring a local wetland called Queen's wetland (see more in Appendix 1), flattening the river banks and planting to enable the river to flow in an unconstrained way. It also included an *engineered approach* (Section 2.1) where a litter trap was installed upstream to collect debris and litter in the Jukskei River, which I identified in the geographic setting (Section 4.2). The significance of the string of projects upstream of Bruma Lake will become apparent when I describe practical understandings and how they preempted actor activities at Bruma Lake in the analysis chapter on uncertainty (Section 7.2).

5.3.2 Flooding at Paterson Park

Paterson Park was historically a farm that became designated as a municipal park in 1928[65]. The park is geographically located at the intersection of three suburbs: Norwood, Orange Grove and Orchards. While the park had existed for many years it gained political attention as part of the Corridors of Freedom Mayoral project in 2013 (Figure 4-3). The Corridors of Freedom project, which was intended to increase access to transportation by increasing densification in a set of hubs or ‘nodes’ across parts of Johannesburg, also included the provision of recreational space and supported the enhancement of public amenity. Paterson Park, due to its geographic location and proximity to the proposed Louis Botha node, meant that it received increased political attention as part of a broader vision for the city under the Corridors of Freedom project.

While the suburb of Norwood has seen little social and economic transformation since Apartheid, Orange Grove and Orchards have seen a marked social and economic change. On the one hand, Norwood has attracted white middle-class residents due to its location in proximity to Sandton and Centurion, which have developed as the new central business districts and commercial hubs of

[65] Planning records at the Johannesburg Municipality Archives record the site as ‘Klipfontein farm’ prior to renamed Paterson Park in 1928 (City of Johannesburg Metropolitan Municipality, 2003). I viewed the planning records at Johannesburg Municipality during the fieldwork period.

Johannesburg. On the other, the neighbouring suburbs of Orange Grove and Orchards have seen significant social transformation since the 1970s and 1980s, where there has been a large influx of migrants from other African countries (Appelbaum, 2016). By implication, the park is not only surrounded by a melting pot of cultures, but also a set of tensions around cultural differences.

A reason for the socio-economic standings of Orange Grove and Orchards is attributed to their location relative to the old central business district, or inner city. Their geographic location became significant after the old central business district fell into decline in the 1970s and 1980s. The decline resulted in middle-class white South Africans moving to areas closer to fledgling economic centres such as Sandton and Centurion where they could find work. As a result, existing properties were bought and rented by migrants, with a range of other cultures and backgrounds. The social change sparked ‘white flight’, or the voluntary relocation of white middle-class residents to other parts of Johannesburg or South Africa.

The Norwood and Orange Grove resident associations resisted the development of high-density mixed-use housing in the park[66], indicating existing infrastructure services were not at an adequate standard to support the increase in residents and property sub-divisions that had taken place. Also, there was concern among some residents about what a mixed-use development may imply for the profile of

[66] Resistance stemmed from earlier attempts by the City of Johannesburg to build a shopping mall in the vicinity of the park (Chapter 6 and Chapter 7).

the area. The development of housing in the park soon became a contested municipal project, which fuelled existing tensions between the Johannesburg Municipality and residents' associations. It also sparked tension between the two residents' associations.

Residents' associations and other members of the community initially lobbied to prevent the development taking place in the area. Over time, however, instead of resisting the development, the Orange Grove Residents Association began to realise the opportunity it had for shaping the outcome of the mixed-use development in the area, rather than lobbying against it. Their actions then turned to work together with the municipality. A contractual arrangement was made between a member of the Orange Grove Residents Association and Johannesburg Property Company and they worked on the project as a facilitator. Involvement by one community group in the development of the project created a wedge in the relationship between residents' associations where one became highly involved in the development of housing and park upgrades, while the other opposed it.

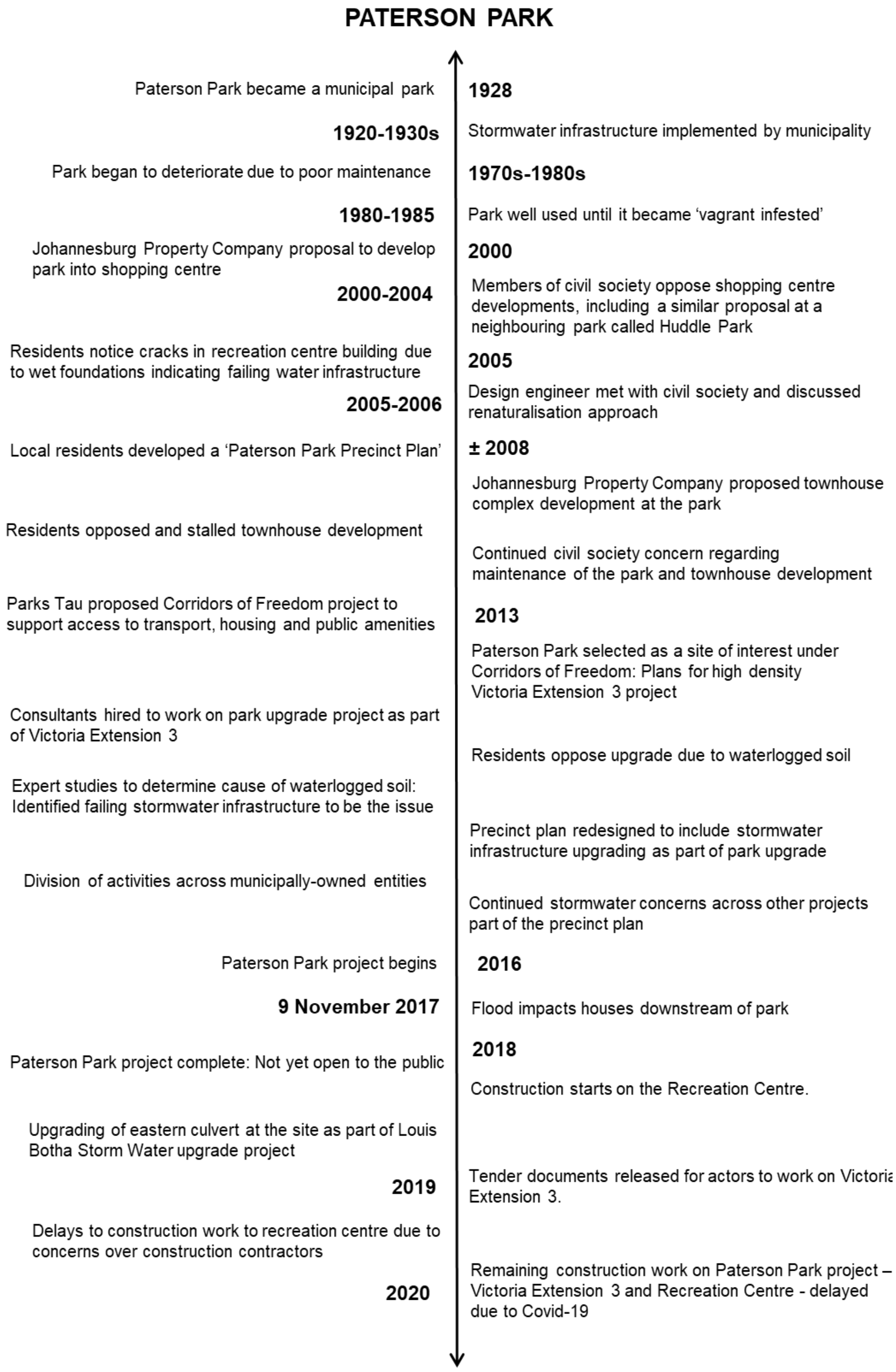

Figure 5-6: Timeline of key activities at the Paterson Park site. The timeline presents the historical events and activities that influenced the use of green infrastructure concepts.

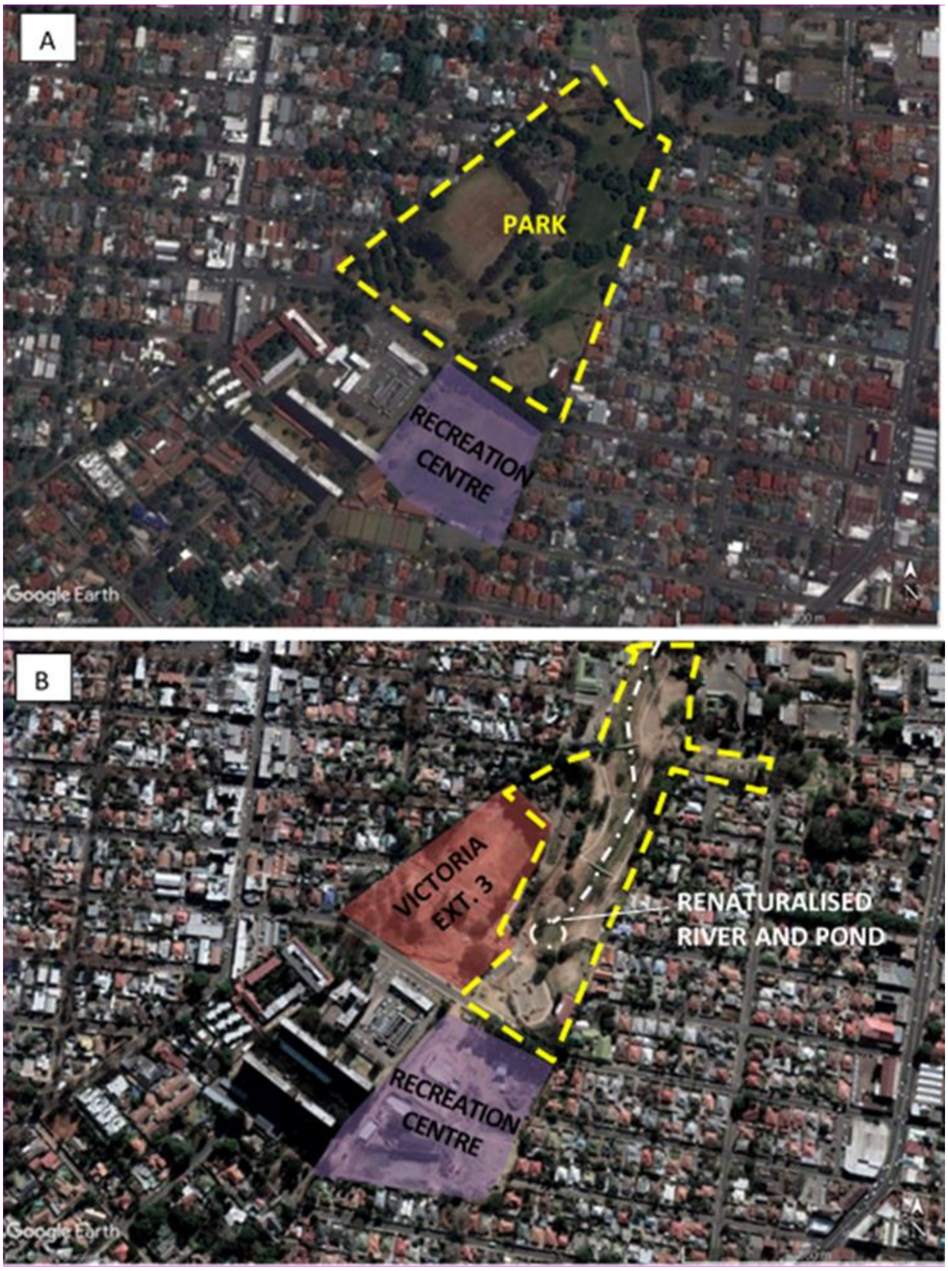

Figure 5-7: Before and after aerial photographs of the Paterson Park project. Aerial imagery sourced from Google Earth for years (A) 2011 and (B) 2018. The area covered by Paterson Park in (A), was redesigned to include a renaturalised river and park (B). This also included reclaimed a small piece of land as parkland in the top right-hand corner. For a technical overview see the appendix (Appendix 7).

Ageing and failing stormwater infrastructure

The stormwater management intervention at Paterson Park was coincidental. It evolved out of preliminary activities on the Corridors of Freedom project on mixed-use housing upgrades to the local recreation centre. Municipal officials and members of the community explained water appeared to be an issue from early in the project, where parts of the park were always saturated and houses located on the perimeter of the park became flooded by stormwater. Moreover, it was explained that the foundations of the existing recreation centre showed signs of water damage. The significant of which will become apparent in the analysis chapter, where I explain that community members believed saturated ground as a sign of a wetland, which would have legal implications for the development of the site going forward. As developing on a wetland is considered illegal under South African environmental law, it would have stalled the project.

One of the reasons the park had low walkability was due to two culverts that ran through it. Sections of the culverts had been closed and covered with soil[67], while other segments were left open and were a safety concern. Culverts were built in the early part of the 1920s and channelled stormwater away from the inner city. During preliminary work for the park upgrades, it was found the culverts were degraded and failing. Depressions, or holes, began to develop where culverts collapsed, and water had worn away at the surface layers of soil. Several depressions developed in the park and surrounding private properties. Also, the

[67] Enclosed with corrugated iron sheets and cement.

park was in a floodplain where, during high rainfall events, properties were flooded.

While a stormwater intervention such as the upgrading of existing culverts could have been used, the contested nature of mixed-use development, together with rising stormwater concerns, made this difficult to achieve. Residents, particularly those at the Orange Grove Residents' Association advocated for the development of park space, rather than concreted engineering works. There were also interests to achieve this outcome at the Johannesburg Municipality. This involved building relationships with members of the public to support mixed-use development and social amenity.

Upgrading the stormwater system

The proposed solution involved 'daylighting' the flow of water through a river renaturalisation approach. Daylighting in this instance means redirecting water conveyed in underground culverts into a channel above ground. Water in the culverts was redirected above ground using an artificial channel, allowing it to flow more 'naturally' (Figure 5-7). Using river renaturalisation replaced the need for a concrete channel. Instead of conveying the water through the site as it would in a concrete channel, the renaturalisation project allowed water to spread into the surrounding park during high rainfall events instead of overflowing from the culverts. Spreading out of the water was considered to limit flood risk to the surrounding properties and created a more aesthetically pleasing environment

(Figure 5-7). It also framed this ‘new river’ as a focal point for mixed-use development and recreation activities.

5.4 Actors involved on Bruma Lake and Paterson Park projects

A variety of actors were involved in the use of river renaturalisation concepts at Bruma Lake and Paterson Park. As I flagged when I described the roles and responsibilities of actors on infrastructure projects in Johannesburg, not only municipal actors were involved in the use of river renaturalisation concepts in practice, others included private professionals and civil society (Section 5.1). Therefore, project procurement under Johannesburg Municipality identifies only one of the institutional process through which actors became involved in Bruma Lake and Paterson Park projects. To explain the involvement of actors procured on the Bruma Lake and Paterson Park projects, I have put together an overview schematic for each (Figure 5-8 and Figure 5-9).

Municipal and private sector professionals

To start, while the Bruma Lake and Paterson Park projects include the same kinds of actors[68], they exhibit very different procurement arrangements. As such, it outlines two different kinds of actor configurations and relations. One where the municipally-owned entity commissioned service providers (Bruma Lake) and another where the design engineer commissioned additional service providers to

[68] Government officials, private sector professionals and members of civil society.

fulfil roles (Paterson Park)[69]. Both Bruma Lake and Paterson Park projects were managed under the Johannesburg Development Agency on behalf of the client department at the City of Johannesburg. Johannesburg Development Agency commissioned service providers under the Public Finance Management Act to carry out functions such as project management and design engineering[70].

On the Paterson Park project, the design engineer played a leading role in the procurement process as they sub-contracted functions on the project. The functions they contracted included landscape architects, environmental authorisation, and structural and construction engineering (Figure 5-8). The experience and expertise of the actors involved cut across a range of disciplines and functions including actors with roles and responsibilities related to infrastructure development and environmental management. The actors involved in the Paterson Park project were different from Bruma Lake as the Johannesburg Development Agency commissioned the stakeholders through the official Johannesburg procurement process. Given the budgetary constraints at Bruma Lake, the landscape architect on the project was only able to carry out a limited number of activities on the project.

[69] Responsibilities were less clear on Paterson Park, where it was uncertain which municipally-owned entity would be the client department. In the end, Johannesburg Property Company managed the park, while Johannesburg Development Agency managed other aspects of the broader Paterson Park precinct project.
[70] The procurement process followed by local government in South Africa is regulated by the Public Finance Management Act (1999) and Municipal Finance Management Act (2003). Johannesburg Municipality has a supply-chain management department that manages procurement under the abovementioned acts.

Members of civil society

Both projects showed strong involvement of civil society groups. This included Bruma Lake Owners Association at Bruma Lake and The Norwood and Orange Grove resident associations in Paterson Park. While their involvement did not take the form of a contractual relationship between officials at Johannesburg Municipality, these groups were equipped with members that have expertise around business, law, town planning and architecture. The disciplines and/or backgrounds of participants, with expertise in architecture, law and environmental science (Appendix 2) had a marked impact in the outcomes of both projects. Therefore, their voluntary activities on the projects were rooted in a personal and/or business interest.

One noteworthy feature of civil society involvement on the Bruma Lake project was an independent environmental expert. The Bruma Lake Owners Association hired an environmental specialist to provide insight on legal and remedial works. The specialist was on a retainer and became the driving force for asserting and enforcing environmental and social rights in the area under South African law. The significance of hiring an expert will become apparent in the analysis chapters, where civil society placed pressure on Johannesburg Municipality to address water pollution (Chapter 6 and Chapter 7).

At Paterson Park project the head of Orange Grove Residents Group created a consultancy with a former municipal government employee and they began working on the project as facilitators. They were contracted to Johannesburg

Property Company. These arrangements indicate an interesting cross-over between disciplines, experience and skills that influenced how green infrastructure concepts were used in practice. In addition, it added a further layer of interaction, where personal and professional interests could play out at a higher level of engagement or interaction on the projects.

Green infrastructure in the words of the participants

As I stated in the methodology chapter, participants at Bruma Lake and Paterson Park described green infrastructure in different ways. To provide the necessary context for the analysis chapters, I include an overview of the different ways participants spoke about their activities to solve water concerns at Bruma Lake and Paterson Park. The participants I interviewed did not necessarily refer to 'green infrastructure', but they did refer to 'environment and infrastructure' projects as being something where physical nature was used on infrastructure projects in new or different ways. For these reasons, the projects were considered 'remarkable' or 'significant' when compared to conventional approaches.

Participants described green infrastructure through their descriptions of what it offered. In many cases, their descriptions were linked to their role and disciplinary background in the city. Ways of supporting greater functionality were identified by a range of participants across planning, engineering and landscape architecture backgrounds, where they explained the projects according to their value in terms of public amenity (CIVSOCL006; CONSL007; GOVL006; CONSL009 and CONSL013), see Table 5-1. Other participants referred to physical nature as creating sustainable neighbourhoods or supporting the green economy (GOVL014; GOVL017) and where an infrastructural intervention supported environmental management and the restoration of ecological systems (GOVL007; CONSL004 and CONSL009). Consequently, despite identifying them as being 'environment and infrastructure' projects, which brought together physical nature and infrastructure, participants understood them in slightly different ways.

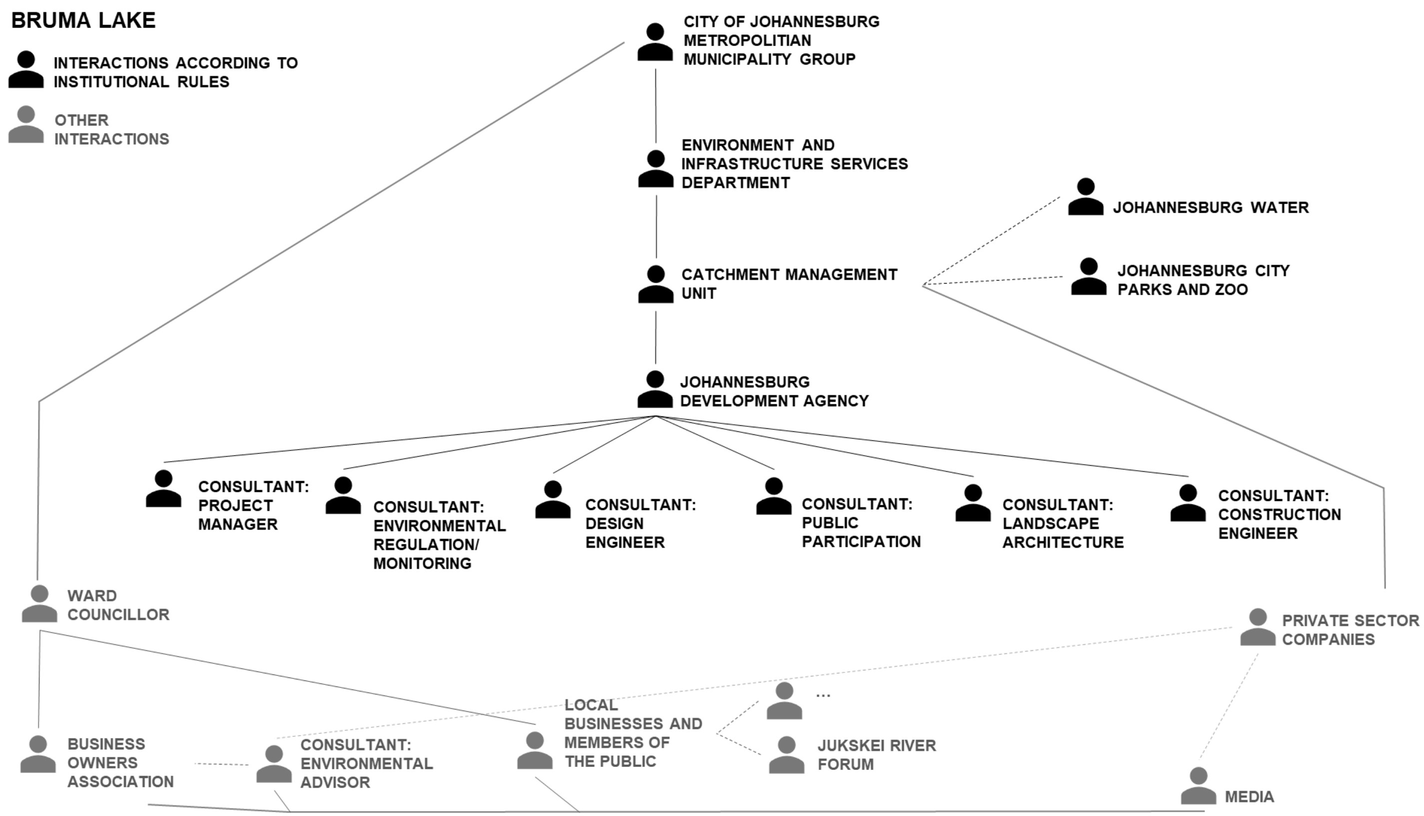

Figure 5-8: Overview of the actors involved in the Bruma Lake project

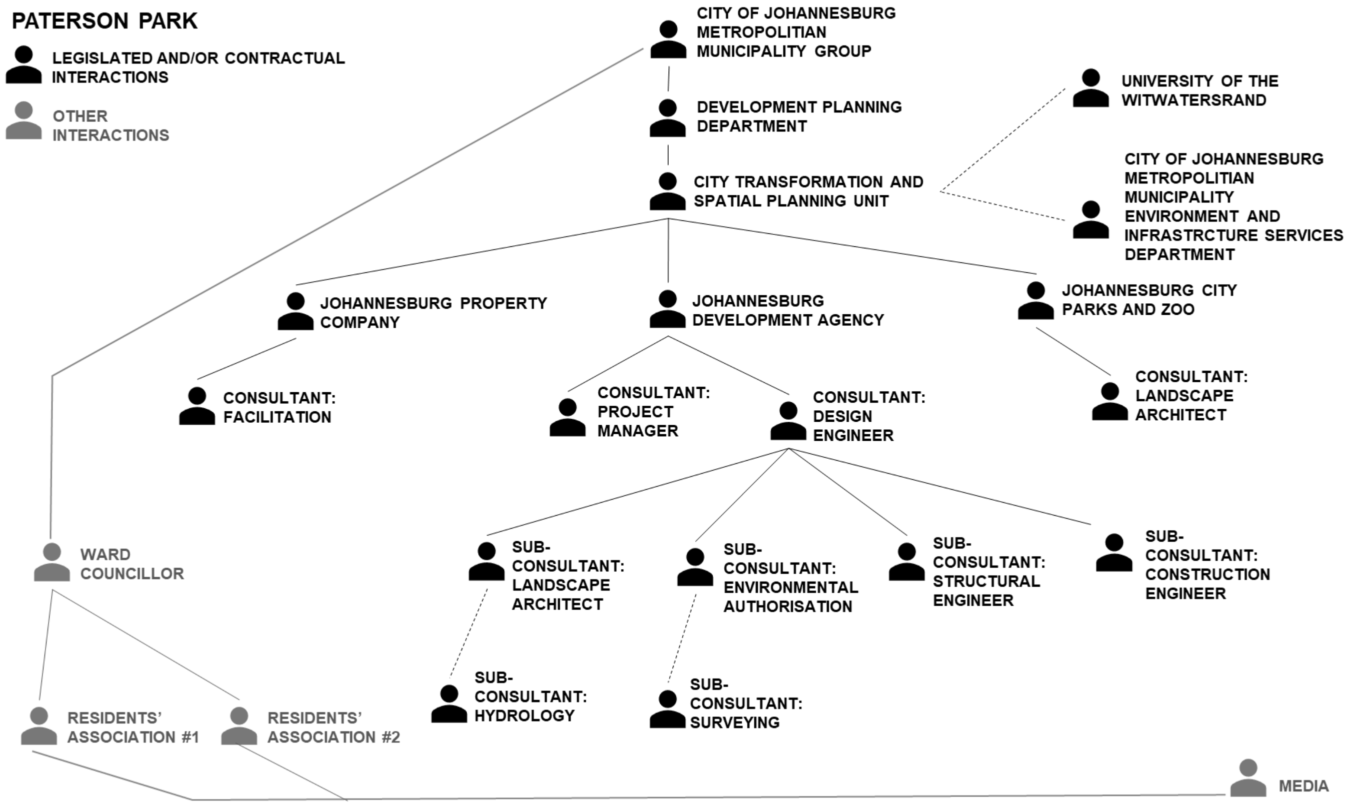

Figure 5-9: Overview of the actors involved in the Paterson Park project.

Table 5-1: Overview of participant descriptions of green infrastructure at Bruma Lake and Paterson Park

PARTICIPANT	PROJECT	DESCRIPTION	CONTEXT
CIVSOCL006 Hospitality	Bruma Lake	"…we ultimately said there is two options, either we must look at filling it up completely, or we turn it into something that can be used to by companies and residents alike and turn it into a park, and why not? I mean we all want to be green […and…] benefit […] environment and the people around it, and how do we do that?"	Reflects on the two options to hand, where river renaturalisation presented an infrastructure solution, but could also create other recreation and environmental benefits
GOVL017 Biological sciences	Bruma Lake	"The reason for that is that obviously from an environmental point of view you want that environmental sustainability"	Refers to the rationale for river renaturalisation at Bruma Lake, where it was used to enhance environmental sustainability
GOVL007 Wastewater engineering	Bruma Lake	"That was the last solution we looked at, to say how auto we take this stream to what it was and take out the lake part of it and restore and landscape what it used to be and that turned out to be sort of a visible option one could look at" "…we realised we got a few spin-offs sort of nature doing some work for us […we…] can deal with some of the stench coming so we realised that, and we attracted some of the bird life around the area"	Justifying the choice of river renaturalisation at the site, where it addresses concerns at the lake, including a wider approach to restore the Jukskei River

GOVL014 Planning	Bruma Lake/ Paterson Park	“The minute you think of water quality, to my mind, you head into green territory because you almost replicate what plant can help you in terms of water through sand filters and in man-made engineering things it is almost impossible” “It is like the green economy. To me it is another component of the green economy, you change your infrastructure, you change your methods of sustainable things. And it is just brilliant”	Describes the use of physical nature in new/different ways to manage urban water. Also reflects on the benefits of including physical nature as part of engineering design
CONSL007 Engineering	Bruma Lake/ Paterson Park	“…the concrete channel is part of archaic stormwater engineering practice. It doesn’t do anything other than to convey excess water down the catchment. […] So if you are building something to drain stormwater you try to build something that, who, its secondary function is to drain stormwater” “…these philosophies always come from a different side…”	Describes the rationale for the project, where there are options to contribute ‘added value’ by using physical nature and infrastructure as part of a combined approach
GOVL006 Planning	Paterson Park	“…the park connects to what should be accessible to the public and whatever else. So, guys, we are going to force you to step out of the single, the single focus solution thing […] We would go hold on, what is that broader outcome that we would like?”	Describes the logic behind the precinct project at Paterson Park, where green infrastructure enabled them to think at a broader scale to provide public amenity as well as solving the problem with flooding
CONSL013 Construction engineering	Paterson Park	“It was supposed to be an attractive space for the public to come, family, friends you name it, if people want to jog around the park, they wanted them to experience something that felt refreshing and natural and was attractive, not something that just was very hard and harsh”	Reflecting on their approach to constructing river renaturalisation, where they followed general environmental principles that included or introduced

		"… it's meant to be an environmentally friendly system […] even if it animals, frogs or fish or whatever and that would exist in a riparian corridor and it is also meant to be self-cleaning […] so, anything coming down there would eventually flush itself…"	physical nature and the project sites in new ways
CONSL004 Planning	Paterson Park	"…in terms of naturalising and creating something within the park, which is both has an ecological back and from a river rehab point of view. First, it creates a river and allows for natural, soakaways etc. Helps in terms of flooding, but it also then takes the flood line away from the boundary of the development.	Describes the multiple benefits of using a green infrastructure approach at Paterson Park
CONSL009 Architecture	Paterson Park	"…not only because it was a response to what people fears, it was also trying to achieve a better use of the land and make more attractive for affordable housing and I think it was also looking at the environment and what the actual environment can support […and…] integrate different species and actually help with the water, the cleaning of the water […and…] almost like bring into the water system into the park instead of hiding it is a much better practice these days.	Describes the use of urban nature in different ways to create public amenity in other parts of the precinct development part of the broader Corridors of Freedom project. Reflects on a general trend in engineering toward making the most out of water management, rather than concealing it

5.5 Grounding Bruma Lake and Paterson Park projects within the contexts of infrastructure management in Johannesburg

In this chapter, I described the background for the use of green infrastructure concepts in Johannesburg. I demonstrated the provision and management of infrastructure and physical nature fall under the legislated roles and responsibilities of Johannesburg Municipality, in particular the Environment and Infrastructure Services and Development Planning departments. I also explained the environment and infrastructure concerns experienced by participants at Bruma Lake and Paterson Park being associated with the city's political history, which became codified in space. As former white suburbs under Apartheid, infrastructure at the project sites has tended to attract fewer resources for maintenance and upgrading given the political focus on infrastructure redress. The use of green infrastructure concepts at Bruma Lake and Paterson Park developed out of the approaches that participants to address material problems that manifested at the sites, including polluted water (Bruma Lake) and flooding (Paterson Park). The background, therefore, provides the context and setting for the use of green infrastructure in practice.

Chapter 6 CLAIMING OWNERSHIP

In this chapter, I explain how municipal, private sector professions and members of civil society *claimed ownership* through their activities or ‘doings and sayings’ at Bruma Lake and Paterson Park. ‘Ownership’ was an analytical theme that emerged during the data analysis phase of the research project. As I already mentioned in the Introduction (Chapter 1), ‘ownership’ is not a new theme for understanding projects such and infrastructure projects. That said, my choice to focus on ownership was linked to its ability to explore more about green infrastructure concepts in general, where it enabled me to illuminate the processes through which participants understood and evolved their meanings of green infrastructure as part of a contextually bound and situated process. Therefore, by focusing on ‘ownership’ I was able to draw out how green infrastructure concepts were practiced using the conceptual framework I set up in Chapter 3. Therefore, focusing on ownership underscores my contribution to knowledge whereas I contend in the conclusion (Chapter 8), it is used as a situated and contextually bound concept.

General understandings emerged as a prominent conceptualisation for how participants claimed ownership (Chapter 3). General understandings brought participants together and encouraged them to carry out their activities according to their practical understandings (or not). Interests to leave a viable and manageable legacy emerged as a general understanding that was a common interest among participants at Bruma Lake and Paterson Park. Leaving a legacy manifested as a common belief or value that despite their range of backgrounds, had shared understandings of physical nature-infrastructure interactions, where it acted as a “collective identity” or “pursuit of collective objectives” (Welch and Yates, 2018, p. 9), (Section 3.3). Having an identity or reason to pursue a collective objective contributed to the development of a window of opportunity for using green infrastructure in practice.

Claiming ownership formed only one component of how participants left a legacy in the city. *Uncertainty* also emerged as a key theme among participants, where they explained they managed uncertainty through their activities (Figure 6-1). For example, as I show in Figure 6-1, participants claimed ownership by carrying out activities to manage uncertainty around the future of the project sites. In addition, participants also explained that they had experienced technical or political uncertainty while carrying out the projects, to which they responded by claiming ownership in new or different ways. Therefore, carrying out activities to leave a legacy defined a mutually constitutive relationship around how a green infrastructure approach, or in this case river renaturalisation, was followed.

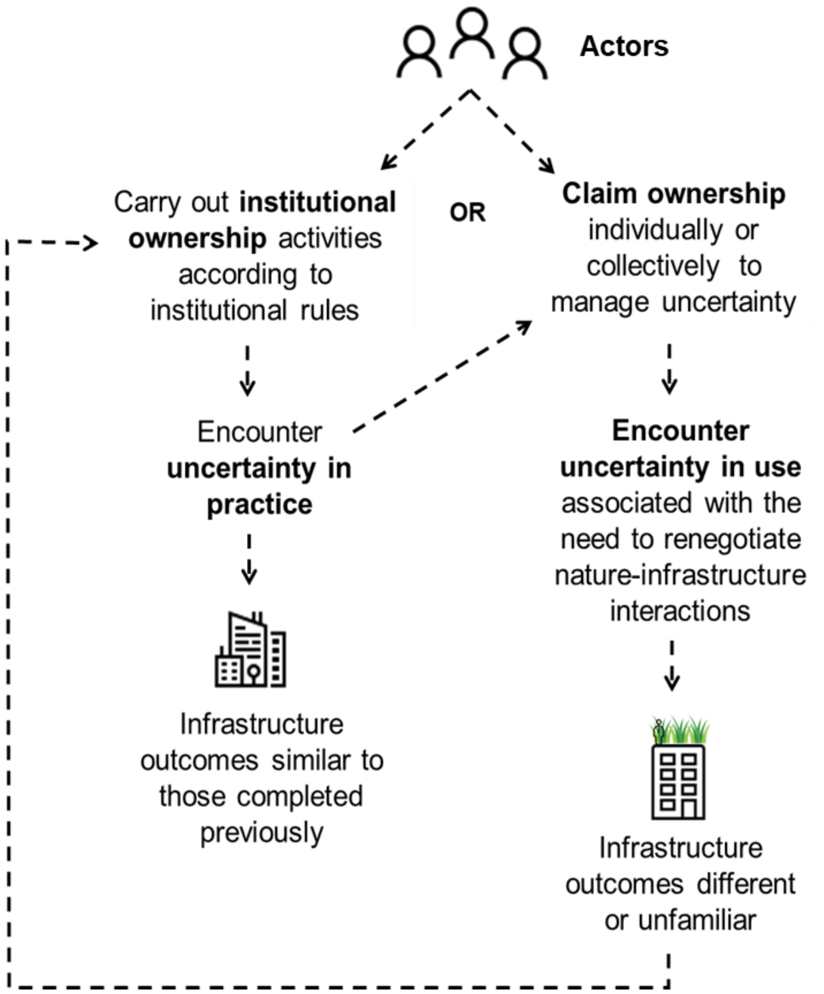

Figure 6-1: Relationship between ownership and uncertainty and the links between them.

I have chosen to set up the analysis chapters side-by-side to present on the links between ownership and uncertainty and how it enabled participants activities to leave a viable and manageable legacy. In the first chapter, I refer to the ways participants *claimed ownership* to leave a legacy at the project sites, where actors carried out their activities outside of institutional and professional rules (Section 6.2). In the chapter to follow, I describe *uncertainty*, and how it influenced the way that participants claimed ownership to own the future of Bruma Lake and Paterson Park projects (Figure 6-2), (Chapter 7). Setting out the analysis chapters in this way presents different sides of the same coin to show the interlinkages between ownership and uncertainty emerged. They also help me to demonstrate the evolution of the practical understandings of green infrastructure practice in the city.

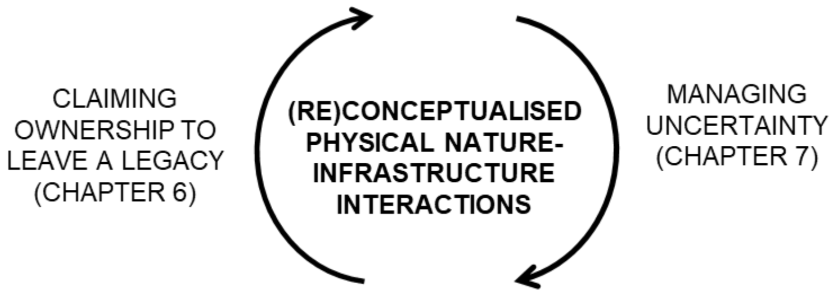

Figure 6-2: Mutually constitutive relationship between claiming ownership and managing uncertainty

Instead of presenting on the same themes or topics across the two chapters as a mirror image of one another, I have chosen to illuminate specific aspects of ownership and uncertainty and how they emerged in unplanned ways. In other words, I let the themes guide my analysis and presentation of the data where it enabled me to highlight certain practical understandings, rules and general understandings and how they came together at different points in the conceptualisation of green infrastructure concepts. As the meanings of green infrastructure concepts did not evolve as a linear process and so presenting accounts that respond to each side of the coin would intimate relatively smooth and streamlined processes that would not have shown the true nature of the topic. Therefore, by illuminating the many themes, topics and processes identified by participants in relation to Bruma Lake, enables me to present on the unplanned or organic ways in which green infrastructure concepts were conceptualised and developed over time.

To describe how participants claimed ownership to leave a viable and manageable legacy in the city, it is important to first describe the context and setting of the material concerns at the Bruma Lake and Paterson Park sites. Material concerns, namely polluted water (Bruma Lake) and flooding concerns (Paterson Park), illuminated a starting point for understanding how green infrastructure concepts were conceptualised. Material concerns had developed out of historical actor[71] activities and existing institutional rules, which had implications for ownership and who was legally obliged to address the concerns (Section 6.1). General understandings brought participants together to address water pollution (Bruma Lake) and flooding concerns (Paterson Park), where they shared intangible interest to leave a legacy in the city (Section 6.2). Coming together through their general understandings, which influenced how participants carried out their activities to own the future, where they worked outside of existing institutional and professional rules to evolve their practical understandings. Last, coming together under a general understanding had implications for ownership going forward, where it became necessary to claim ownership in new ways to ensure that projects continue to function.

[71] I refer to historical actors a broad category to describe the activities of actors that had been carried out in the past. I have chosen to refer to these actors as part of a broad and anonymous category as this is how the participants referred to them. In many cases, participants did not know who these people were, they just knew they had influenced the infrastructure networks and/or problems they inherited.

6.1 Material concerns and their links to actor activities and institutional rules

When I asked municipal and civil society participants about the ‘environment and infrastructure’ interventions at Paterson Park and Bruma Lake, they began their explanation with a description of what they considered to be the root cause of the problems they faced. The reason they chose to begin with the root cause of the problem was that it formed the first step to describing what they did and how they did it at the project sites. In other words, the material concerns they faced at the site influenced the steps they took to address or respond to them. I mentioned that I ‘anchored’ the study around the material outcomes of the projects sites, which served as a basis to study the multiple and evolving meanings of green infrastructure in practice (Chapter 1 and Chapter 2). As the material aspects of the study sites form a key component of the thesis, I feel it is necessary to first describe how participants carried out their activities to leave a legacy in the city by presenting on historic ownership and institutional rules and how it led to material concerns at Bruma Lake and Paterson Park (Section 6.1.1), before describing how water pollution at Bruma Lake and concerns over flooding at Paterson Park prevailed over time. As I explain in more detail below, the material issues experienced by participants at the sites was exacerbated Johannesburg Municipality, which was not able to carry out maintenance and upgrading activities as part of their legal duty of care under institutional rules (Section 6.1.2).

6.1.1 Historic actor activities and material concerns

Participants from Johannesburg municipality, municipally-owned entities and civil society such as business owner and resident groups explained the problems they faced at Bruma Lake and Paterson Park were attributed to what was done and said in the past by historical actors working on, or at, the project sites. For example, the Bruma Lake Owners Association and municipal officials explained that the activities of a private developer, *Oz Construction*, at Bruma lake played an integral role in the environmental and associated health implications that they faced (CIVSOCL003 and GOVL014). At Paterson Park, the Norwood and Orange Grove resident associations and municipally-owned entities explained fragmented institutional roles and responsibilities, limited interest, and insufficient resources were to blame for water and flooding problems at the park, including and safety concerns that stemmed from a lack of maintenance (CIVSOCL001 and CONSL003). By implication, the activities carried out by participants at the sites was used influenced by what historical actors 'did' and 'said' in the past.

The municipal officials explained that they had inherited the sites, whether it be from a private developer, former municipal officials, or both. Inheriting the sites had implications for the ongoing management and maintenance activities, where they needed to carry out roles and responsibilities according to institutional rules such as statutory law, where it solidified a "colloquial intercourse" among theme (Schatzki, 2002, p. 226). I already presented that local metropolitan municipalities were responsible for "ensur[ing] the provision of services to communities" under the South African Constitution and South African Municipal Systems Management Act (Act 32 of 2000) in the context chapter (South African National Government, 1996, p. 74; Parliament of the Republic of South Africa, 2000). Inheriting the sites had implications for municipal officials in terms of their roles and responsibilities. Despite inheriting the sites, they were required to maintain and upgrade them under existing institutional rules that acted as colloquial intercourse that defined their activities on the project sites as part of their legal duty of care.

While inherited legal ownership and its history at Bruma Lake and Paterson Park might not seem significant, government participants indicated that it played a critical role in framing the way participants ‘did’ and ‘said’ things. I mentioned the ‘doings and saying’, or activities, of actors, form a key feature of the conceptual framework, where it enables an exploration of the socio-political aspects of green infrastructure as part of an ethnographic encounter (Star and Ruhleder, 1996; Star, 1999; Schatzki, 2002) (Chapter 2 and Chapter 4). Municipal participants at Environment and Infrastructure Services Department, Johannesburg Development Agency and Johannesburg Roads Agency explained that their activities under their colloquial intercourse and legal ownership associated with institutional rules formed the starting point for their activities at the project sites. While it may be expected that municipal participants were talking about their legal duty of care Constitution of The Republic of South Africa (1996) (see Sections 155(6)(a) and (7), South African Municipal Systems Management Act (Act 32 of 2000), they were also speaking about the activities to claim ownership under general understandings which will become significant in the last sections of the chapter, where it enabled them to respond to material concerns through a common interest leave a legacy.

Inheriting a 'mess' at Bruma Lake

As a starting point, the involvement of a private developer at Bruma Lake influenced the attitude and approach among municipal officials to infrastructure concerns that emanated at the site. The attitude and approach of municipal officials played a role in how participants responded to the problems they faced, where they found it necessary to work outside of existing rules. In the conceptual framework, I identified practical and general understandings as providing a basis to explore social life, where it "underwrites" the "maintenance of practices" and the "senses" that infuse how and why actors do what they do (Schatzki, 2002, p. 78, 2012, p. 16). Despite being the legal owner of the site, many municipal participants believed they should not need to deal with infrastructural and environmental concerns that developed at the lake from the early 1990s onward, given its history, they had a limited inclination or interest toward solving material concerns at the site. For example, officials believed they had little influence over the lake's early conceptualisation and development in the 1980s completed by Anglo-American Property Services[72] and Oz Construction. Therefore, despite inheriting a gift that was intended to enhance the commercial and aesthetic value of the lake, it became a bone of contention among participants that influences their approach, or general understandings.

In the first instance, inheriting the lake as an asset had implications for municipal ownership where despite not having been involved in the design and construction

[72]An influential developer in Johannesburg during the 1980s and early 1990s that supported the decentralisation of the central business district (Murray, 2011, p. 359).

of the site[73], the municipality had legal ownership over it under institutional rules. I mentioned rules play an integral part of how social life come to exist, where it can influence how actors know “how to go on” (Schatzki, 1996, p. 156). Two officials at Environment and Infrastructure Services Department I interviewed believed Oz Construction, the developer of Bruma Lake, went ahead and developed the property despite reticence from members of the municipality at the time (GOVL007). Senior municipal participants from across management, planning and environmental portfolios also indicated they felt Bruma Lake was their ‘mess’ to clean up framing it as a liability, rather than an asset. As one participant at the Environment and Infrastructure Services Department further described, they had “inherited that mess that way”, and now they needed to do something about it (GOVL007).

Inheriting legal ownership of failing infrastructure and environmental concerns placed pressure on already constrained municipal finances in terms of existing capital and operational budgets, which created even more tension between municipal officials at the Johannesburg Municipality. In the context chapter, I pointed to the political objectives of Johannesburg that are acutely aligned to achieving redress in infrastructure and services access. In instances where there was already infrastructure at project sites, it was believed that funds should rather be spent to achieve political developmental interests to redress post-Apartheid infrastructure deficits (Section 5.1), (FGOVL002). Therefore, despite gaining

[73] One member of the Bruma Lake Owners Association believed a municipal official at the time had business interests in Oz Construction and was therefore in support the development of the lake acting as a liaison between the private developers and the Greater Johannesburg Metropolitan Council.

legal ownership of the site, municipal participants were divided around whether they should be the owners of failing water infrastructure and environmental concerns in the first place.

At least four municipal and civil society participants pointed to one further element of the Bruma Lake site that caused contestation. One municipal official and one member of Bruma Lake Owners Association identified a City Councillor, affiliated to the Greater Johannesburg Metropolitan Council at the time, was reported to have business interests in Oz Construction. While the exact details of what exactly took place remain uncertain, it was explained that “all the plans for the lake were done literally with the city” that added additional frustration where historical actors that had previously involved in the project had benefitted from it, that amounted to the ‘mess’ they needed to clean up (CIVSOCL003). As they explain further:

> If I recall…this is something at the back of my mind. Little alarm bells tell me that one of the directors of Oz Construction at the top was a city councillor.
>
> (CIVSOCL003)

Scepticism around the exact relationships between the City Councillor and the development of Bruma Lake appeared to add to the annoyance of the municipal officials legally responsible for dealing with the problem. As a result, Bruma Lake received little interest from municipal officials.

Flooding concerns and limits to trust at Paterson Park

Concerns over flooding and safety at Paterson Park were embedded within existing tensions around ownership at Johannesburg Municipality and between them and the Norwood and Orange Grove residents' associations. As one participant at Johannesburg Roads Agency responsible for a broader stormwater upgrading programme in the vicinity of Paterson Park explained, the stormwater infrastructure network dates to the 1920s (GOVL009). As such, concerns around flooding in the vicinity of Paterson Park is not a new concern, rather it is related to the activities of their "predecessors", where concerns such as stormwater infrastructure could not be resolved using a quick fix[74] solution (GOVL009). References to their predecessors illuminate past activities or practices, which has implications for their activities around Paterson Park at that time thus highlighting the procedural elements of infrastructure practice (Schatzki, 2002) (Section 3.1). By implication, municipal officials were held accountable for the activities that were, or were not carried out by their processors. This created resentment amongst officials, where they felt they were now required to take institutional ownership of a problem that had already existed for what they described as being an exceedingly long time.

A lack of municipal activities to address the problem resulted in trust issues between residents' associations and Johannesburg Municipality. As an official at Johannesburg Development Agency responsible for project management points out, there is a general lack of "confidence" between the municipality and residents. First, they explained residents and civil society groups "didn't think that the city [referring to Johannesburg Municipality] would be able to deliver the projects successfully" based on failures in the past concerning procurement of

[74] Refers to solutions that are straightforward and simple, often superficial, which can solve a problem rapidly.

services and delivery of completed projects (GOVL017). To add, residents' associations "were not convinced that the city [Johannesburg Municipality] would then….maintain the park" given that Johannesburg Municipality has developed a "reputation in terms of its maintenance [which] is not so good" due in part to limits on resources (GOVL017). Therefore, projects and programmes initiated by Johannesburg Municipality such as those under the Corridors of Freedom project, of which Paterson Park was a constituent, tended to arouse enhanced scrutiny from residents and members of civil society.

A lack of trust between resident groups such as the Norwood and Orange Grove community groups and Johannesburg Municipality had been building for some time. Resident groups believed municipally-owned entities such as the Johannesburg Development Company did not have the interests of the community at heart. For example, they believed prior activities by Johannesburg Property Company at another park called Huddle Park[75] were deceptive, where they were "hiding" information about the value of the park (CIVSOCL001). One Orange Grove resident involved in lobbying against Johannesburg Property Company interests in Huddle Park pointed to the use of Diepsloot as an ill-fitting example to value land (CIVSOCL001). As they further explained, "Diepsloot is farmland" and resulted in skewed land values which instead of being "worth about R250 000…Johannesburg Property Company was selling it for R46 [000]" (CIVSOCL001). Consequently, concerns over the intentions Johannesburg

[75] Huddle Park is one of Johannesburg's largest parks located in the suburb adjacent to Orange Grove. There is a wetland at the park, which is valued among residents for its birdwatching potential.

Property Company and their transparency contributed to a lack of trust between residents and Johannesburg Property Company, but also toward the Johannesburg Municipality as a whole, where failing infrastructure at Paterson Park illustrated one further way Johannesburg Municipality were not delivering on their legislated roles and responsibilities under institutional rules.

The lack of trust among residents at Norwood and Orange Grove residents' associations precluded all developments at Paterson Park, where they became suspicious regarding any municipal activity in their area (CIVSOCL001). One official working on the Paterson Park project from the Development Planning Department explained there tended to be a "damned if you do and dammed if you don't" kind of relationship with residents, where the activities of other historical actors influenced how they interacted on the projects (GOVL006). Consequently, a lack of trust among Johannesburg Municipality and members of civil society influenced how participants and municipal officials activities at Paterson Park, where it influences how they designed, planned and implemented stormwater solutions at Paterson Park.

6.1.2 Fragmented institutional rules and prevailing concerns

When I asked residents' associations, business owners associations and municipal officials why concerns around polluted water (Bruma Lake) and flooding and safety (Paterson Park) concerns prevailed at the sites, they explained institutional rules served to limit their activities, along with political objectives of the city. The above refers to formalised and informal sets of rules, or ways of doing things, that had a bearing on how the activities unfolded at the project sites (Schatzki, 2002) (Chapter 2). Municipal participants and residents highlighted institutional rules translated to a variety of fragmented roles and responsibilities around environment and infrastructure management (GOVL0014, GOVL009 and GOVL017). This also included a range of fragmented practical understandings of physical nature-infrastructure interactions.

The implications of fragmented roles and responsibilities were so significant that for four municipal officials from Environment and Infrastructure Services Department and Johannesburg Roads Agency, they felt that even if they wanted to have resolved concerns earlier, their activities were constrained. These municipal participants explained they remained fundamentally limited by institutional rules such as the Municipal Finance Management Act 56 of 2003 and the institutional set up of the Johannesburg Municipality that limited the scope of the activities they could carry out as part of their roles and responsibilities, including their practical understandings for doing so (see Figure 5-2 and Figure 5-3), (GOVL007, GOV0014 and GOVL009). Consequently, polluted water and flooding and safety concerns prevailed at the project sites.

Fractured institutional rules for environment and infrastructure management

At Bruma Lake and Paterson Park, municipal participants from planning and environmental portfolios and municipally-owned entities responsible for water and open space management explained the range of fragmented roles and responsibilities for managing water and parks (Section 5.2). For example, rivers fall under the ongoing management activities of Johannesburg City Parks and Zoo, however; should it be linked to flooding, it legally falls under the duty of care of Johannesburg Roads Agency. Should the riverbanks be exposed[76], then management activities fall under Johannesburg Water. Consequently, fragmented institutional rules contributed to contestation around who ought to provide maintenance and upgrading (GOVL009 and GOVL0014).

Participants from Johannesburg City Parks and Zoo and Johannesburg Roads Agency explained that drawing differentially on municipal budgets also created tension between municipally-owned entities (GOVL009 and GOVL012). To provide context for the tension between municipally-owned entities, two senior representatives at Johannesburg Roads Agency and Johannesburg City Parks and Zoo and one senior official at Environment and Infrastructure Services Department responsible for environmental water management, explained that when environmental and/or infrastructural concerns landed on their desks such as flooding and failing infrastructure, they did not have enough resources to address them (GOVL007, GOVL009, GOVL0010, GOVL012 and GOVL018). In many cases, concerns such as flooding and failing infrastructure were added to their growing list of projects, where one Johannesburg Roads Agency participant illustrated, their budget was so constrained that they needed to create a priority list from their already priority list projects (GOVL009).

A response from a senior official at Johannesburg City Parks and Zoo echoed this point. They indicated that during the rainy season, when plants grow much faster than they normally do, they were not able to maintain parks sufficiently so

[76] One participant at Johannesburg Roads Agency described this tends to occur in instances where sewers were exposed close or near to a river, or where the foundations of a structure have become visible due to erosion (GOVL009).

any additional work would be difficult to accommodate (GOVL018). Consequently, the fragmented roles on environmental and stormwater management were exacerbated by existing budgetary constraints. By implication, I got the impression from participants at Johannesburg Roads Agency and Johannesburg City Parks and Zoo that any change in how maintenance and upgrading services were performed would serve to heighten existing tensions around institutional roles and responsibilities, especially where it had budgetary implications.

Concerns and political interests

Municipal officials at Environment and Infrastructure and Services Department also explained local politics influenced how they carried out their activities at Bruma Lake and Paterson Park. One participant at Environment and Infrastructure Services Department responsible for water management explained that environmental projects are viewed as being “not as compelling” as they are for other infrastructure applications such as building houses or providing water and sanitation infrastructure (GOVL0014). In other words, “fixing a lake” with a “massive” budget was grounded in the data, where it did not stack up well against a project for implementing toilets in an informal settlement[77] (GOVL014). By implication addressing environmental concerns, such as polluted water, was considered secondary to other political and infrastructure needs.

[77] Environmental concerns were being secondary to developmental needs. I have explained the political context for development at Bruma Lake and Paterson Park in the context chapter, where under the political priorities in Johannesburg at the time, the focus was on developing new infrastructure to redress inequalities created and strengthened during Apartheid.

To put limited political interest into perspective, I draw on a response from another participant at the Environment and Infrastructure Services Department responsible for environmental water management. The current municipal model for proposing and allocating municipal funds was not set up to financially support environmental projects, where practical understandings around the benefits associated with physical nature were not widespread. For example, they explained practical understandings to use physical nature to support development where not common and in many cases issues around the environmental were labelled as a ‘step-child’.

> …we are in a very difficult sector and we have sort of a lot conflicting sort of interests in the city and in the process the environment it would be more like your step-child.
>
> (GOVL007)

Their use of ‘step-child’ implies environmental concerns are of secondary concern to infrastructure. This had implications for how the budget was allocated. The existing model used at Johannesburg Municipality is based on an algorithm that was explained to prioritise the allocation of capital budgets for infrastructural ones over and above environmental ones, where it has “double-counted on certain areas and didn’t really take cognisance of others” (GOVL008). By implication, political interest affected the ability for municipal participants to carry out their activities on Bruma Lake and Paterson Park that were labelled as ‘environmental’ concerns.

The municipal model for allocating budget to projects also demonstrated the politics associated with capital investment projects funded by the municipality. As

I have presented in the context chapter, Bruma Lake and Paterson Park fell in opposition political party local government administrative ward (Section 5.3). As such, it was not politically attractive to spend municipal resources by the African National Congress which was the ruling political party at the time. Limited interests in spending funds in opposition party wards at sites such as Bruma Lake and Paterson Park created uncertainty around whether concerns could be addressed under the Johannesburg Municipality's annual capital and operating budgets.

Local politics also contributed to a contested space for municipal officials. While municipal participants explained that they were institutionally bound to provide infrastructure services, they also believed their practical understandings to use physical nature for development were thwarted by local politics. For example, Environment and Infrastructure Services Department and Development Planning Department who are responsible for the strategic oversight of water and open space management explained that they were constrained by political priorities and limited capital budget to remedy historic conditions (GOVL014 and GOVL009). In addition, they believed that it had escalated to the point where they could not be fixed easily due to their scale and cost (GOVL009). The frustrations felt by participants manifested differently across these groups where they felt limited in their scope of activities under institutional rules to address pollution at Bruma Lake and flooding concerns at Paterson Park.

The Bruma Lake Owners Association, Norwood and Orange Grove residents framed water pollution at Bruma Lake and flooding and safety concerns at

Paterson Park as the outcome of Johannesburg Municipality's neglect of their legal activities attached to institutional rules. Residents' associations felt limited by the availability of municipal funds, where political imperatives did not necessarily serve their practical understandings for a well-functioning infrastructure network and aesthetically pleasing area. As such, members of residents' associations felt it was their responsibility 'to do something' to ensure environmental and infrastructure concerns at Bruma Lake and Paterson Park did not decline further[78] (CIVSOCL001 and CONSL003). Consequently, mounting frustrations over unresolved pollution and flooding concerns sparked the need for one or more participants to claim ownership over infrastructure at the site.

Attempts to bring together legal roles under the Johannesburg Open Space Policy

One noteworthy example of institutional rules that aimed to bring together fragmented roles and responsibilities around park, river and open space management was the Johannesburg Open Space Policy. Under the policy, both Bruma Lake and Paterson Park would have already been defined as a "resource" that can provide "services as recreational open space and stormwater management areas, conservation sanctuaries and oases of agricultural land, economic engines and urban greenbelts" (City of Johannesburg Metropolitan Municipality, 2004, p. 6). Toward maintaining both sites, they were both identified as a multifunctional resource that can be used and extended to support ecological, infrastructural, or recreational features straddling the three disciplinary

[78] Allowing the situation to worsen would have been detrimental for businesses and households located beside Bruma Lake or the aging and failing culverts at Paterson Park. This was owed to their environmental and social risks.

approaches I outlined in the literature review (Section 2.1). Therefore, in theory, the legislated fragmented roles and responsibilities across Johannesburg Municipality ought to have been provided as a combined service under the Johannesburg Open Space Policy.

Before I move on, I flag the significance of the Johannesburg Open Space Policy as it illuminates a broader set of ways that municipal participants worked within existing institutional rules to leave a legacy. The Johannesburg Open Space Policy was driven by a senior official in the Environment and Infrastructure Services Department responsible for open space, water management and biodiversity. With a disciplinary background in planning, the official performed activities to support policy development around physical nature as having functional, recreational and ecological value. For example, they explained their understanding of such as parks, where:

> …it is not just about looking after parks, not about the set provision of parks…it is all the processes that are happening on the top of the ground and the bottom of the ground that impact on the landscape.
>
> (GOVL0014)

To support the vision they had, they worked within existing institutional rules to develop practical understandings associated with manage parks for their multifunctional value. The explained that they took ownership to “climb” into the “space myself and define it for myself” (GOVL0014). As they further add, they felt that they used it to influence how activities were carried out on maintenance projects, where they were able to “interfere with everything” where they can influence open space planning by “emphasising the spatial planning link”

(GOVL0014). Therefore, while strategic guidelines are used to define activities to maintain and upgrade open space in the city, in some cases it is not followed. I refer back to the development of the Johannesburg Open Space Policy (Section 6.2).

However, as the Johannesburg Open Space Policy is not a legislated institutional rule it does not specify the exact conditions for utilising the sites for such purposes. There are also no clear roles and responsibilities for municipally-owned entities to incorporate a green infrastructure approach into their maintenance and/or development. As such, despite forming part of the strategic vision for open space management, where it encouraged managing open spaces for their functional values, its vision only went so far. As it was not enforced by a set of legislated duties for carrying out maintenance and upgrading activities in the city, it was not able to support the development of practical understandings around developing and managing parks in accordance with their multifunctional benefits.

The significance of explaining such a document is two-fold. On the one hand, it shows the pertinence and development of formal and/or institutional rules in the city; while on the other, it reveals how codified rules can have limited impacts on how social life exists and evolves. The dynamics of the use of rules that are not always codified, be they institutional or social practices, sets the context for how ‘rules’ shape social life. Exploring how green infrastructure is practiced therefore illuminates the complexity and dynamism of social life in Johannesburg where instead of conforming to rules at an institutional level that is simultaneously comprised of what is ‘easier’ and ‘safer’ for the actors at hand (Schatzki, 1996).

The latter point demonstrates how what actors do 'opens up' in practice where it cannot be scripted.

6.2 Coming together under general understandings to leave a legacy

I now present on how participants claimed ownership by carrying out activities outside institutional rules to address prevailing water pollution (Bruma Lake) and flooding and safety concerns (Paterson Park). In some instances, they drew on their existing practical understandings or 'know-how' to guide their activities, which they evolved or developed to manage the uncertainty associated with the context and setting (Schatzki, 1996, 2002). The projects were not considered to be green infrastructure projects from the start, rather they became green infrastructure projects according to the variety of ways that participants claimed ownership to manage uncertainty at the project sites, thus demonstrating how nature is a constructed concept (Bird, 1987). To describe how participants used the green infrastructure concept in this way, I build on the section before on material concerns.

The idea of leaving a legacy was commonly held among the municipal, residents' and business owners associations, including private sector professionals working. Leaving a viable and manageable legacy formed a general understanding common among participants, where it developed as a collective identity around how they would carry out activities at the project sites, including their constructions of nature (Bird, 1987). For many of the participants I interviewed, they had already developed practical understandings or a 'know-how' for working outside institutional or professional rules (Schatzki, 2002). That said, it also became clear through our conversations that participants across the groups developed these further to respond to the material concerns that they faced at Bruma Lake and Paterson Park.

To fulfil a common objective, participants aligned their interests around a general understanding. I mentioned general understanding that held participants together was comprised of a common interest to leave a legacy in the city. Ambitions to leave a legacy brought together actors with a range of physical nature-infrastructure interactions. Coming together under a common object resonates with the studies I already mentioned, where despite holding a range of constructed meanings of physical nature, participants can be united under a broader approach or interest (Schatzki, 1996, 2002; Austin, 2014). Participants, therefore, came together under the ‘breadth’ or capaciousness of green infrastructure concepts (Lennon, 2019; Horwood, 2020) (Section 2.3).

I showed that physical nature-infrastructure interactions were understood in different ways according to participant’s practical understandings. The way that participants spoke about Bruma Lake and Paterson Park projects revealed their understanding of green infrastructure concepts. For them, river renaturalisation as an ‘environment and infrastructure’ intervention was a practical solution (CIVSOCL006), public amenity (CONSL007 and CONSL009), environmental sustainability (GOVL017) and infrastructure services (GOVL017 and CONSL007), (Section 5.5; Table 5-1). Consequently, while river renaturalisation was the approach followed at the site, it meant different things to the actors working on the projects. Actors with different understandings of physical nature-infrastructure came together to carry out their activities.

‘Leaving a legacy’ was the terminology used by municipal officials at Environment and Infrastructure Service and Development Planning departments, Johannesburg Development Agency (GOVL006, GOVL007, GOVL014 and GOVL017). Although not explicitly expressed using this terminology, private sectors professionals such as the engineers, architects and landscape architects working on the projects and residents’ and business owners associations also explained their interests in leaving a legacy in other ways (CIVSOCL001, CIVSOCL003, CONSL003, CONSL007 and CONSL009). Therefore, despite not forming a predefined endpoint, such as setting out a green infrastructure outcome from the start (such as teleoaffective previously discussed in Chapter 3), the common interest around leaving a legacy brought participants together on projects. Leaving a legacy, therefore, manifested as a general understanding that united actors under a shared interest.

While the civil society, private sector professional and municipal officials I interviewed exhibited a personal interest, it is worth mentioning this sentiment was not shared among actors in the city. As I explained at the start of the thesis (Section 1.2), the participants I interviewed were self-selecting. Participants that identified Bruma Lake and Paterson Park as ‘environment and infrastructure’ tended to be those that felt proud of their activities and the activities of other actors on the project. Therefore, while claiming ownership to leave a legacy is not unique to the project sites, or even infrastructure project in general, it did contribute toward how green infrastructure was conceptualised at Bruma Lake and Paterson Park projects.

While participants from each of the groups I interviewed understood their legacy to be something different, what was common among them was an assumed ownership to go beyond institutional rules to produce a project that could 'add value' in some way (GOVL006, GOVL007, GOVL014, GOVL017, GOVL007, CONSL007 and CIVSOCL002). Ambitions to leave a legacy were defined by the intended outcome of the participant[79], where they each had a different idea of what their legacy would be according to their practical understandings and background. Interests to leave a legacy acted as a common sense of "worth, value, nature of place of things" that "infused" in their activities (Schatzki, 2012, p. 16). Therefore, the vision was not necessarily tied to what could be done as part of institutional rules, rather it was guided by their aspirations of what the project could be and which values could be derived for personally, for the community and Johannesburg in general given the context and political setting for environment and infrastructure projects.

Civil society's drive to influence their local area

Residents and business owners associations demonstrated their general understandings through the way that they claimed ownership at Bruma Lake and

[79] I discuss the implications of this personal interest when I describe the limitations of the thesis in the Introduction (Chapter 1). Participants interested in speaking to me tended to be those who were interested in the projects and worked outside their professional capacity to support them.

Paterson Park. Residents[80] had interests to create a well-maintained and safe neighbourhood. To achieve their ambitions, the Bruma Lake Owners Association and the resident's associations at Norwood and Orange Grove took steps to hold the Johannesburg Municipality to account under their legal duty of care outlined in institutional rules. The business owners and residents associations wanted to ensure the quality of water was at a sufficient standard, flooding was managed and that the neighbourhood looked a certain way. The civil society participants I interviewed who held these views were mainly white middle-class South Africans[81].

At Bruma Lake, I interviewed members of the Bruma Lake Owners Association and two residents that had an interest in water quality concerns at the site. Leaving a legacy for them was directly linked to polluted water and its implications for human health and local businesses. As one member of the Bruma Lake Owners Association described, the smell that "permeated" from the lake travelled "quite a distance" and created sinus and respiratory concerns (CIVSOCL006). The smell permeating from the lake "had an impact on our business[82]", where patrons would no longer stay at hotels beside the lake (CIVSOCL006). The health and financial implications of polluted water encouraged residents and Bruma Lake Owners Association to take action to address the water pollution. Leaving

[80] Participants explained they felt this was unlike the sentiments of more recent residents, such as migrants into the area. They believed they were more silent or not interested in managing the park compared to mor longstanding residents.
[81] While Norwood still has a large white middle-class population, Orange Grove has undergone remarkable social transformation with the influx of new residents in the form of migrant workers from all corners of Africa (Section 4.3).
[82] Implications of the smell included were health issues such as sinusitis. The manager of a business located beside the lake explained "I am very sensitive to sinusitis and that is one thing I struggled with" before the lake was renaturalised (CIVSOCL006).

a legacy, therefore, encapsulated activities to relieve the impacts on their health and business, where it was possible to create public amenity while doing so.

At Paterson Park, the ambitions of civil society were slightly different. Residents from Norwood and Orange Grove had concerns around the look and feel of the neighbourhood, which they believed had declined in aesthetic and safety since the 1980s. Residents that I interviewed explained that the outward movement of residents from Orange Grove resulted in buildings being “sold” or “abandoned”, and in some cases, they were taken over, or “hijacked[83]” by illegal landlords that housed informal tenants (CONSL003). There was a “feeling of disintegration” among the original residents and a “security risk”, where “women and children […] we would have never suggested they go in [into Paterson Park], unless in a group” (CONSL003). Ambitions to leave a legacy among the participants underscored activities to restore control over the neighbourhood to manage illegal housing activities and security risks in Paterson Park. Therefore, leaving a legacy was intended to restore the area to how it looked and felt before they believed it had fallen into decline, where it was believed other values such as public amenity could be created.

At both sites, residents and business owners associations did not have the financial means to address problems on their own. While public participation does form part of institutional rules, such as the South African legal system, activities to hold municipal government accountable through these means had produced

[83] A South African word for the illegal takeover of something, in this case a building.

limited results at the project sites. As such, participants explained that they claimed ownership to find alternative platforms to voice their concerns. For example at Bruma Lake, business owners associations held Johannesburg Municipality accountable to its legislated responsibilities around environmental and water laws. They even hired an environmental expert to help the exert even greater amounts of pressure. At Paterson Park, residents' associations lobbied against development and used environmental law as a tool to influence the outcome of the Paterson Park as defined under the broader remit of the Corridors of Freedom project. In both instances, they used their practical understandings to influence new or different activities to respond to the context and setting.

Municipal official activities to define the scope for solutions

Municipal officials described their general understandings through outlining their focus on supporting equitable outcomes in strategy documents such as plans or guidelines, or by specifying certain project deliverables they believed were important for the development of the city. For example, on Bruma Lake project, a municipal official responsible for managing the project explained "whatever we did on that lake would have an impact downstream and on the natural lifecycle of a river", to reduce the downstream impact, it was considered necessary to "improve the ecology" at the Bruma Lake site (GOVL017). On the Paterson Park project, an official responsible for the development of the project described it could be "something more" from the start, where it was necessary to "push everyone's boundaries on where […it…] was going" (GOVL006). Consequently, the abovementioned participants knowingly worked outside institutional rules to support a vision they believed would be beneficial for Bruma Lake and Paterson Park.

One-way municipal participants worked outside institutional rules was to perform activities beyond the scope of their municipal scorecards. This supports the theoretical descriptions of general understanding, where they can exhibit "pre-reflexive" elements for how practices are carried out (Welch and Yates, 2018, p. 5). Johannesburg Municipality uses scorecards as a management tool to ensure staff meet a set of predefined tasks to action development priorities[84]. As one project manager at Johannesburg Development Agency explains, even though you have "ticked off your scorecard" to develop a building for example, where it was completed at the agreed budget when it ends up being a "white elephant and nobody uses it" (GOVL017). They further described that as "an individual", it becomes necessary to "look at the long-term sustainability of the project […] to benefit communities there" (GOVL017). Consequently, developing meaningful projects for communities was identified to require municipal participant activities over and above those outlined on municipal scorecards.

A common legacy among three participants responsible for project management at Johannesburg Development Agency and Johannesburg City Parks and Zoo included the development of parks. For them, leaving a legacy formed part of achieving a vision they had for urban development in Johannesburg. When I

[84] Scorecards are a tool used by the municipality for monitoring the progress of local officials. Should an item be listed on the scorecard of a local official it becomes an 'allocated task' that needs to be completed in terms of progress management. Officials are held accountable to the items listed on their scorecard.

asked more about what leaving a legacy meant for them, they described the same kind of vision: children playing in a park (GOVL012, GOVL017 and GOVL018). For many children living in Johannesburg in informal settlements, parks can provide safe outdoor green space for them to play to escape their poor living conditions in informal settlements (GOVL018). River renaturalisation as a form of green infrastructure suited the ambitions of municipal officials to leave a legacy, where parkland could be created as part of urban water management projects, where under a different infrastructure approach it might not be possible.

Municipal officials who worked outside of their municipal scorecards to leave a legacy were not common. As one engineering consultant explains, the municipal officials involved in Bruma Lake and Paterson Park projects such as those at Environment and Infrastructure Services Department, Development Planning Department and Johannesburg Roads Agency are “very committed” and in particular, “very committed to doing things right” (CONSL007). These officials tended to use their practical understandings as a way to work outside of existing institutional rules. For these reasons, they were often “spread really thin” across departments and projects, where they felt “they are constrained” by resources to perform activities to leave a legacy in Johannesburg (CONSL007). Consequently, the municipal officials that are committed tend to be involved in a wide range of projects that interest them, and they are constantly faced by limitations for their ambitions.

Private sector interests to ‘add value’

The projects brought together a range of professionals to support the development of the interventions at Bruma Lake and Paterson Park (Section 5.3). Apart from producing an infrastructure intervention to address water quality (Bruma Lake) and flooding (Paterson Park), the private sector participants explained their ambitions to go one step further, by moving beyond only ‘ticking the boxes’ of disciplinary practice. In the conceptual framework, I showed that disciplinary practice often had a set of rules or professional guidelines to support activities. For example, the architect working on the broader Paterson Park precinct plan, of which the Paterson Park project is one element, explained that they saw it as part of their role to “not only as practitioners serving a client brief”, but it included “collectively trying to develop stronger agendas”, with the ambition to “assist development” in Johannesburg (CONSL009). The architect supported their ambition through including a strong focus on environmental functions to “integrate the park” as part of the “continuous” set of green corridors in the vicinity of Paterson Park (CONSL009). Therefore, private sector professionals focused municipal projects around their ambition to leave a legacy.

For the design engineer on Bruma Lake and Paterson Park, their ambition was to include ‘value add’ at the project sites. The design engineer explained they followed a “mechanism and a method” they believed would “extract extra value” through providing stormwater management services (CONSL007). For example, instead of building a “concrete channel [… that…] doesn’t do anything other than convey excess water down the catchment”, they saw the opportunity to create “secondary value” by developing their practical understandings to include “riparian connectivity” and a “parklike environment so […] people can enjoy it” (CONSL007). Accordingly, the design engineer worked with existing institutional rules to support their ambitions to leave a legacy in the city.

Despite the strong reliance on engineering standards and knowledge as part of the *engineered approach* (Section 2.1), the design engineer also explained how general understandings encouraged them to evolve their practical understandings and work outside existing professional rules to address polluted water and flooding. As they explained, “infrastructure has to do a job” and “this is what it comes down to” (CONSL007). Once you are “sure your intervention does the job”, you can draw on “protocols to an extent”, but you do not need to “comply with the detail” to design and implement them in practice (CONSL007). Therefore, leaving a legacy required professional practitioners, such as the design engineer, to be open or flexible in applying and developing existing approaches in infrastructure practice. I refer to flexibility in more detail in the chapter to follow, where I describe technical and physical uncertainties (Section 7.2).

Private sector interests to leave a viable legacy was not the norm among practitioners. Again these, participants were described as being few and far between, with a “professional jealousy” developing among those practitioners who did not carry out activities along these lines (GOVL017). An official at Environment and Infrastructure Services Department responsible for the management of open space and water put this into perspective, where they highlighted the “skills” to respond to infrastructure differently “are not there” and not many practitioners want to take on the “public liability” to engage solutions by “trial and error” (GOVL014). The project manager responsible for the broader Corridors of Freedom reflected on the activities of the design engineer, where they explained there is “a damn well a difference between using this person who is trying to find different solutions”, including their approach that “continue a professional commitment on projects like these”, which offer a range of benefits such as a continued interest around the continuity of the projects in the city (GOVL006). Therefore, private practitioners who have ambitions to leave a legacy in Johannesburg through their strategic approach and efforts to add value, are considered sought after for professional engineering and other services on municipal projects.

While each of these groups of participants supported leaving a legacy for different reasons, their understanding and activities supported it in different ways. Part of carrying out their activities included following a range of meanings of physical nature. For example, participants “align[ed] their different commitments and beliefs…towards a shared activity” to create value or multiple benefits for the residents of Johannesburg (Welch and Yates, 2018, p. 10). In doing so, they supported this shared vision by understanding and taking action around physical nature in ways that support aesthetic, functional and utilitarian values. While carrying out these activities they supported the development of common practical understanding, where experimentation served to evolve their ‘know-how’ (Schatzki, 2013).

6.3 Leaving a legacy, evolved physical nature-infrastructure interactions and its implications for institutional rules

Participant activities to claim ownership at Bruma Lake and Paterson Park have implications for how green infrastructure is used in Johannesburg going forward. As a starting point, participants explained they were “stretched” to work outside existing rules, where they relied on their practical understandings or ‘know-how’ to identifying procedures for developing and implementing the projects (GOVL006 and CONSL013). Working in new or different ways also created a vested interest in the continued functionality of the projects going forward as the sites would continue to fall under the same ongoing legislated activities and practical understandings to manage and upgrade infrastructure services. In this section, I explore the need for new kinds of ownership to support the long-term functionality of the projects (Section 6.3.1) and its implications for practical understandings amid a broader set of infrastructural water concerns in Johannesburg (Section 6.3.2).

6.3.1 Stretching practical understandings and its implications for future ownership

Participants from across all the groups I interviewed asked the question: “who takes the baton forward?” Exploring the abovementioned question is significant for understanding the long-term implications of claiming ownership at Bruma Lake and Paterson Park projects where it demonstrates a range of ongoing concerns in Johannesburg. Resident groups, private sector professionals, and municipal officials claimed ownership in a variety of ways to achieve the vision they wanted to see in Johannesburg (Section 6.2). Participants undertook activities in a variety of ways where they 'said' and 'did' things to support the use of green infrastructure at Bruma Lake and Paterson Park such as lobbying against Johannesburg Municipality (civil society), developing solutions outside of institutional and professional rules (consultants), and setting up the scope to guide different kinds of projects (municipal officials). Without claiming ownership in a variety of ways, it is unlikely water pollution and flooding would have been addressed using a green infrastructure approach where uncertainty influenced the use of the approach, while also requiring participants to claim ownership to use it. Therefore, under different circumstances, polluted water and flooding may have persisted. Alternatively, another infrastructure approach would have been followed.

The question of "who takes the baton forward?" reveals one further aspect of green infrastructure where it illuminates some of the complexity around infrastructure and how it mediates social life. For example, I explained viewing infrastructure as an ethnographic feature of the city illuminates the "mundane things", which from the outset may appear to be familiar and understood can conceal "hidden mechanisms" (Star, 1999, p. 377). The question of "who takes the baton forward?" therefore underscores the need to delve deeper into the more complex relationships that exist around infrastructure, where it is "always a relational, never a thing" (Star, 1999, p. 253). Toward exploring the more complex relationships that exist around green infrastructure and its future in Johannesburg it becomes necessary to explore maintenance in greater detail.

Maintenance as an on-going concern

As with any infrastructure project in Johannesburg, the projects at Bruma Lake and Paterson Park created concerns over which municipal actor is responsible for its ongoing functionality under institutional rules. I illustrated at the start of the chapter (Section 6.1) that Johannesburg Municipality does not have a good “reputation in terms of maintenance” due to a spilt in intuitional roles around parks, rivers and river banks and limited budgets for ongoing maintenance (GOVL017). As such, there were resource constraints for claiming ownership to support the long-term functioning of the projects. Municipal participants at Environment and Infrastructure Services Department and Johannesburg Development Agency explained limited resources would result in the same kinds of infrastructural outcomes, where they are likely to fall into disrepair (GOVL007, GOVL014 and GOVL017). Consequently, municipal officials and business owners and residents’ associations flagged the need to consider which participants will take on new voluntary or legislated obligations to ensure the long-term functionality of the reconstructed rivers over time.

Identifying which participants would ‘take the baton forward’ would firstly play a significant role in how Bruma Lake and Paterson Park would be developed and maintained over time. I explained the interests of actors can influence the nature of infrastructure projects, where despite falling under a common and broad narrative, they can “reconfigure” space in “specialised, privatised and customised ways” (Luque-Ayala and Silver, 2016, p. 4) (Chapter 2). The implications of which actor takes the baton forward is significant as it can create an “uneven” distribution of responsibilities in relation to “political, economic interests and capabilities" (Luque-Ayala and Silver, 2016, p. 5). By implication, the impacts of which would become problematic in terms of its potential justice and equity concerns going forward.

Second, the use of river renaturalisation as a form of green infrastructure contributed to one further level of complexity regarding practical understandings and new kinds of ownership that need to evolve. As the projects drew on certain practical understandings of physical nature and infrastructure, it had implications for the municipal, private sector and civil society actors involved and how they should claim ownership to provide maintenance. Toward illustrating the specificities of new kinds of ownership of the project sites, I reflect on the use of river renaturalisation and its implications for the already fractured practical understandings of green infrastructure across Johannesburg Municipality (Chapter 5). By reflecting roles and responsibilities on different actors in the city, I show how the use of river renaturalisation as a green infrastructure solution is characterised by an evolved, narrow, or niche, approach, which evolved as part of the general understandings of participants (Welch and Yates, 2018, p. 10) (Section 3.3). Consequently, by identifying the significance of the approach at the project sites, it illuminates evolution in the meanings of green infrastructure in practice.

Ensuring the functionality into the future by 'taking the baton forward'

The question of who 'takes the baton' forward was raised by participants from all groups. At the start of the chapter, I discussed how the fragmented responsibilities between Johannesburg City Parks and Zoo, Johannesburg

Roads Agency and Johannesburg Water created tension around who should maintain open space, parks and water (Section 6.1). As a consultant working on the Paterson Park project responsible for the design of the parkland commented, “who will ultimately be responsible for it?” (CONSL006). They pointed out it was questionable as to whether “[Johannesburg] City Parks [and Zoo], Johannesburg Roads Agency, Johannesburg Development Agency” should take ownership of the project because “we have been on site for so long it is now [and] at this point where we need to say okay this is now your baby carry on with it” (CONSL006). Therefore, because a green infrastructure approach draws together three elements – open space, a river and stormwater infrastructure – there was no clear owner of the entire project, including its maintenance.

An engineering consultant in Johannesburg explains the maintenance of infrastructure in Johannesburg is contentious at the best of times. Maintenance presents itself as a limiting factor for working outside disciplinary rules in the first place. For example, “not all the parties want to play a role” because they “don’t want to be responsible for maintaining because maintenance is such an administrative nightmare” (CONSL001). As maintenance forms an essential part of the long-term functionality of the project, where projects could fail and “they don’t want to be blamed for it” when it is not provided or where the project does not work as intended (CONSL001). Therefore, engaging in river renaturalisation as a form of green infrastructure was daunting, but not necessarily from the technical point of view, rather because of existing administrative concerns over maintenance and how they would adapt to provide necessary services.

Reticence also emerged from within municipally-owned entities, such as Johannesburg City Parks and Zoo. In addition to creating tension among municipally-owned entities, a renaturalised river created contestation among practical understandings of physical nature-infrastructure interactions, institutional rules and associated roles and how they were split within the entity. Within Johannesburg City Parks and Zoo, parkland and rivers fall under two separate sub-units that carry out different maintenance activities. For example, a manager responsible for the maintenance of parks in one of Johannesburg's regions points out, "when you are talking streams, water bodies and so forth that is done by our conservation department" (GOVL0018). The division of roles and responsibilities has implications for the maintenance of Bruma Lake and Paterson Park as a whole because "my guys will only concentrate from say a metre away from the water body and the rest of the park […] we don't go in there" (GOVL0018). By implication, while a certain part of the project, including the river and water body, might be maintained as part of a fixed rota for maintenance, the parkland may not be.

Therefore, Johannesburg City Parks and Zoo do not function as an integrated entity. The entity's various sub-units function in an independent manner and their maintenance rotas are co-ordinated over different time frames. For example, the same entity does not offer a "one-stop-shop sort of maintenance plan" for ensuring the functionality of the projects (GOVL0018). Providing long-term maintenance on Bruma Lake and Paterson Park would take place with existing tools and resources, where they explained:

…like if you have this concept [referring to what was used at Bruma Lake and Paterson Park] I always refer to it as a toolbox. You turn the toolbox upside down. Sort out your resources and see what you have.

(GOVL018)

Therefore, the implications of limited resources and a 'toolbox approach' were that while there was a wide range of variation in skills and options for maintenance, it may not be the right ones to ensure the long-term functioning of the projects over time where it became necessary to evolve practical understandings to maintain river renaturalisation projects.

Limited resources for maintenance illuminate one further implication of claimed ownership for the long-term management of the projects. The use of unplanned and voluntary activities to address water pollution and flooding resulted in an infrastructure that diverged from existing practical understandings and institutional rules related to maintenance. While I explain the need for new kinds of practice understanding to address uncertainties around how to maintain projects in the chapter to follow, I flag its implications for ownership here. For example, the participants responsible for maintaining the projects, "they couldn't even conceptualise a [bio]swale some of them" (GOVL007). The implications of this are that the "tools that we are having and the training that we are having […] for stormwater doesn't talk to a [bio]swale" (GOVL007). Therefore, specialist knowledge, or training, on how to ensure the long-term functionality of Bruma Lake and Paterson Park should form part of ownership activities going forward.

The need for more specialist insights, or specific practical understandings, was identified to be part of a broader and more concerted effort between Environment and Infrastructure Services Department and Johannesburg City Parks and Zoo. As one official at Environmental and Infrastructure services responsible for the management of open space remarks on the completion of projects, “they kept on giving the project to [Johannesburg] City Parks [and Zoo]”, which only have “grass cutters and litter pickers, so they don’t know what they were dealing with” (GOVL014). Ownership of the projects going forward requires “careful bedding down, nurturing, managing which plant, it is a finely tuned thing” (GOVL014). Therefore, developing what is required to take ownership was not straightforward, and this often came at a cost to the overall success of the projects. I return to this point when I discuss uncertainties and knowledge in the chapter to follow (Section 7.3).

Toward claiming the future of the projects, participants from the Environment and Infrastructure Services Department had already taken steps to engage with civil society such as residents and local businesses to discuss continued maintenance at both projects. As one participant at Environment and Infrastructure Services Department points out, “now we are in the process of where we are sort of in discussion with both stakeholders and the residents’ associations” (GOVL007). At Bruma Lake, in particular, some headway had been made toward the maintaining the project going forward, where one property owner had “come up with a business model where they don’t have to rely on the city to sort of maintain” the site (GOVL007). Therefore, continued ownership was demonstrated by officials at Environment and Infrastructure Services Department to work around existing accountability and funding constraints at Johannesburg Municipality.

Civil society, municipal official, and private sector activities to own the future included working consistently toward leaving a legacy even beyond the completion of the project. The dialogue that had taken place between Bruma Lake Owners Association and interested officials at Environment and Infrastructure Services Department to try to negotiate a joint venture, where it may be possible to “maybe only as a basis we contribute something toward maintenance and they also use their resource[s]” as a starting point (GOVL007). From then on there can be “some kind of model to maintain” (GOVL007). Subsequently, despite raising valid questions over who would take the baton forward, vested interests in the projects across participant groups resulted in continued negotiation and unplanned and voluntary activities toward realising participant visions for the projects.

6.3.2 Shifting from activities to practice

Questions over ownership also illuminated a broader question around the ownership of green infrastructure in Johannesburg. Officials, residents, members of the Bruma Business Owners Association and some private sector professionals asked: “Was that really a solution?” (CIVSOCL003, CIVSOCL006, GOVL014, GOVL017 and CONSL006). Participants from all groups, particularly on the Bruma Lake project, commented on green infrastructure as addressing the immediate problem, however, it did little to address the broader infrastructural concerns in the city. Bruma Lake Owners Association and municipal officials believed the root cause of concerns at Bruma Lake was associated with a “water quality problem in the inner city” associated with the “dilapidated buildings and buildings that were abandoned” (GOVL014 and CIVSOCL003). Therefore, water quality concerns at Bruma Lake were wide-reaching and broader than the lake alone.

In addition to Bruma Lake, the Environment and Infrastructure Services Department had a string of projects upstream of the lake to address water quality and the integrity of the physical environment. The same official that had strategic oversight of the Bruma Lake project had oversight of these projects too. Projects included a range of “river restoration” measures in the early 2000s that included activities to “flatten the banks [and] replant them” to “give the river space to spread-out” (GOVL014). River restoration measures[85] were followed up by the provision of constructed wetlands, such as the Queen’s Wetland, to try to address the water quality of the Jukskei River from “source to Bruma [Lake]” (GOVL014). Therefore, despite being a focus of the study, the Bruma Lake project was only one intervention as part of a range of interventions for addressing failing urban water infrastructure and water quality on the Jukskei River. I refer to Queen’s Wetland in the chapter to follow when I show the need to develop knowledge on green infrastructure (Section 7.3).

Despite using green infrastructure approaches to address water quality in-situ, interventions could only go so far to sort out the broader water problem. As explained by one senior official at Environment and Infrastructure Services Department, the “challenges always come down to water quality”, where “it always keeps bringing us back to the sewer” (GOVL014). Reflecting on

[85] Other interventions included the implementation of a litter trap upstream to try to collect or gather debris before it entered Bruma Lake. See earlier descriptions of projects in Section 5.3.

institutional rules and resources, the same official explained, “we have to be realistic” as “we are never going to solve things”, where the best they can do is to “secure your patch and then you move out” (GOVL0014). Thus, the Bruma Lake project formed only one water quality intervention along the Jukskei River.

The design engineer pointed out that while the water quality along the stretch of river at Bruma Lake has been addressed, water pollution prevailed (CONSL007). These sentiments were echoed by another environmental expert working on the Bruma Lake project where they explained that while the renaturalised stream “made it look pretty”, it still did not address the underlying issues around water quality (CONSL010). They further explain the changes at the site, where they emphasise the aesthetic benefits rather than providing a noticeable change to the quality of water:

> …you no longer have this waterbody which is a feature from a passive recreational perspective and people wanting to look at a water feature that was really smelly [emphasises]… you now have a flowing, running system, with no impoundment pushing back, but you have got landscapes banks on the side and quite a nice big space.
>
> (CONSL010)

The need to address water quality concerns prevailed, where it became necessary for participants to claim ownership in a variety of ways to manage uncertainties in the future. Uncertainties were not only linked to ownership concerns, but also around the practical understandings required to maintain the functionality of river renaturalisation over time.

New avenues for ownership and the need to manage an uncertain future

According to one participant at the Environment and Infrastructure Services Department at the City of Johannesburg, the responsibility to upgrade the urban water network fell on the shoulders of Johannesburg Water. As the root cause of the problem was described to be a result of “broken pipes”, the ownership falls under Johannesburg Water because it is “their infrastructure” (GOVL014). At the time of research, Johannesburg Water’s activities under their institutional duty of care included the discussion of using closed-circuit television systems to locate areas where pipes needed to be replaced. Officials at Environment and infrastructure Services Department explained that using an approach such as this was as effective as “putting a plaster on the wound kind of scenario” as it would not remove the need to upgrade and replace the entire network (GOVL007). Therefore, broader concerns around taking ownership to address failing water infrastructure in the form of broken pipes demonstrated a much larger need to engage with water management in the city, which followed a similar pattern to what I have described here.

Inadvertently, the inability for Johannesburg Water to deliver on their institutional mandate to maintain infrastructure led to further frustrations over the continued need for maintenance and repair at the project site. Ongoing maintenance requirements associated with failing water infrastructure and polluted water became part of the daily roles and responsibilities of municipal actors, such as participants responsible for open space and water management at the Environment and Infrastructure Services Department. Carrying out these activities often came at the cost to the municipal participant in question (GOVL014). As participants at Environment and Infrastructure Services Department and Johannesburg Development Agency, responsible for the management of Bruma Lake and related projects in the city, pointed out that not delivering on their institutional mandate had implications for urban development such as meeting political priorities outlined by the Spatial Development Framework 2040 and annual Integrated Development Plans (GOVL014 and GOVL017), (see Section 5.1 for earlier descriptions of the Spatial Development Framework 2040). One area related to the political imperatives of the city is densification, where increasing access to things such as transport and housing, including other facilities including recreation space, is contingent on creating demand to offset the costly upgrades.

At present, Johannesburg's development plans and frameworks earmark the inner city for further densification. As the inner city is also the site of failing infrastructure, many officials I interviewed expressed their concerns around ongoing water management concerns and poor water quality. As an official at the Environment and Infrastructure Services Department responsible for water management explains, we "caution" the densification of the inner city, simply because the "infrastructure cannot cope with that" (GOVL007). To their mind, Johannesburg Municipality must "address the infrastructure", before "even thinking about densifying further (GOVL007). Therefore, the use of green infrastructure not only demonstrates the need to engage ownership over the projects in slightly different ways, but it also demonstrated the need for ownership around broader concerns around addressing water quality.

6.4 Claiming ownership to leave a legacy

In this chapter, I explained how participants claimed ownership through their activities to leave a legacy at Bruma Lake and Paterson Park. A common objective, or general understanding, among participants to leave a legacy influenced the way that participants carried out their activities, where they found it necessary to develop their practical understandings. Municipal officials, private sector professionals such as the design engineer, and members of civil society such as the Bruma Lake Owners Association and Norwood and Orange Grove residents claimed ownership through taking on legal roles and responsibilities at the project sites. Historic ownership concerns, including political and resource constraints around funding for projects, created the need for participants to leave a legacy in different ways, such as holding Johannesburg Municipality accountable to their legal obligations (Bruma Lake Owners Association and Norwood and Orange Grove residents), broadening the scope for solutions (municipal officials at the Environment and Infrastructure Services Departments and Johannesburg Development Agency) and experimenting with different solutions to create value (design engineer). The ways that participants claimed ownership had implications for the projects going forward, where it pointed to the need for participants to claim ownership over ongoing maintenance in relation broader water quality concerns in the city, but also evolve different practical understandings of physical nature-infrastructure interactions.

Chapter 7 MANAGING UNCERTAINTY

In this chapter, I explain the second part of the mutually constitutive relationship between *ownership* and *uncertainty*. *Uncertainty* is linked with *ownership*, where participants felt they needed to carry out activities to respond to the uncertainty they faced around the future of the project sites. I explained *ownership* and *uncertainty* were two analytical themes that emerged out of the data analysis process (Section 4.4). The relationship between these two analytical themes enabled a description of how actors carried out their activities where they encountered uncertainty associated with their activities to leave a viable and manageable legacy. The conceptual framework I set up enables me to explore the relationship in greater detail, where I identified three key concepts for exploring how green infrastructure concepts are practiced, *practical understandings*, *general understandings* and *rules*. The three concepts enable me to present on the complexity of green infrastructure in practice, where it is not a mundane material feature of urban areas, but a socio-political process.

I explained that to leave a legacy, participants tended to work outside of existing institutional and professional rules in different ways to own the future of the project sites. They also developed their practical understandings to enable them to leave the kind of legacy they believed was important. Both of these features of green infrastructure “opens up” the “conceptual and methodological space” for exploring how green infrastructure manifests outside of conventional “locations and mediators” (Von Schnitzler, 2016, p. 9). By implication, working outside of existing rules shows how green infrastructure is practiced as a situated and contextually bound phenomenon where activities to claim ownership to manage uncertainty framed the need to claim ownership in new or different ways due to it "unforeseen" contextual effect (Star and Ruhleder, 1996, p. 118). The interaction between ownership to uncertainty contributed to the conceptualisation of green infrastructure concepts in practice.

Like ownership, *uncertaint*y emerged out of the data analysis phase of the research project where it presented an analytical theme for explaining how green infrastructure concepts were practiced. Again, while 'uncertainty' is not novel or new for any project, it is noteworthy to make explicit that it does help to explain how green infrastructure concepts were practiced in Johannesburg, where it illuminates key features of how the concept was used in a situated and contextually bound way. Highlighting how green infrastructure concepts were practiced through managing uncertainties, therefore illuminates the where actors negotiated evolution in the understanding and meanings of physical nature-infrastructure interactions. It also underscores my contribution to knowledge, which I will elaborate on further in the conclusion (Chapter 8).

To explain how participants managed uncertainty through their activities, I begin by describing how uncertainty around the future of Bruma Lake and Paterson Park project influenced their activities (Section 7.1). I then present on how participants managed uncertainty associated with working outside of rules, where they (re)conceptualised their practical understandings of physical nature-infrastructure interactions (Section 7.2). Finally, I reflect on the evolution of shared understandings around physical nature-infrastructure interactions through participant activities to claim ownership (Section 7.3). The (re)conceptualisation of physical nature-infrastructure interactions has implications for how the projects are understood going forward, where it illuminates uncertainty around its maintenance and how it can have far-reaching consequences for the future functionality of the project sites.

7.1 Managing an uncertain future

Participants from the Bruma Lake Owners Association and residents of Norwood and Orange Grove, including municipal officials at the Environment and Infrastructure Services Department, Development Planning Department and Johannesburg Development Agency, described the uncertainty they faced at the start of the project. To be more specific, the participants from these group explained uncertainty around whether or not Johannesburg Municipality would perform their legal duty of care (Bruma Lake Owners Association and Norwood and Orange Grove residents' associations), whether Johannesburg Municipality would allocate funds to address the project sites under the annual budgeting process (Environment and Infrastructure Services Department at Bruma Lake), and whether or not the projects related to Corridors of Freedom (Development Planning Department at Paterson Park) could be implemented according to a very tight project timeline. Consequently, participants explained they claimed ownership to own the future of the site, where they could achieve the ambitions that they had in mind for the project.

I explained participants came together under a general understanding around leaving a manageable and viable legacy in Johannesburg. Wanting to leave a manageable and viable legacy brought together actors through their activities, where they 'did' and 'said' things in different ways, according to different understandings of physical nature-infrastructure interactions. General understandings gave participants a "collective identity", where they were held together by "commitments, beliefs and values" (Welch and Yates, 2018, pp. 9–10). Activities under a collective identity bring actors together in practice, where they engaged in experimentation, which resulted in the "gradual evolution" of meanings of green infrastructure (Schatzki, 2013, p. 39). To achieve the ambitions, participants explained they encountered uncertainty around the material properties of the sites.

Municipal officials and private sector professionals explained that that faced significant uncertainty associated with the material properties of the sites, such as the characteristics of the polluted water and sludge and how to remove it (Bruma Lake), or how to reduce flooding by developing a project to accommodate the local geography and political interests of residents (Paterson Park). I mentioned materiality and meanings of physical nature-infrastructure interactions, where it can be understood differently in accordance to its "physical-chemical composition", where different kinds of actors such as engineers, architects, environmental professionals, and members of civil society may construct its meaning may differ according to their background and experience (Schatzki, 2010a, p. 136). Consequently, while the broad material concern was understood as being associated with polluted water or flooding, the exact understandings of it as a physical nature-infrastructure concern and its amelioration was mixed among participants where municipal participants at the

Environment and Infrastructure Services Department, Development Planning Department and engineers claimed ownership in different ways.

Participant's interests to own the future

It is unlikely that Bruma Lake and Paterson Park would have taken place at all given the fragmented roles and responsibilities of municipal participants, limited resources and politics (Section 6.2). Toward leaving a legacy in the city, participants carried out activities to 'own the future' of Bruma Lake and Paterson Park, where they were required to work within and outside rules to realise their ambitions. One way in which participants 'owned the future' was through creating political pressure to influence activities. For example, steps were taken by both Bruma Lake Owners Association, Norwood and Orange Grove residents to respond to material concerns such as burning eyes, sinus problems, or loss of incomes at Bruma Lake and safety concerns at Paterson Park (CIVSOCL003, CIVSOCL006 and GOVL007). While businesses around Bruma Lake explained that they bore the brunt of concerns at the lake, where it became "a very sore issue for a very, very, long time" (GOVL007), they did not have the legal authority to address the problems in their entirety. Also, due to the sheer cost of intervening to alleviate their concerns, taking action lay outside of their realm of possibility. By implication, participants carried out activities to claim ownership.

7.1.1 Creating pressure for change at Bruma Lake

To own the future of the project site, the Bruma Lake Owners Association and Norwood and Orange Grove residents voiced their complaints via established routes such as public participation sessions and by taking the initiative to contact

Johannesburg Municipality directly through existing rules. For example, residents and local businesses embarked on a “long [and] steady road” of “constant battles, constant communication, constant email” (CIVSOCL006). After attempting to draw attention to the problems at both sites via communicating their concerns with limited effect, they felt it was necessary to strengthen their presence by taking a “quasi-legal” approach (CIVSOCL003). In doing so, they used their practical understandings to hold Johannesburg Municipality to account for their legal requirements under existing institutional rules.

Taking action in this way illustrates rules and how green infrastructure evolved out of a mix of institutional, or formal, and unplanned ways of doing things. Civil society used existing rules for voicing their concerns with Johannesburg Municipality, but after their attempts were unsuccessful, they followed alternative activities, were use judicial rules to their benefit. Rules influenced how green infrastructure was practiced, where it included how actors ought to voice their concerns i.e. through municipal structures and processes, but also where they enabled actors to engage with ‘easier’ ways of going about leaving a viable and manageable legacy (Schatzki, 1996). Finding ways to achieve their ambitions encouraged civil society to look to national legislation, but also alternative avenues which had been used previously to hold Johannesburg Municipality to account.

Another way civil society placed increasing political pressure on the municipality was through the media. Journalists, environmental professionals and members of society used practical understandings to draw attention to water pollution at

Bruma Lake by publishing articles in national and local newspapers such as The Star, The Citizen and Caxton Press. Headlines of articles included persuasive and emotive titles, including "*Dirty Bruma Lake a real health hazard*" (Cox, 2011) and "*Big stink over sewage flooding Bruma Lake: Thousands of residents under threat, businesses losing millions*" (Cox, 2010) and "*Joburg is failing Bruma's wildlife*" (Anonymous, 2014). This also included coverage on investigative journalism television programmes, such as *50/50* and *Carte Blanche*[86], to show unlawful management of the sites. These activities developed existing practical understandings held by members of civil society associated with related projects such as Huddle Park (Section 6.1 and 7.1).

Activities to place continued pressure on Johannesburg Municipality influenced how the projects developed over time. An official at Environment and Infrastructure Services Department responsible for open space and water explains that activities undertaken by members of civil society created a situation where they found it difficult not to address water pollution at Bruma Lake for example. As they reflect, the "temperature [was] increasing […] it increased to the point where […] we put in a solution" (GOVL014). The activities undertaken by civil society worked to hold Johannesburg Municipality accountable in terms of its legal obligations, but also took steps to "publicly pressure" the municipality, which had political implications for the Mayor and the political party in power

[86] These two shows gained credibility in the public eye for reporting on the 'real facts' for at least 30 years.

(GOVL0014). The mounting pressure to intervene at Bruma Lake encouraged action from Johannesburg Municipality.

Creating pressure for action around water pollution at Bruma Lake illustrates the political nature of green infrastructure, where apart from being a material feature, it is also symbolic of much broader and more complicated socio-political factors. In this instance, the Bruma Lake Owners Association, comprised of predominately white-owned businesses and members of society, illustrates the power of certain groups toward shaping infrastructure, in this case, green infrastructure in the city. Like infrastructure, green infrastructure can showcase instances where “affluent and powerful groups” and their influence can be “deepened” through the activities they carry out (Graham and Marvin, 2001, p. 348). The latter of which will become more apparent when I explain how the Bruma Lake Owners Association worked outside institutional rules to shape the outcome at Bruma Lake in Section 7.2 below.

Municipal officials and their activities to build pressure from within

To explain how funding was allocated to the project, it is important to draw on municipal officials descriptions and how their activities to place pressure from within administrative structure and rules resulted in the overall funding of the Bruma Lake project. As a senior official at Environment and Infrastructure Services Department responsible for open space and water explained, funding did not “emerge […] naturally” because the project was allocated funding in a “budget lekgotla[87]” where it is possible to “override the model with strategic projects” (GOVL014). Toward making the Bruma Lake project possible, the abovementioned official worked to set out “funding over two years […that…] made it tolerable for the council […referring to Greater Johannesburg Metropolitan Council…] to grant us that funding” (GOVL014). Therefore, while it was decided that funds for the project would be granted to Bruma Lake as a strategic project, the granting of the budget was supported by municipal official activities to place pressure on the Johannesburg Municipality from the inside, working within the existing institutional frameworks.

It is important to mention one further way municipal officials owned the future of the project sites. One participant at Johannesburg Development Agency explained that to leave the legacy they wanted, they were able to adapt the scope of the projects they managed through the supply chain management process. For example, they explained that on Bruma Lake, they specified the exact “specs” (specifications) for the kind of project they wanted, which they added to the procurement documents (GOVL014). On the Bruma Lake project, they explained that they looked for “people with a hydrological background that understand the ecology of a river” to support their visions for the site (GOVL017). Consequently, outlining the professional work to deliver on municipal ambitions enables municipal participants to define the scope of the project.

[87] ‘Lekgotla’ is a Setswana term used to describe planning or strategy meetings that are called by government. A Budget Lekgotla in this instance refers to the official planning meeting in Johannesburg Municipality where political objectives and spending priorities are discussed.

Design engineer's activities to adapt existing knowledge

To own the future, the design engineer claimed ownership by proposing an alternative way to address urban water management through river renaturalisation. Their idea included creating 'value add' by building in secondary values in the project, such as the creation of parkland and the filtrating of water through ecological services. 'Value-add' formed part of their "commitments, beliefs and values" toward the project (Welch and Yates, 2018, p. 10). To create secondary values, the design engineer used ideas learned about at an international conference, where they had met and been inspired by a practitioner involved in the *Living River Leising* project that renaturalised a river in Vienna to deal with water pollution in a river that had been modified in the past (European Commission, n.d.). Therefore, the design engineer's ambitions to leave a legacy through creating secondary values could be achieved through following a river renaturalisation approach at Bruma Lake. I refer to how the approach was adapted to overcome specific project level uncertainties (Section 7.2).

7.1.2 Overlapping interests at Paterson Park

I now focus on Paterson Park to explain how activities to own the future encouraged project actors to carry out different kinds of activities. To start, instead of being granted strategic project funds (as in the case of Bruma Lake), the action at Paterson Park formed part of a broader programme to develop Johannesburg's transport network. The department responsible for the programme were given a "very high-level mandate", with significant project funds attached (GOVL006). The Development Planning Department, the department legally responsible for Paterson Park, had "a lot of authority with more resources than we would normally have" that supported their vision, where they believed the site was seen to be 'something more'" (GOVL006), (Section 6.2). Therefore, the availability of resources enabled the municipal officials responsible for the project to take steps to create a more ambitious project that allowed them to claim ownership to bring their vision into reality.

River renaturalisation did not form the starting point of the project. Until the design engineer proposed their idea, the Development Planning Department had considered a conventional *engineered approach*. The official responsible for the project at the Development Planning Department entered the project with the ambition to "solve more than one problem with one solution", which formed part of the broader "Corridors [of Freedom] ethos" (GOVL006). To support the 'Corridors ethos' the official saw it necessary to claim ownership in ways to "force" other municipal officials, contractors and residents to "step outside of the single […] focus solution thing" (GOVL006). Therefore, the official responsible for the Paterson Park development took ownership of the future by setting out a general direction and ethos for what they wanted to see take place at the site and how resources ought to be spent.

The design engineer endeavoured to create secondary values in their projects, which resonated with the 'Corridors ethos'. An overlap around the ambitions and activities of the official responsible for the Paterson Park project and the design engineer supported this objective. As the official at the Development Planning Department in charge of the project explained:

> …when [name design engineer] introduced…I think we all went wow, that is very, we didn't even, honestly, I don't even think we thought that would even be an option so…
>
> (GOVL006)

The river renaturalisation approach was received as a "surprise", where it allowed officials to "actually create a natural system or something more natural than we have [laughs]" (GOVL006). Therefore, river renaturalisation enabled the legacy or vision held by the official responsible for the project and the design engineer to overlap.

The river renaturalisation approach also resonated with what residents at Orange Grove and Norwood residents wanted for the site. One Orange Grove resident had outlined that they had met the design engineer to discuss possibilities for addressing flooding and "water problems in the area" in around "2005 or 2006" (CIVSOCL001). The fact that the design engineer had met with Orange Grove residents before the Corridors of Freedom project illustrates an overlap around interests on the project, which enabled participants at the Development Planning Department, private sector consultants, and residents to come together to use a river renaturalisation approach. The resident further explained that although there was "no money to do anything" at that stage, they did "discuss the river and daylighting [referring to renaturalising the river] it" (CIVSOCL001). Therefore, although not directly affecting how activities were carried out on Paterson Park under environmental law as I will explain below, it created a starting point around what could be achieved at the site, which influenced the activities of residents.

7.1.3 Working within institutional rules

South African environmental law and environmental professionals played an influential role in supporting activities to manage uncertainty. Residents, resident associations, and business owners' associations at the sites used environmental law to make their voices heard. This is an example of where a participant drew on administrative rules to influence the activities of other actors (Section 3.2 and 3.3). Legislative documents they drew on included the National Water Act 1998 (South African National Government, 1998a) and the National Environment Management Act 1998 (South African National Government, 1998b) to attract political interest on the Bruma Lake project, while the National Environment Management Act 1998 and protected tree species list influenced the kind of outcome influential residents wanted to see at Paterson Park.

Claiming ownership by enforcing water laws at Bruma Lake

Polluted water at the Bruma Lake site provided the impetus for legal action by civil society groups, where the Johannesburg Municipality was breaking the law by not addressing elevated levels of contaminants. High levels of *E. coli* at the lake surpassed the legal threshold and thus by not addressing, or treating, the source of the problem. Johannesburg Municipality, as the legal managing agent, was liable for legal action. A member of the Bruma Lake Owners Association explained it used a 'quasi-legal' approach to addressing polluted water at the site. Their legal approach took three avenues. The first two were under the South African National Water Act 1998, followed by Helsinki Rules on the Uses of the Waters of International Rivers.

The legal efforts of Bruma Lake Owners Association were bolstered through the hiring of an environmental expert[88]. Municipal participants explained the environmental expert was very knowledgeable in the field of water management and informally called 'Mr Jukskei' after his lifelong dedication to preserving and enhancing the environmental functionality of the Jukskei River, where they had gained a wealth of practical experience for managing rivers and wetlands. As the head of Bruma Lake Owners Association remarked, "initially we didn't have [name of environmental consultant], but when [name of environmental consultant] came on board, we put incredible pressure, we made sort of life intolerable for some of the officials" (CIVSOCL003). The environmental expert advised Bruma Lake Owners Association to take legal action and media coverage to place pressure on Johannesburg Municipality.

The first avenue the association followed was to hold the municipality accountable under the South African National Water Act 1998. Under this act, the municipality was breaking the law by allowing water to flow from Bruma Lake into the neighbouring Ekurhuleni Municipality, where it is not permitted for municipalities to allow contaminated water to leave its jurisdiction. As a member of the Bruma Lake Owners Association further describes:

> …water leaving one Municipality or city entering the other, the next neighbouring town should be clean, okay, and be of good quality and it is up to the city to see that the quality is maintained.

[88] Although they did not read for a degree on the topic, participants indicated their considerable practical understandings and 'know-how' that they had gained over decades of working on projects. Therefore, in practice actors such as 'Mr Jukskei' drew on other kinds of knowledge that lies outside of disciplinary knowledge (see disciplinary approaches in Section 2.1).

(CIVSOCL003)

After Bruma Lake Owners Association wrote letters and formal complaints to the municipality to make this breach of environmental law explicit, Bruma Lake Owners Association looked to find other avenues to support their action.

The second avenue for legal action was taken up by Bruma Lake Owners Association given a limited response to their first avenue to hold the municipality accountable to the South African National Water Act 1998. The second avenue appealed to a different legal actor in the city, the National Department of Water Affairs. A member of the association explains the reason for this was to appeal to an actor with greater institutional power to enforce the Johannesburg Municipality to adhere to institutional rules. In their words, they explained they were trying to:

> …get the Department of Water Affairs to say 'Johannesburg, you are allowing contaminated water with incredibly high sewerage, E. coli counts and more diseases to leave the boundaries of Johannesburg and get into the other councils.

(CIVSOCL003)

Appealing to a more powerful institutional actor under institutional rules resulted in instructions to be placed on Johannesburg Municipality. The instruction, therefore 'forced' officials at Environment and Infrastructure Services Department to engage activities on the site under existing national institutional rules.

To place an even greater amount of pressure on the National Department of Water Affairs and Johannesburg Municipality, Bruma Lake Business Owners Association used Helsinki Rules on the Uses of the Waters of International

Rivers. The ‘rules’ or guidelines stipulate how rivers and groundwater should be managed across international borders. Under this agreement, Bruma Business Owners Association accused the South African National Government of breaking the rules by allowing water of poor quality to leave its international borders. A member at Bruma Lake Business Owners Association explains this indicating the connections between the Jukskei River and the Crocodile River which flows into Botswana:

> …we tried [national department of] Water Affairs on that. To say that ultimately, I don’t know if you know the Crocodile [River] after the Hartbeespoort Dam goes through Brits, goes west, goes all the way, almost to Botswana, it becomes the Limpopo river goes around the northern boundaries of SA and through Mozambique and into the Indian Ocean.
>
> (CIVSOCL003)

This framed a further set of legal actions for holding national government into account, whereby activities under institutional ownership were necessary for addressing infrastructure concerns.

Finding common ground through environmental legislation at Paterson Park

Under the National Environmental Management Act 1998, a screening process is carried out before development takes place in the city. The purpose of the screening process is to preserve ecological integrity by preventing or limiting development in the presence of noteworthy features of physical nature such as wetlands or protected trees. If the environmental integrity of a site is under threat, a full Environmental Impact Assessment is required to determine the conditions for the development. An Environment Impact Assessment is an example of an institutional rule that can influence actor activities by either granting or advise against development. It can also set out the conditions for development for Johannesburg Municipality and private sector professionals to support the ecological integrity of the site.

Environmental consultants conducted a review of the Paterson Park site and recommended that no Environment Impact Assessment needed to be conducted under South African law[89]. While they found no grounds to proceed with an Environmental Impact Assessment, the Orange Grove Residents I interviewed believed waterlogged soil at the site was linked to the presence of a wetland. Waterlogged soil arose as a key physical limitation at Paterson Park. Residents from the Orange Grove Residents' Association believed waterlogged soils were a physical sign of a wetland[90], which they were able to protect under the South African legal system.

Finding a wetland on a site designated for development would have stalled the Paterson Park project under the National Environmental Management Act. Although I do not describe it in detail here, residents from the Orange Grove Resident's Association also believed a historic river flowed through the site and that a tree listed on South African protected tree list[91] was also present that would chiefly require a formal Environmental Impact Assessment under South African law. Questioning a wetland and protected tree under the South African law

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[89]Consultants concluded that no formal Environmental Impact Assessment was required as the river renaturalisation project was considered ecologically more advantageous for the site than a concrete canal and therefore served to enhance physical nature, rather than degrade it (CONSL010).
[90] Wetland soils are typically saturated and are mottled with grey streaks. These grey streaks are iron deposits.
[91] This list is legally enforced through the National Forests Act, 1998. It outlines that no person can remove or damage a tree on the protected tree list. Contravention of this may result in a fine or imprisonment.

demonstrates different meanings of physical nature and infrastructure, where it illuminates some of the complexities around practical understandings of physical nature in policy and practice.

On the one hand, residents at the Orange Grove Resident's Association understood and interpreted material features at the site according to their background and experience. For the residents, they identified the physical-chemical composition" such as shape, colour and texture to resonate with particular understandings of physical nature part of practical understandings included in existing rules (Schatzki, 2010a, p. 136). After closer inspection, water at the site did not appear to be attributed to a wetland. Rather, it was found to be a result of "leaking pipes" and associated issues with existing stormwater infrastructure (GOVL006 and CIVSOCL001). The difference in understanding flags the many meanings of physical nature in policy and practice and how they can be contested.

Despite not falling under legal controls for development under South African law, and not stalling the development of the broader Corridors of Freedom project, the actions carried out by Orange Grove residents influenced how the project proceeded after that point. While their influence will become more apparent in Section 7.2, it is noteworthy to flag resident interests around the environmental aspects of the project created a window of opportunity for the use of river renaturalisation. Despite "not [being] able in 10 years to get the City's [referring Johannesburg Municipality] attention" to address flooding and safety issues, under the Corridors of Freedom project and associated budget, a senior official at Development Planning explained, “this space could become something else” and they worked with interested residents to reach a compromise (GOVL006). Therefore, river renaturalisation became an approach where residents and Johannesburg Municipality struck a compromise.

7.2 Working outside of institutional and professional rules to manage uncertainty

Toward owning the future, participants at the Environment and Infrastructure Services Department, Development Planning Department, and private consultants managed uncertainty that emerged around water pollution and flooding that manifested as material concerns. In the conceptual framework, I described that rules such as professional guidelines tend to represent the social world through organising activities according to known understandings of physical nature-infrastructure interactions, where they exhibit or are comprised of known properties in association with their “physicality” (Schatzki, 2019, p. 2) (Section 3.1). Physical phenomenon can become associated as being physical nature and infrastructure according to how actors encounter it in their daily lives, where they facilitate the “development, persistence, and dissolution” of practices (Schatzki, 2019, p. 19). Materiality and how it is understood by participants as being physical nature and/or infrastructure, therefore, has a profound influence over how practices persist.

Setting out how participants understood and responded to material concerns according to their physical properties illuminates different understandings of physical nature and infrastructure. I mentioned physical-nature interactions formed a central feature of my conceptual framework where they help to define "what makes sense" for actors to do (Schatzki et al., 2001, p. 55) (Chapter 3). Exploring the practical understandings and the material properties of the project sites and how actors responded to it enables me to delve deeper into the "intelligibility" of actors where it can demonstrate "understanding, roles and structure" (Schatzki, 1996, p. 106). In this section, I consider practical understandings and water pollution and flooding as they manifested as material concerns at Bruma Lake and Paterson Park projects (Section 7.2.1). I then describe how participants used creativity to work outside of the current professional guidelines to evolve practical understandings to (re)conceptualise physical nature-infrastructure interactions represented by rules (Section 7.2.2).

7.2.1 Practical understandings and the material properties of physical nature-infrastructure interactions

The material properties of water pollution and flooding influenced how participants carried out their activities to leave a legacy in the city. Once the Bruma Lake Owners Association and residents from Norwood and Orange Grove had placed pressure on Johannesburg Municipality to act, either via legal means and the media (Bruma Lake) and used environmental legislation to support a more environmentally orientated outcome (Paterson Park), their activities then shifted to addressing the material properties of water pollution and flooding at the project sites. I explained in the conceptual framework that materiality is comprised of physical-chemical properties that can 'qualify' practice (Schatzki, 2000, p. 136) (Section 3.1). While in many cases, rules support known ways to address materiality concerns, in some instances, the properties of physical nature-infrastructure interactions are known and other cases they are not. While the physical-chemical properties can be demonstrated by conducting experiments, scoping studies and tests, due to the variability of the social world, concerns such as water pollution and flooding can manifest in uncertain ways.

Unfamiliar chemical-physical properties at Bruma Lake

From the outset, participants working on Bruma Lake described it as a project in managing uncertainty in practice. A senior official at Environment and Infrastructure Services Department and project manager at Johannesburg Development Agency involved in the Bruma Lake project explained the project was complex given the uncertainty they faced in managing how river renaturalisation was used (GOVL014 and GOVL017). At Bruma Lake managing “technical [elements and] scale” created uncertainties around how to manage the “upstream catchment-wide dynamics [and] all the impacts arriving at a lake” (GOVL014). Managing the catchment dynamics and impacts was “quite a brave step” as Johannesburg had not worked on a similar project before (GOVL014). Therefore, from the outset, there was uncertainty around how participants from the Environment and Infrastructure Services Department, Johannesburg Development Agency, and private sectors professionals ought to carry out their activities due to its novelty of the concern.

To manage uncertainty, engineers on the project worked outside professional guidelines. I explained experimentation can result in the evolution of different understandings of physical nature and infrastructure, where meanings may no longer match those in existing practical understandings. This point marks the “gradual evolution of practice” (Schatzki, 2013, p. 39) (Section 3.3). To evidence this, the construction engineer explained, “nothing was conventional” (CONSL0013). Addressing water pollution concerns required dealing with contaminated water in a flowing watercourse and silt became “quite challenging”, where “conventional things were formalities for us” (CONSL0013). Toward explaining the unconventional characteristics of Bruma Lake, I now explain the different ways that materiality and its context and setting created uncertainty.

To begin with, the original plans for the lake could not be found[92]. The construction engineer explained not knowing what lay at the bottom of the lake until water and sludge were removed. The construction engineer explained, “so we started with no existing drawings…we didn’t know if the base floor was solid or not” (CONSL0013). The implications of not knowing the design of the lake were that there was ambiguity around how to design the river renaturalisation approach, while it was known that a “riverbed was going to be rebuilt”, there was a “body of water that we had to deal with firstly”, before continuing to remove the “muddy stuff” at the bottom of the lake (CONSL013). As they further explained, the process and management of removing the water and sludge itself constituted even more uncertainty and adversity on the project.

A first step to dewatering the lake was managing water flowing into it. Bruma Lake was located on the Jukskei River, part of a broader system (Section 5.4). As the construction engineer explained, the Jukskei River “continued to have that route”

[92] A senior official at Environment and Infrastructure Services Department working on Bruma Lake explained the “documentation just went missing”, when the Greater Johannesburg Metropolitan Council integrated departments to form Environment and Infrastructure Services Department (GOVL007). One interested member of the community said they found a copy of the first sketch drawings. The availability of these drawings was not verified, or triangulated, by municipal officials and service providers.

that was explained to be a “big challenge” because the flow of water into Bruma Lake would compromise engineering activities (CONSL013). The engineer and his team worked out how to “divert the river” using a lined berm to convey water as “far away as possible for the workplace” where it would not compromise engineering activities (CONSL013). After uncertainties over how to deal with a flowing river on the site, participants then removed the water using syphons.

After removing the water from the lake, the construction team turned their attention to removing sludge from the bottom of the lake. Removing the sludge became more challenging than expected (CONSL007, CONSL013 and GOVL007). The on-site construction engineer described the sludge as “slop” or “soup”, and existing methods for dealing with related kinds of material to remove it as being as effective as “stirring soup with a toothpick” (CONSL0013). To place the material properties of the sludge into perspective, the senior official at the Environment and Infrastructure Services Department involved in the project recalls, “you could not just use your yellow toys kind of amphibian machine” because “it is soft and it’s muddy” (GOVL007). Therefore, adversity presented by the unfamiliar physical and chemical properties of materiality influenced the order and types of activities carried out on the project.

The order activities that were carried out on the project had implications for how the green infrastructure approach was used. As the design specifications could not be agreed upfront, the senior official at Environment and Infrastructure Services Department involved in the project explained it was necessary to develop the design in “iterative fashion over time”, where it became necessary "to amend some of [the design engineer's] drawings as we were implementing" (GOVL007). Working iteratively encouraged the construction engineers to engage in a "brainstorming process", where "none of this [what was done on the project] was ultimately thought out to the 'T' at the beginning stage of the project" (CONSL013). Consequently, the interactive process followed encouraged the construction engineers to work outside existing professional rules in project management where designs are agreed upon upfront before a project begins.

Diagnosing the problem at Paterson Park

The Orange Grove Residents' Association used their practical understandings of physical nature to hold Johannesburg Municipality to account under the South African Environmental Management Act (Section 7.1). One resident, who described themselves as "tak[ing] a very keen interest" in local developments and the environment, explained that they "keep their eyes and ears open about" for soil mottling to identify wetlands (CIVSOCL001). Soil mottling is one sign of a wetland, which is protected under the South African law[93]. In an attempt to stall the development to protect the possible wetland, the Orange Grove resident used this mottling to draw on South African environmental law to manage the outcome of the project (CIVSOCL001 and CONSL010). By implication, resident

[93] In general, wetlands are a contentious feature of physical nature. For many years, practitioners such as government officials and engineers developed on sites that had wetlands as they were considered to have no value for urban development. Subsequently scientific study has revealed the value of wetlands, which has led to the inclusion of wetlands as a protected feature in South African law. That said, some of the sentiments to develop sites with wetlands remain. In some cases, residents like those at Paterson Park feel the need to fight to 'save' the wetlands from being developed.

understandings of physical nature initiated a legal process to respond to proposed developments at the site.

On closer inspection, the physical properties of the water problem were diagnosed as part of a failing water infrastructure network. As Paterson Park fell within the 1 in 100-year flood line for the city, existing infrastructure had been developed in the 1920s to manage the problems (GOVL009). Existing stormwater infrastructure included two concrete culverts to run through the park to funnel and direct surface water runoff from the city through the site and downstream. The Greater Johannesburg Metropolitan Council had modified portions of the existing stormwater culverts over time with corrugated iron sheeting to create a roof (CIVSOCL001 and CONSL003). As a result of limited maintenance, the concrete base of the culverts, including the sheeting, began to fail and collapse, this resulted in waterlogged soil and flooding.

While material properties pointed to the presence of a wetland, environmental and infrastructure professionals used professional and institutional rules to identify the main concern as being failing infrastructure. That said, activities to hold Johannesburg Municipality accountable solidified Norwood and Orange Grove resident's perceptions that Johannesburg Municipality did not perform its legislated duty of care to maintain stormwater infrastructure. As one Orange Grove resident explained:

> So here you get your channel…it gets a crack in it and that crack gets into the steel which rusts and steel expanded when it rusts which causes more cracking.
>
> (CIVSOCL001)

The results were that the culvert creates “a water cannon”, where water “rushes down these channels (CIVSOCL001) creating areas of water saturation in the park, which gave the illusion of a wetland.

Understanding the material properties of flooding contributed toward a tension between Norwood and Orange Grove residents and the Development Planning Department (Section 3.1). There were existing trust issues that evolved between residents and Johannesburg Municipality, where they felt the development of parks took place at the cost of public amenity (Section 6.1). As an official at Development Planning Department remarked, interpreting the water at the site created an “interesting tension” between residents and Johannesburg Municipality, where it was uncertain as to “who [and] how” the project would take place (GOVL006). In the end, the same official explained “one thing led to another and more confidence was created” (GOVL006). Therefore, understandings of the material properties of water created uncertainty around how the Paterson Park project would proceed.

Again, contestation over understandings of physical nature illuminates the political of green infrastructure, where despite its range of physical nature-infrastructure interaction, its meaning can be used to find common ground. Confidence and trust developed between Johannesburg Municipality and residents part of both residents’ associations, where both groups of participants evolved and used their understandings of physical nature to support a common objective to leave a manageable and viable legacy. Toward creating a legacy, participants at Development Planning and residents’ associations embarked on a process of “altering” and “creating” meaning going forward (Schatzki, 2010a, p. 139). Altered meanings in this instance, supported by experimentation, enabled practices to “henceforth evolve differently” (Schatzki, 2013, p. 38). A central feature of finding common ground and evolving shared practical understandings of physical nature-infrastructure interactions going forward was creativity.

7.2.2 Creativity to experiment with different physical nature-infrastructure interactions

To respond to uncertainty around the properties of physical nature and infrastructure at Bruma Lake and Paterson Park, municipal officials at Environment and Infrastructure Department, Development Planning Department and the design and construction engineers explained that they needed to ‘think outside the box’ to address the uncertainty that evolved around the technical (Bruma Lake) and social (Paterson Park) uncertainties (GOVL006, GOVL007, GOVL0014 and CONSL013). Exploring how participants ‘thought outside the box’ illuminates the process through which they individually, and collectively, (re)conceptualised their meanings of physical nature, where they “acquire knowledge and abilities” and “build and alter the physical environment” (Schatzki, 1996, p. 161). At both project sites, thinking outside the box required working outside professional rules(such as guidelines) to alter the physical environment where it was necessary to be creative, including instances where it was necessary to test or trial solutions to (re)conceptualise physical nature-infrastructure interactions.

Re-establishing physical nature-infrastructure interactions through creativity

The design and construction engineers on the Bruma Lake project outlined that to implement a renaturalised river required them to carry out activities outside of their professional guidelines (CONSL007 and CONSL013). As the construction engineer explained, dewatering the lake and removing the sludge required them to be more flexible, where they needed to work beyond understandings outlined by existing rules. For example, the construction engineer indicated that “certain rules couldn’t be broken”, but there was room to adapt and modify what they did (CONSL013). Being flexible by following a more iterative approach “stretched” the construction team working on the project to “allow for different things to happen to achieve the end goal” (CONSL013). Therefore, working in different ways encouraged the use of different practical understandings of physical nature-infrastructure interactions.

Uncertainty influenced how the project developed. As a senior official at the Environment and Infrastructure Services Department responsible for the Bruma Lake project remarked, it was cloaked by adversity:

> So, like I am saying it really tested, and we had to think and very fast. We had no time, so we had to come up with way how best we sort, we would contribute to the environment and at the same time implement the project…
>
> (GOVL007)

While participants used river renaturalisation through their interests and values to leave a legacy in the city in the previous chapter, managing uncertainties in practice also required them to have a more flexible approach to the management of infrastructure, where they were required to be creative out of necessity, where they needed to think fast and balance priorities.

To demonstrate where it was necessary to be creative, I refer to sludge as an example. I explained in the context chapter, the cost to remove and treat the sludge exceeded the amount made available by Johannesburg Municipality. Uncertainty around what to do with the sludge resulted in the use of it to form the parkland part of the Bruma Lake rehabilitation project. As the construction engineer explains, the sediment was treated and used in situ:

> So, it was decided to instead of spoil they used that silt in place [, so instead of having to put it somewhere and classify it as hazardous.
>
> (CONSL0013)

After it was treated to make sure it was safe, it was used “for backfilling to create landscaping and a nice park area for the public” (CONSL0013). Therefore, re-using sludge highlights creativity in practice.

Creativity occurred where participants worked together to manage uncertainty. I explained Section 7.2.1 above, solutions were devised by brainstorming and sharing ideas. Brainstorming and sharing ideas resonates with “pockets of experimentation” I presented earlier, where actors (re)conceptualise their understanding in situated ways (Schatzki, 2013, p. 39) (Section 3.3). A participant at Environment and Infrastructure Services Department explains how they used pockets of experimentation, where the participants working on Bruma Lake by “toy[ing] around with a few ideas” such as de-silting, which was “actually thought would be ideal, and then we thought of doing islands and where we were doing the geological assessment it did not make sense" (GOVL007). The activities they followed developed out of a brainstorming process:

> Ultimately, we came up with saying…how do we take this stream to what it was and take out the lake part of it and restore and landscape what it used to be and that turned out to be sort of a visible option one could look at.
>
> (GOVL007)

Working together to manage uncertainty through creativity stretched the practical understandings of participants working on the project, where their conceptualisations of physical nature-infrastructure interactions were (re)conceptualised over time.

Another way municipal officials at Environment and Infrastructure Services Department and engineers working on the project were stretched to be more creative was through the interplay that took place between the construction and design engineer. To manage technical uncertainties the design engineered "helped" the construction engineers "to understand what [they] wanted to achieve" (CONSL013). In return, the construction team "helped [them] to understand where the limitations were", where it was "something very different in the nature of conventional construction", the design engineer was flexible enough to show us" (CONSL013). Therefore, working together across disciplines enabled engineers to work outside their professional guidelines to manage uncertainty.

Reflecting on creativity at Bruma Lake, the uncertainty that participants encountered influenced how participants such as municipal officials at Environment and Infrastructure Services Department and the design and construction engineers carried out their activities on the project. Carrying out activities using different kinds of ‘know-how’ illuminates points where practice “henceforth evolve differently” (Schatzki, 2013, p. 38). As one senior official at the Environment and Infrastructure Services Department explains, solutions to material problems were “very natural and creative”, where in many cases practice evolved where there was adversity or uncertainty, where “adversity breeds creativity” (GOVL0014). Working naturally and creatively goes back to my earlier descriptions of participant’s general understandings and how they evolve. They further explain that a combination of “their hard hats and thinking caps” was necessary to manage uncertainty (GOVL0014).

Experimenting and adapting at Paterson Park

Creativity at Paterson Park manifested in a slightly different way. Unlike Bruma Lake, where several uncertainties evolved as the project unfolded, the intervention at this site evolved as a creative approach to manage uncertainties and tensions between actors around how the site would be developed (GOVL006). Tensions between Orange Grove residents and the municipality created uncertainty around whether the Corridors of Freedom Project could continue or not, but in the end, due to the use of creative problem solving, river renaturalisation emerged as the preferred option. River renaturalisation developed out of overlapping interests, or general understandings, that were held among officials and Development Planning Department and residents at the Norwood and Orange Grove residents’ associations to achieve shared objectives. I now explain how practical understandings of the design engineer and other participants familiar with the Bruma Lake project experimented and adapted the river renaturalisation approach.

The design engineer explained that the fundamentals of designing a river renaturalisation project were not straightforward. River renaturalisation required an understanding of the functions of physical nature-infrastructure (in the same way as the *engineered approach* I demonstrated in 2.1). For example, they explain “technically it is not an easy thing to design”, you need to get the “hydraulics right and you also have to get the stability of the lining correct” (CONSL007). The design engineer also reflects on the use of river renaturalisation in practice, where unlike a laboratory where “sheer stresses and bedsheets and things” are fixed, in practice, rivers are “mobile”, where they are in an “active equilibrium” (CONSL007). Therefore, while river renaturalisation forms an overall approach or practice, it is adapted or modified to respond to local needs and characteristics.

At Paterson Park, the design engineer adapted the river renaturalisation approach to suit the flood management and social interests among officials at the Development Planning Department and residents’ associations. While all engineered projects require adaptation around the local context, Paterson Park enabled a series of additional values to be realised, which were of interest to residents at the Norwood and Orange Grove Residents’ Associations. To start, Paterson Park is “hydraulically pretty steep” compared to the Bruma Lake catchment (CONSL007). As such it was necessary to include boulders and a “series of steps” to reduce the velocity of the water (CONSL007). Other adaptations included the creation of a pond and pockets for vegetation along the stretch of renaturalised river.

The design engineer’s description indicates that practice around river renaturalisation had already evolved, where some of the technical uncertainties had been overcome at Bruma Lake. The process of continual evolution in practical understandings of physical nature and infrastructure points to the continuous nature of practice and how experimentation results in greater or the development of ‘know-how’ over time. The procedural features of practical understandings and how they influence practice demonstrates how it can “underwrite” and support the “persistence and transformation of social life” or in this case how infrastructure is developed as a known phenomenon (Schatzki et al., 2001, p. 12). As explained in the section above, it also underscores how knowledge on the physical and chemical components of physical nature and infrastructure are constructed as part of a continuous process (Bird, 1987; Macnaghten and Urry, 1999). Therefore, while on the one hand know-how can develop around the approach, it is adapted in new and/or creative ways to respond to site-specific or situated elements.

Testing out different options demonstrated the need to experiment with different materials in practice to respond to situated material factors, where their properties either supported the design and functionality of the project, or they did not. While the design engineer explained they got their overall idea from the *Living River Leising* project (Section 7.1), the activities they carried out were influenced by “a combination of talking to people, listening to presentations, stealing ideas from journals and reading technical literature” (CONSL007). After assimilating information from these sources, “eventually you find something that you think works and you give it a go”, where it becomes necessary to “try it on a smaller scale first and then you get more confident as you go along" (CONSL007). Therefore, existing understandings of *Living River Leising* were adapted at Paterson Park. The significance of which will become apparent when I describe the (re)conceptualised meanings of physical nature-infrastructure interactions and shared knowledge in more detail (Section 7.3).

7.3 River renaturalisation and (re)conceptualised meanings of physical nature-infrastructure interactions

As discussed in Section 7.2, managing uncertainty in practice required Bruma Lake Business Owners Association, Norwood and Orange Grove residents, municipal officials, and engineers to evolve their practical understandings of physical nature-infrastructure interactions. Exploring how practical understandings evolved at Bruma Lake and Paterson Park demonstrated the development of shared practical understandings that when taken together represents an evolution of practical understandings of physical nature-infrastructure interactions. To explain what the implications of (re)conceptualised physical nature-infrastructure interactions are, I begin by explaining how meanings evolved as shared practical understandings (Section 7.3.1), before reflecting on its implications for infrastructure such as urban water management in Johannesburg (Section 7.3.2).

How practice evolves reveals the influence of existing rules and practical understandings, or ways of doing things in the city. I mentioned the relational aspects of infrastructure, where infrastructure is not simply an autonomous and apolitical object, rather it is highly integrated and not used in a vacuum (Section

2.2 and 2.3). For example, infrastructure and how it evolves can have a set of “unforeseen or unknown” contextual effects (Star and Ruhleder, 1996, p. 118). Unknown effects can also stem from those who “own", or in this case, who takes ownership of green infrastructure as they can be “locally determined” or where specific “technical choices” are made (or not) as a result of how green infrastructure was (re)conceptualised (Star and Ruhleder, 1996, p. 119). Therefore, the broader implications of (re)conceptualising green infrastructure both individually and as part of a group has implications for social life going forward.

7.3.1 Shared practical understandings around river renaturalisation

When I interviewed participants at Bruma Lake and Paterson Park, they were knowledgeable about adversity associated with uncertainty and how steps were taken to overcome these. In the methodology chapter, I explained participants ranged from municipal officials at Johannesburg Municipality and its associated municipally-owned entities, private sector professionals across engineering, environmental science and landscape architecture, and civil society as residents or part of a group such as business owners’ or residents’ associations (Section 5.3). Even though being knowledgeable that the steps taken did not form part of their legislated role and responsibility for the project, participant’s interests to leave a legacy encouraged their involvement in all stages of the project (Section 7.2). The wide range of participants that claimed ownership at different points of the process to manage uncertainty contributed toward building a shared understanding of physical nature-infrastructure interactions.

Linking activities to practice

While I set out to interview participants involved in the Bruma Lake and Paterson Park projects, including participants at Johannesburg Municipality, private sector professionals and members of civil society they were all aware of similar or related projects that had been completed before the actions at the two project sites. Participants identified a range of 'environment and infrastructure' projects in Johannesburg (Section 4.3; Appendix 1), including related urban water management approaches. Participants such as senior officials at the Environment and Infrastructure Services Department and Development Planning Department, the design engineer, and participants at Orange Grove Residents' Association had been involved in one or more of the projects. Their involvement in these projects pointed to a continuum of understanding that had developed around the ways physical nature and infrastructure were managed in Johannesburg.

Whether conscious or not, the understanding held among individual participants, or shared among them, influenced how river renaturalisation evolved as a form of green infrastructure at Bruma Lake and Paterson Park. For example, a senior official at Environment and Infrastructure Services Department explained there was a "body of practice'" that had developed, where physical nature had been drawn on in different ways (GOVL014). A body of practice reveals the development of shared practical understandings that evolved among a range of participants at the sites. Therefore, evolving practical understandings enabled the development of the necessary 'know-how' for how the approaches were used and adapted over time.

Information sharing platforms also enabled practical understandings to influence the activities of other participants on the Bruma Lake and Paterson Park projects. Municipal officials at the Environmental Infrastructure Services Department, Development Planning Department, and Johannesburg Development Agency, including the design engineer and landscape architect, explained that they used WhatsApp to communicate the steps they took or to discuss decisions around troubleshooting adversity (CONSL006, CONSL007 and CONSL014). Sharing project information such as the plans, designs, environmental studies over platforms such as Google Drive, Dropbox and other management software[94] formed part of standard practice on 'environment and infrastructure' projects, where it was considered to "make a very big difference" as it encouraged shared activities, where consultants felt as if they were not "starting things on their own" (CONSL006). In instances where physical nature-infrastructure concepts had evolved, it served as a key resource for supporting practice going forward.

Sharing practical understandings that evolved from, and during, experimentation enabled the green infrastructure approach at Bruma Lake and Paterson Park to be carried out. While the projects were not earmarked funds for green infrastructure projects explicitly, the approach used at each evolved out of an interplay between general understandings, practical understandings and rules (Section 7.3). As a consequence, experimentation and shared practical

[94] On the Bruma Lake project, the project manager explained that they used management software called *Team Work Management* to share project related information (CONSL014).

understandings enabled green infrastructure to be used at Bruma Lake and Paterson Park.

Experimentation supports the idea that green infrastructure develops out of a dynamic process rather than being a technical solution. I mentioned green infrastructure tends to be understood as a technical concept, where river renaturalisation would tend to be conceptualised to be part of an engineer's scope of activity (under the *engineered approach* in Section 2.1). That said, experimentation as an individual and shared activity demonstrates how river renaturalisation evolves outside of the "black box" of "engineer's stuff" (Graham, 2001, p. 340). Experimentation, although existing within the realm of engineering activities, evolves as a more open and dynamic process, which is shaped and informed by a range of participants, where it can support "plasticity" in practice, where it can to "overlap" and "join" with other practices among actors (Schatzki, 1996, p. 98). Overlaps and joins therefore illuminates how practice can evolve across one or more actors involved in experimentation.

Experimentation took place as a shared activity on Bruma Lake and Paterson Park projects (Section 7.2). That said, the activities to try and test the material properties of physical nature and infrastructure were carried out by the private sector. As one senior official at Environment and Infrastructure Services Department explains, "government is not great for evolving experimental things", where it is much "easier to get the private sector to innovate" (GOVL014). To encourage experimentation on projects, they official described how they used private sector consultants as a "sitting duck" for experimentation, where they used “the development control process” to experiment on physical nature-infrastructure interactions. By implication, experimentation and shared understandings developed out of shared activities by the municipality and private sector.

The string of prior projects, where understandings of physical nature had evolved, supported other efforts to experiment. For example, as one senior official at the Environment and Infrastructure Services Department explained, “no one is comfortable with [it], specifically not […] the engineers” that are used to using “conventional approaches to installing new infrastructure” (GOVL008). Shared understandings of physical nature-infrastructure interactions influenced the activities of municipal officials and private sector professionals going forward, where the same official explained, “we are getting to now getting into space where we are now talking more about the innovations side” where other actors on infrastructure projects in the city were starting to work outside existing rules (GOVL008). Thus, shared understandings also influenced how participants carried out their activities, where they may be more likely to experiment with material properties.

While shared understandings evolved around physical nature-infrastructure interactions at Bruma Lake and Paterson Park, it also formed a noteworthy counter practice among engineers in the city. The engineers I interviewed at Johannesburg Municipality and the private sector explained Bruma Lake and Paterson Park were ‘unconventional’ approaches (CONSL013). A municipal official at Environment and Infrastructure Services Department explained that many private engineers felt this would be detrimental to the reputation of their company or institution, where there was likely to be a “public liability issue” (GOVL014). As a result, many private sector engineers “do not want to take the risks” (GOVL014). Therefore, the use of green infrastructure, such as river renaturalisation, tended to be labelled as risky by engineers, which may result in personal or professional failure.

The engineers I interviewed at municipally-owned entities echoed these sentiments. As an engineer at Johannesburg Roads Agency explained, it is not easy to follow a different approach to water management where “…sometimes it will work and other times it will not, especially with green engineering” that manifests as a “risk […] the city cannot afford” (GOVL010). Given the resource-constrained environment at Johannesburg Municipality, officials tended to follow rules, where in “10 years, 15 years, or 70 years” they know water infrastructure “will stay” (GOVL010). As a consequence, certainty prevailed among many engineers in Johannesburg toward working within existing institutional rules and engineering practice.

7.3.2 (Re)conceptualised physical nature-infrastructure interactions and its implications for maintenance

The Bruma Lake and Paterson Park projects both feature a reconstructed river and parkland. While on the one hand these features can be defined as mundane urban outcomes where they are indifferent from other kinds of urban infrastructure such as culverts; on the other, they have come to exist as material features through participants carrying out activities in a different way and are outside the ‘traditional’ approach to overcoming infrastructure challenges in

Johannesburg. River renaturalisation is an example of where participants 'stretched' their practical understandings to respond to uncertainties at Bruma Lake and Paterson Park. The implications of stretching the practical understandings of participants were that the final project may not resemble representations of physical nature-infrastructure interactions within existing rules.

I demonstrated that practical understandings of (re)conceptualised physical nature-infrastructure interactions can be shared (Section 7.2.1). While practical understandings can be shared among those involved in the Bruma Lake, Paterson Park, or affiliated 'environment and infrastructure' concepts I identified in Section 4.3 (Appendix 1), it does not mean the shared understandings are held among all participants, including those responsible for the long-term maintenance and upkeep of these projects. Therefore, the implications for using a river renaturalisation approach is that they rely on the same kinds of maintenances practices that were there before they began.

Maintaining unfamiliar material features

As participants practical understandings of physical nature-infrastructure evolved, it raises important questions around the institutional rules and professional guidelines in place to manage river renaturalisation projects over the long term. The need for ongoing maintenance at the sites raised concerns over who would claim ownership of the sites going forward. I presented that the split in the roles and responsibilities of municipally-owned entities created ambiguity around which actors ought to carry out these activities for managing the stormwater components, river features and parkland (Section 6.1). In addition, evolving meanings of physical nature-infrastructure interactions created challenges around what needed to be done to ensure river renaturalisation projects were maintained sufficiently.

Even if one or more municipally-owned entities carried out activities to maintain the river and parkland features, it became apparent that their practical understandings of physical nature-infrastructure interactions would have been insufficient to result in the right kinds of maintenance required. One senior official at the Environment and Infrastructure Services Department explained that in addition to who should take ownership of the projects over the long-term, there was a concern that it was the practices they used to perform the maintenance that was going to be a problem. As they reflect, municipally-owned entities tended to follow a generic or “sausage machine” approach to procuring maintenance services on parks that includes “grass cutters and litter pickers” and that is all (GOVL014). By implication, ‘environment and infrastructure’ projects such as Bruma Lake and Paterson Park require a process that “nurtures it”, rather than a generic approach as they outlined above (GOVL014). Therefore, providing maintenance activities with a similar practical understanding of the physical nature-infrastructure interactions that went into the design of the projects was fundamental to their long-term success.

The (re)conceptualised practical understandings of physical nature-infrastructure interactions at the design and implementation stages created uncertainty around how to provide adequate maintenance. Uncertainty arose around the practical understanding of materiality, where it remained unknown how river renaturalisation projects would continue to function and evolve. A private engineer working in Johannesburg contextualises the limited practical understandings by using a water retention pond as an example:

> …we know its size, we know its volume, we know what storm it is supposed to attenuate, and we can plan for that downstream. We can make provisions based on that.
>
> (CONSL001)

As they further explain, to be able to “do the same” for projects is an important feature of infrastructure projects, where physical nature-infrastructure interactions had evolved. Therefore, to produce the same kinds of detail, required participants to claim ownership over these new projects goings forward.

The way physical nature is used on projects, such as river renaturalisation, is based on the premise that the necessary add on or supporting services (such as maintenance) are adapted to respond to new or slightly different needs would be available. The design engineer on Bruma Lake and Paterson Park puts this into perspective, when they say, engaging with physical nature-infrastructure interactions tended to come with a “Field of Dreams philosophy” where if you “built it”, environmental functioning “will come” (CONSL007). As they further explain:

> …there are many instances in the literature where there has been a physical rehabilitation of watercourses and the habitat has been carefully designed and people believe […] the environment will establish itself.
>
> (CONSL007)

However, the benefits provided by (re)conceptualised understandings of physical nature-infrastructure interactions may not always be achieved. One official at the

Environment and Infrastructure Services Department named another similar project, Queens Wetland, an example of where the environment was not able to establish itself. Queens Wetland, which is located just upstream of Bruma Lake, was an Environment and Infrastructure Services Department project (Section 4.3; Appendix 1). The project was designed to passively[95] treat water flowing in the Jukskei River. After the Environment and Infrastructure Services Department completed it, the necessary maintenance work to nurture it did not take place. The outcome was a project that was "not well maintained, not well understood and not performing to its best" and "then everyone says you didn't design that properly" (GOVL014). Therefore, the outcomes of (re)naturalised physical nature-infrastructure interactions is that it becomes necessary to develop shared understandings on how they ought to be managed.

Officials at Environment and Infrastructure Services Department and Johannesburg City Parks and Zoo explained resources presented a formidable barrier. For them, nurturing green infrastructure projects required continuous maintenance to develop the necessary practical understandings to know how to continue them over time, where "globally if we go to literature the failures [are] relating to maintenance" (GOVL007). As such, they explained it became necessary to start "looking institutionally how we would [go about it]" (GOVL007). Therefore, the continued evolution of physical nature-infrastructure interactions is required to bring other city actors together, where it becomes necessary to

[95] Passive treatment, in this case, refers to the creation of a constructed wetland, which is low cost and electricity independent, to treat water at the site.

bring them up to speed with evolved practical understandings and to co-develop the rules for environment and infrastructure.

Uncertainty around the future of Bruma Lake and Paterson Park projects manifested in the need for participants to claim ownership to initiate necessary monitoring and maintenance work. A senior official at the Environment and Infrastructure Services Department explained they had made efforts to “get that data”, as they reflect:

> I was please, please, please …so, every year I put it in the budget to get flow rate meters and get nanotechnology because we are planning infrastructure without the proper data, so they plan in the dark.
>
> (GOVL014)

Therefore, an outcome of a limited political interest that tended to favour capital investment meant that the functionality of the projects required continued activities to claim ownership over its uncertain future. Again, general understandings that held participants together form one step toward claiming ownership in the city, where practical understandings and rules are stretched to include a different conceptualisation of physical nature-infrastructure interactions.

7.4 Managing uncertainty through claiming ownership - a mutually constitutive relationship

In this chapter, I explained how uncertainty influenced the way that municipal officials, private sector professionals, and members of civil society claimed ownership to leave a legacy at Bruma Lake and Paterson Park. I showed that uncertainty emerged at the start of the project, where participants from all groups were required to claim ownership outside of legal roles and responsibilities to manage uncertainty around planning, funding and implementation of the projects. I also showed that uncertainty arose out of the way participants carried out their activities to leave a viable and manageable legacy at the sites, where they carried out activities outside of existing institutional rules and professional guidelines. To manage both instances of uncertainty, municipal officials, private sector professionals and members of civil society carried out their activities according to different understandings of physical nature-infrastructure interactions than what was conventionally used.

The shifting or evolving understandings of physical nature-infrastructure interactions are an example of how green infrastructure concepts are conceptualised in practice. Evolving shared understandings of physical nature-infrastructure interactions illuminate incongruences between understandings developed through practice and those represented by rules. These incongruencies risk the long-term functionality of the project, despite the outcomes resembling a river, park and stormwater management intervention, as they are unfamiliar to institutional rules in place to maintain and manage them in the long term. By implication, participants pointed to the need for project actors to claiming ownership in new or different ways to manage uncertainty around the evolved sets of practical understandings and to develop new rules to ensure that a legacy is left into the future.

Chapter 8 CONCLUSION

Green infrastructure has gained increasing interest in recent years as a concept for supporting more sustainable urban development. While it has been written and spoken about as a being a relatively simple concept in disciplinary knowledge and policy, its use in practice is not always straightforward. I highlighted the complexity of green infrastructure concepts, where amid its many disciplinary meanings and policy representations, the concepts can be drawn on in unplanned ways. Toward understanding how green infrastructure concepts are conceptualised in practice, I followed a practice theory approach to explore the momentary power of green infrastructure concepts, where it can be used in unplanned ways as part of a window of opportunity. By implication, I highlight a range of city actors that use green infrastructure concepts at the local level and how they contribute to its shared or re(conceptualised) understandings.

By developing Schatzki's practice theory approach, I explored how green infrastructure concepts are conceptualised in practice as part of a social process. Exploring how green infrastructure concepts and how they are used as part of a social process illuminated how participants used green infrastructure concepts according to their disciplinary knowledge, know-how and background. It also drew attention to the way that green infrastructure concepts are used by a range of project level actors in response to the context and setting. Therefore, I highlighted how green infrastructure concepts are conceptualised as part of an embedded process, where project level actors can gain a shared understanding of physical nature-infrastructure interactions through their use.

8.1 Summary and research findings

At the start of the thesis, I explained the rise of green infrastructure concepts in policy and practice to manage urban development more sustainably. To support sustainability, green infrastructure concepts tend to be proposed, and used, at a national, regional and city levels to respond to a wide range of concerns such as conservation, infrastructure service management and increased quality of life. To respond to a range of urban concerns, government officials, private sector professional, and members of civil society draw on different meanings of the green infrastructure concepts where it influenced their daily activities.

In Johannesburg, green infrastructure concepts had been spoken and written about in a range of disciplinary and policy texts, with a limited understanding of how concepts are interpreted and used in practice. Knowledge generation tended to be located around two core areas of academic and applied literature, which focused on technical or scientific disciplinary studies or around policy mainstreaming (Figure 7-2). In cases where local green infrastructure examples had been drawn on, they were framed as 'best practice', where despite the local context and setting, the prevailing technical considerations became the topic of interest. This approach to knowledge generation intended that if the opportunities and barriers toward mainstreaming the approach were identified, it could then easily be incorporated into city planning.

To make sense of green infrastructure, municipal officials, researchers and academics focused their energies on developing the detail they believed was necessary to interpret broader meanings and international best practice. To develop the detail they believed was necessary, municipal officials and research academics tended to measure or quantify the services or functions of physical nature and infrastructure under the *ecosystem services* and *engineered approaches* (Section 2.1), (Figure 7-2) Municipal participants also felt this kind of knowledge was essential for ensuring the long-term maintenance of the Bruma Lake and Paterson Park projects in Section 7.3, where it tended to support the burden for proof I presented in the literature review (Chapter 2).

The desire for technical evidence-based knowledge to provide the necessary detail to interpret meanings of green infrastructure in practice established a common interest around trying to mainstream green infrastructure. Existing research methods used to support the mainstreaming of green infrastructure concepts into policy and practice tend to follow a technical or social studies approach where specific examples from the United Kingdom, the United States of America and Europe are drawn on such as the *Living River Leising* example (Section 7.1), (Figure 7-2). Under this framing, green infrastructure becomes an object of academic and technical investigation, where it can be understood, encouraged and transferred to other settings based on its relative success elsewhere.

Choosing to focus on how green infrastructure concepts are conceptualised in practice contributes an alternative way of understanding how they are interpreted. Rather than focusing on developing the detail, I followed a more explorative approach to consider how participants negotiated the many meanings of green infrastructure in practice, where, as broader literature on green infrastructure highlights there are multiple actor interests in the city according to the local context, policy setting and politics (Wright, 2011; Finewood, 2016; Finewood et al., 2019). Therefore, in addition to the technical details, I also contend that the city and project level actor interests, the local context, the policy setting and politics also play a role in how green infrastructure is practiced.

Practice theory is one approach that is used to study how the social world is organised. As green infrastructure is a social phenomenon, exploring how it comes to exist through participant activities can present important findings around how concepts are interpreted in practice. I selected Schatzki's practice theory approach as it enabled a study of the many individual conceptualisations of green infrastructure and how they evolve. Exploring the evolution of green infrastructure concepts in this way fills a gap in existing knowledge on green infrastructure as they have become known in Anglo-American scholarship and policy studies.

By using Schatzki's practice theory I was able to build on critical studies in green infrastructure. Broader literature on green infrastructure had already identified its fluid boundaries, where the concept comes to have comfortable meanings in policy and practice (Wright, 2011; Horwood, 2011, 2020). It also pointed to the fact that it was used in unplanned ways (such as Mell, 2020). A practice theory approach enabled me to embark on a more dynamic exploration of the fluid way that meanings of green infrastructure are understood and used in practice.

Understanding how green infrastructure as practice illuminated the unspoken or unwritten beliefs or values that hold participants together, or their general understandings. The relationship between general understandings and practical understandings played a key role in exploring the (re)conceptualised understandings of physical nature-infrastructure interactions. In the conceptual framework, I used physical nature-infrastructure interactions as a conceptual device to reveal how meaning evolved on projects where they can bring together actors from a wide range of backgrounds such as government officials, private sector professional and members of civil society. Therefore, while critical studies focus on decision-making and who or what influences the meaning of green infrastructure concept, practice theory enables a closer exploration around the fluidity of the concept and how meaning can evolve over time.

An abductive research design enabled me to explore the conceptualisations of physical nature-infrastructure interactions held by actors and how these developed as part of a temporal journey. Exploring physical nature-infrastructure interactions in this way illuminated the many practical understandings of physical nature-infrastructure interactions held among a range of project level actors involved in the Bruma Lake and Paterson Park projects. One benefit of using an abductive approach to explore how green infrastructure is practiced was that it enabled me to explore individual project level actor activities and how they comprised a collective process or practice.

Participants from all groups expressed a desire to leave a viable and manageable legacy. While leaving a legacy took a variety of forms, such as having ambitions to influence the local area in which they live and work (Bruma Lake Owners Association and residents), broaden the scope of municipal projects to create meaningful outcomes for residents (municipal officials at the Environment and

Infrastructure Services Department, Development Planning Department, and Johannesburg Development Agency), or contributing more than one value or benefit on infrastructural projects (design engineer), they were all brought together under a common intangible interest. Working together to leave a legacy enabled study participants from a range of backgrounds to plan, design and implement green infrastructure solutions despite holding a range of individual physical nature-infrastructure interactions.

To leave a legacy in Johannesburg, participants claimed ownership to manage the uncertainties they encountered at Bruma Lake and Paterson Park. While I go into more detail on exactly which kinds of ownership and uncertainty below, it is important to flag that they formed a mutually constitutive relationship. In other words, green infrastructure was something that participants could claim ownership of to manage uncertainty in practice. Describing the mutually constitutive relationship between ownership and uncertainty demonstrated how green infrastructure concepts are practiced as a situated and contextually bound concept. I return to my latter point after I have described how the participant's claimed ownership at Bruma Lake and Paterson Park.

As I explained above, claiming ownership to leave a legacy took different forms. Civil society carried out legal activities under South African environmental law to hold municipal government accountable to their responsibilities for urban water management systems[96]. Members of Bruma Lake Owners Association and

[96] These duties were defined in statutory law, where government is responsible for environment and infrastructure in the South African Constitution and national laws on water and infrastructure management.

Norwood and Orange Grove residents lobbied against Johannesburg Municipality using South African environmental law to influence the kind of area they lived in (Section 6.2). In addition to providing comment and feedback as part of formal avenues for public participation outlined by South African legislation, Bruma Lake Owners Association and residents communicated with the Environment and Infrastructure Services Department and Development Planning Department via telephone and email to voice their grievances. They also engaged in a broader set of legal steps to hold Johannesburg Municipality accountable under the South African Constitution, the South African National Water Act 1998, South African Environmental Management Act 1998 and the Helsinki Rules on the Uses of the Waters of International Rivers (Section 7.1).

Members of civil society also managed uncertainty around the future of Bruma Lake and Paterson Park sites. Uncertainty was characterised by the inability of the Johannesburg Municipality to deliver on their duty of care over water infrastructure and park management that resulted in continued water pollution concerns at Bruma Lake and flooding and safety concerns at Paterson Park. Over time mistrust began to develop between members of Bruma Lake Owners Association and Norwood and Orange Grove residents, where it contributed to a mounting uncertainty around whether or not the Johannesburg Municipality would intervene on water pollution and flooding at Bruma Lake and Paterson Park. Activities to claim ownership at the sites to respond to these uncertainties were aimed at placing pressure on the Johannesburg Municipality, where environmental law created a basis for overlap and common ground.

Municipal officials claimed ownership through their activities to attract budget to respond to uncertainty around the future of the Bruma Lake and Paterson Park projects. How municipal officials carried out their activities to leave a legacy in the city supported the use of green infrastructure, or in this case river renaturalisation. River renaturalisation was conceptualised as a multifunctional urban intervention to provide infrastructure services while also supporting recreational values. To carry out their activities to manage the future of the project sites municipal participants, at the Environment and Infrastructure Services Department, worked internally within the Johannesburg Municipality to place pressure on the Mayor and other officials to address problems at Bruma lake by allocating funds to the project. At Bruma Lake and Paterson Park municipal officials at the Environment and Infrastructure Services Department and the Development Planning Department, including Johannesburg Development Agency, also carried out activities to set the scope for contracted professionals working on the project. Both these steps served to influence which approach was used to manage water pollution and flooding concerns.

Uncertainty over the future of the projects emerged around whether or not Johannesburg Municipality would carry out their duty of care to maintain and upgrade water infrastructure at Bruma Lake and Paterson Park. Uncertainty at Bruma Lake arose around whether or not the Johannesburg Municipality would allocate funds to Bruma Lake, where it was explained by municipal officials that environmental issues such as water pollution are considered to be the “step-child” of infrastructure and related concerns in the city, where they tended to not receive budget (GOVL007). Therefore, at Bruma Lake municipal officials responded to uncertainty by placing pressure on internal administrative processes such as the annual budgets and supply chain management[97] to secure project funds.

Municipal officials, such as participants at Johannesburg Development Agency, also explained they took steps to set the scope of the kinds of interventions that could be followed at the sites. For example, municipal officials could edit the "specs", or the specification, of the professionals or professional services sought after on municipal projects (GOVL017). While municipal participants at the Development Planning Department and Johannesburg Development Agency did not explicitly point to the use of fixed specifications for the Paterson Park project, a municipal official at the Development Planning Department carried out activities to widen the scope in other ways. At Paterson Park, officials at the Development Planning Department carried out activities to complete the Corridors of Freedom project in a way that would add value to the city as a mixed transport, housing and recreation project.

The Corridors of Freedom was a Mayoral project that had a fixed timeframe. As such, it became necessary to take steps to find common ground among participants on the project including residents at Norwood and Orange Grove. Toward moving ahead on the project, officials at the Development Planning Department took steps to balance collective outcomes and objectives to ensure they left a legacy on the project. Therefore, on both projects, municipal officials

[97] In the context chapter I indicated the process for local government procurement in South Africa is outlined in the Public Finance Management Act. Referred to a 'supply chain management', the procurement of goods and services on behalf of government in South Africa is regulated through a dedicated supply-chain management department using this act (Section 5.2).

at the Environment and Infrastructure Services Department, Development Planning Department, and Johannesburg Development Agency broadened the scope of the Bruma Lake and Paterson Park projects.

Last, private sector professionals such as the design engineer and landscape architects claimed ownership of the future of the project sites by wanting to contribute ‘value add’ on projects (CONSL006 and CONSL007). Activities to leave a legacy required professionals to respond to technical uncertainty present at the start of the project, where there was ‘adversity’ around the levels of toxicity at Bruma Lake and water concerns at Paterson Park. The design engineer and landscape architects worked within and outside professional guidelines to experiment with different properties of physical nature-infrastructure interactions to find solutions to address water pollution and flooding while also leaving a legacy in the city.

Illuminating the different ways members of civil society, municipal officials, the design engineer, and landscape architects claimed ownership to manage uncertainties around the future of the project sites shows how practice evolved. River renaturalisation, as a form of green infrastructure, therefore, became an approach that participants could claim ownership of and which uncertainties they managed in practice. Therefore, while green infrastructure or river renaturalisation was not conceptualised as the focus of the projects at the start, it influenced how the project proceeded over time, including how participants approached other projects in the city.

8.2 Answering the research question: Implications for practice, empirical data and theory

In this section, I explain how I answer the research question. To begin, I demonstrate my contribution to knowledge by drawing out the practical implications of understanding green infrastructure concepts and how they are used, where meanings of physical nature-infrastructure interactions evolve (Section 8.2.1). Next, I reflect on the methodological approach I followed and how it supported a study of one or more conceptualisations of physical nature-infrastructure interactions (Section 8.2.2). Finally, I reflect on practice theory and its implications for illuminating how green infrastructure concepts are (re)conceptualised through their use (Section 8.2.3). Reflecting on the implications of the research according to their practical, empirical and theoretical provides the necessary context to present on further avenues for research in Section 8.3 below.

8.2.1 Evolving physical nature-infrastructure interactions: What does it say about the conceptualisation of green infrastructure?

The use of river renaturalisation as a form of green infrastructure at Bruma Lake and Paterson Park highlighted one way that green infrastructure concepts can be practiced. Unlike disciplinary knowledge and policy, where I showed there can be a range of understandings of physical nature and infrastructure held among a range of actors at a range of scales (Sections 2.1 and 2.2), I showed that green infrastructure was used in unplanned ways in these sites. In other words, green infrastructure concepts become what project level actors claimed ownership of and which uncertainties they helped them to manage at Bruma Lake and Paterson Park. Therefore, exploring how green infrastructure concepts are used in unplanned ways offers different insights for how concepts such as green infrastructure or river renaturalisation gain meaning in Johannesburg.

In the Introduction, I explained how the social construction of nature scholarship and urban political ecology formed that starting point for my study on green infrastructure in practices in Johannesburg. While both of these bodies of knowledge supported a study of the many meanings of ‘nature’ and how influential actors help to shape how they are produced or re-produced in the city, they tended to focus less on how meanings of ‘nature’ evolve out of practice, how practice contributes to meaning and how this influences urban management, or governance, going forward. Focusing on a practical theory approach enabled me to build on these insights to consider how meanings develop and are used in unplanned ways.

Broader literature on green infrastructure in Johannesburg points to the use of the concepts in planned ways that can be researched as a technical intervention and mainstreamed in policy. For example, the research that I was part of at Gauteng City-Region Observatory, including other South African research institutions, focused on a policy rhetoric to mainstream the concept in policy and practice (Schäffler et al., 2013; Culwick, Khanyile, et al., 2019; Cilliers and Cilliers, 2016). I develop these ideas further as part of my contribution to knowledge by demonstrating how meaning comes to exist in particular settings, where they can evolve in unplanned ways. As I noted in the analysis chapters, participants worked within and outside of existing rules, where the concept evolved activities that stretched and defined the concept in ways not represented in existing rules such as policies, laws or guidelines.

I found that participants wanting to leave a variable and manageable legacy played an important role in influencing how participants carried out their activities. Leaving a legacy is an intangible, unspoken or unwritten interest that is rarely considered in the design and management of urban infrastructure. I showed how wanting to leave a legacy at Bruma Lake and Paterson Park enabled project level actors to be more flexible and open to different activities, it also required participants to experiment with their practical understandings of the physicality and physical-chemical properties of physical nature-infrastructure interactions, which led to the evolution of the practical understandings. Being more flexible and open enabled participants to be more creative in their approach toward leaving a viable and manageable legacy. By implication, creating a shared or common objective at the start of the project can support the use of an alternative approach.

I revealed the way that river renaturalisation evolved out of the relationship between ownership and uncertainty, which in turn revealed that green infrastructure concepts are practiced as part of a more dynamic and fluid process than commonly depicted. I showed that residents, municipal officials and professional consultants use it as part of an embedded process to address challenges, in this case, water pollution and flooding, by working both within and outside of existing rules (Figure 7-2). The implications for including green infrastructure in policy is, therefore, that it must be recognised as an embedded process, rather than only being introduced as a preconceived idea with a budget attached. Therefore, green infrastructure does not necessarily evolve out of an entirely new process, rather it evolves within and outside of the existing 'business as usual', which I identified at the start of the thesis (Section 1.1).

River renaturalisation was used by participants that came from a range of backgrounds such as government, private sector and civil society. Each project level actor had their own understanding of physical nature-infrastructure interactions and this influenced the way they carried out their activities. By showing how the concepts are conceptualised through project level actors wanting to 'do things' at the Bruma Lake and Paterson Park site, it pointed to the mutually constitutive relationship between ownership and uncertainty and how green infrastructure evolved as part of collective or shared practice. Focusing on practice as a more fluid process proves useful for developing and harnessing green infrastructure approaches in the future. For example, it illuminates how a range of actors used green infrastructure concepts by carrying out particular activities at the project design and development stage and where they put in place administrative mechanisms at the start of the to guide water management interventions... Therefore, the process of project design and conceptualisation forms another important entry point for studying green infrastructure in Johannesburg.

The way that green infrastructure evolved out of existing practices in Johannesburg is useful for understanding how concepts like green infrastructure gain meaning in the city. As every city has its own unique set of rules, politics and histories, green infrastructure evolves as a situated and contextually bound phenomenon. Focusing on the meaning-making process rather than on rigid or fixed rules can enable a more open and flexible uptake of green infrastructure ideas. Shifting the focus on to process and how it comes to exist through political interests and other organising factors such as history and disciplinary knowledge. Therefore, the process and points at which project level actors intervene in the process can reveal important insights on how green infrastructure concepts gain meaning in practice.

Gathering data on the temporal journeys of participants enabled an exploration of how participants used technical and experiential knowledge at the project sites. The interplay between the two kinds of knowledge enabled project level actors to develop their understandings of physical nature-infrastructure interactions. For example, the Orange Grove residents used similar activities that they did to hold Johannesburg Municipality accountable for development at Huddle Park (Section 7.1). I also explained that municipal officials and private sector professionals began Bruma Lake and Paterson Park projects with the know-how they had evolved from related ‘environment and infrastructure’ projects such as Moroka Dam and the Kelland wetland (Section 7.3). Therefore, gathering the individual accounts of participants enabled a study of how the understanding of physical nature-and infrastructure is not only used at the project level, but form part of a broader social process, where participants use technical and experiential knowledge or ‘know-how’ developed over time to guide their actions (Section 3.3).

The (re)conceptualised understandings of physical nature-infrastructure interactions at Bruma Lake and Paterson Park demonstrated how a shared understanding evolved among actors working on the projects. Going forward, shared understandings developed from these activities can influence how participants would approach and work together with others on future urban water management projects. Bruma Lake and Paterson Park were two examples of this, where they formed part of a continuum of related projects using an 'environment and infrastructure' approach (Section 7.3). The development of a shared body of knowledge and how it influences the approach and activities of project level actors highlights another area that influenced how green infrastructure concepts were used.

Questions around the on-going maintenance of project sites reveal where municipal officials felt the need to support the generation of technical and scientific data on re-established physical nature-infrastructure interactions. While maintenance is a well-known issue at Johannesburg Municipality, where limited resources meant only a few municipal officials can address as part of the annual budgeting process, it does raise the need for new avenues for research on maintenance processes and how they interface with alternative kinds of infrastructure, such as green infrastructure. Should projects not be maintained and looked after according to the evolved shared practical understandings of physical nature-infrastructure interactions, the benefits provided by river renaturalisation may not continue as originally anticipated by those involved in its design and implementation. This raises important questions around the future of the project sites.

8.2.2 Abductive research: Exploring green infrastructure concepts as an individual and collective process

By selecting an abductive research approach enabled me to foreground physical nature-infrastructure interactions at Bruma Lake and Paterson Park. By focusing on the accounts of participants at the project level, I gathered data on the multiple understandings of physical nature-infrastructure interactions on projects and how they came together as part of a process or practice. Since green infrastructure concepts are conceptualised according to their setting and context, gathering information on how they formed practice demonstrates how green infrastructure is conceptualised in Johannesburg. As I explained, exploring green infrastructure as a process reveals insights on how it is used as practice.

In-depth interviews revealed the different understandings of physical nature-infrastructure interactions that existed at the city and project level. Gathering data on these understandings enabled me to explore how the project level actor's practical understandings evolved according to their activities to leave a viable and manageable legacy. A benefit of using such an approach for exploring how green infrastructure concepts were conceptualised was that it illuminated the "temporal journeys" followed by participants (Schatzki, 2012, p. 25). Understanding the temporal journeys of participants enabled me to explore how green infrastructure evolved as practice where it emerged as both an individual and collective process.

Entering the field as a dialogic facilitator enabled me to gather data on how green infrastructure concepts formed part of the daily activities of participants. To date, studies to understanding green infrastructure concepts in Johannesburg has tended to focus on mainstreaming green infrastructure concepts in policy, where there were “expectations” around how they ought to be used (Section 1.1), (Lennon, 2015, p. 10). By entering the field in this way often requires that participants understand the researcher’s representation of green infrastructure first, before reflecting on how it is used. This locates the researcher as the expert, where participants must respond to their conceptualisation of physical nature-infrastructure interactions. Entering the field as a dialogic facilitator supports a more exploratory study of how green infrastructure concepts evolved as part of an organic process.

The aim of data collection was not to uncover barriers and opportunities for specific kinds of physical nature-infrastructure, I rather wanted to gather a range of physical nature-infrastructure interactions. Taking on a dialogic facilitator role encouraged “variety of ‘voices’ to be expressed” in the research (Blaikie, 2000, p. 54). A benefit of using this approach was that the process through which green infrastructure concepts are conceptualised and the avenues followed within and outside existing rules can be illuminated. Therefore, taking on a dialogic facilitator role support a study of the multiple accounts of physical nature-infrastructure and how they come to exist within a particular setting and/or context.

While using an abductive research design, a purposive (city level), and critical cases (project level) strategy enabled me to draw on the details around how green infrastructure was practiced, it did mean that I only gathered in accounts of participants involved or their understanding of ‘environment and infrastructure projects. While selecting these participants using an abductive research design is valid for exploring how green infrastructure is conceptualised, their accounts are likely to only focus on certain meanings of physical nature-infrastructure interactions. In other words, it focused on specific meanings of green infrastructure that were considered successful if maintained over time. By implication, it does not focus on other meanings of green infrastructure concepts and how they are understood and used. A study of other meanings of green infrastructure concepts forms a viable avenue for future research.

Gathering the multiple accounts of participants has implications for studies on green infrastructure, where it shows there is more than one dominant understanding of green infrastructure concepts at any one time. Broader literature on green infrastructure tends to focus on only one understanding of physical nature-infrastructure interactions (such as the disciplinary approaches I demonstrated in Section 2.1). Literature also highlights that more than one meaning can be used to influence the use of green infrastructure concepts in policy (Section 2.2). The implications of gathering data on the multiple accounts of physical nature-infrastructure illuminate the concept can exclude some actors, while also being capacious enough to bring some of them together. By conceptualising green infrastructure as a collective practice, where project level actors can hold different understandings of physical nature-infrastructure interactions demonstrates an alternative was for understanding green infrastructure concept and how they are conceptualised as part of a social process.

8.2.3 (Re)conceptualised physical nature-infrastructure interactions: Theorising green infrastructure going forward

Developing a practice theory approach to explore how green infrastructure is practiced illuminated how concepts evolved as part of a process or practice. In other words, infrastructure management forms part of a continuum, of which green infrastructure and river renaturalisation form only one moment. The significance of using a practice theory approach for studying green infrastructure concepts is that it identifies which practical understandings and rules come before it, how they influence and are influenced, and how they evolved according to different understandings of physical nature-infrastructure interactions. This is what I demonstrated across the three sections of each of the analysis chapters (Chapter 6 and Chapter 7). The implication of using a practice theory approach is therefore that physical nature-infrastructure interactions have always been part of urban water management practice, where they are (re)conceptualised over time.

Conceptualising green infrastructure practice at Bruma Lake and Paterson Park illuminated noteworthy moments where physical nature-infrastructure interactions evolved. At these points, meanings of physical nature-infrastructure interactions were (re)conceptualised, which had broader implications for the management and maintenance of green infrastructure in the city (Chapter 2). While literature identified the situated and contextual elements of green infrastructure concepts, where they can gain ‘comfortable meanings’ (Wright, 2011) through their fluid boundaries (Horwood, 2011, 2020), they tended to place a limited focus on how green infrastructure concepts can evolve according to how they are used. This study focused on exploring the processes through which green infrastructure concepts come to have comfortable meanings, where boundaries in their meaning are stretched and modified over time.

The findings of the study illuminate the unplanned or unintended ways that green infrastructure concepts are conceptualised and used in practice. In particular, it builds on critical planning studies by Horwood (2011), Mell (2015b) and Horwood (2020) to show how the fluid boundaries of the concepts broadened, narrowed or stretched to accommodate for the context and settings within which they are used. The unplanned ways in which boundaries in the meaning of green infrastructure is negotiated illuminates how Johannesburg is characterised by "incessantly flexible, mobile and provisional intersections", where actors can "operate without clearly delineated notions" of the city (Simone, 2004, p. 407). Exploring how green infrastructure is practiced in Johannesburg therefore illuminates how it mediates social life, where green infrastructure as a concept is also evolving following how it is understood and used in practice.

Focusing on how green infrastructure concepts gain meaning through how they are used, illuminates its politics in practice. While Wright (2011), Finewood (2016) and Finewood et al., (2019) illuminate the contested characteristics for how green infrastructure concepts can be 'corrupted' by influential actors or according to pre-existing ways of doing things, they tend not to explore how they become corrupted according to how they are used. For example, underlying practices or 'grey epistemological approaches' can serve to water down the overall benefit of green infrastructure (Finewood, 2016; Finewood et al., 2019). While findings point to rules and influential actors and how they can influence how green infrastructure concepts are used, they do not draw out the fluidly or variability around how this takes place.

I demonstrated studies in critical geography tend to focus on decision-making processes, where green infrastructure is produced through how city level actors make decisions according to what power they have. While studies along this vein enable the politics of green infrastructure concepts to be considered at any one point in time, they tend not to illuminate how green infrastructure comes to exist through windows of opportunity as part of a process in its own right. In other words, it treats phenomenon such as green infrastructure as a static concept, rather than a dynamic and fluid process on its own. The (re)conceptualisation of physical nature-infrastructure interactions builds on broader literature on green infrastructure, where it points to decision-making and its associated activities taking place as part of a more dynamic process. In other words, history, practical understandings, rules and general understandings can influence how project level actors conceptualise green infrastructure at different points in time.

By following a practice theory approach, the findings of the study also contribute to the ‘infrastructure turn’ in sociology, where infrastructure is foregrounded to show its history and politics. I mentioned at the start of the thesis (Chapter 1), the infrastructural turn illuminates infrastructure as being not only technical and neutral, but equally a social process. The findings of the thesis illuminate green infrastructure as something that is socio-technical, relational, splintering, everyday and political. I will now present how the findings of the study and how to build on existing theory on the infrastructural turn, where it can reveal different insights about how (green) infrastructure both influences and is influenced by the social world. To do so, I cover key concepts within the infrastructural turn to show how I have developed or built on knowledge in this area.

To start, infrastructure is conceptualised in the social sciences as a socio-political process. Authors writing on infrastructure such as Silver and McFarlane (2019, p. 6) contend it ought to be explored as ‘social infrastructure’. In other words, infrastructure is “made up and held stable through work and changes ways of connecting”. Viewing how infrastructure holds stable and connects reveals how it is “peopled” (Silver and McFarlane, 2019, p. 6). The thesis contributes to the concept of social infrastructure by revealing the actors (at a city and project scale) that engage in it through their social and political aspirations and how this helps to define and (re)define its meaning and role in social life over time.

Infrastructure has been conceptualised as a relational phenomenon, where it can be constituted by relationships in time and space. ‘Infrastructures of relationality’ is a concept that has been used to describe how infrastructure is the “materials themselves to be articulated in various forms” (Simone, 2014, p. 18). Under this assumption, infrastructures are the “vehicles” of movement, where they mediate the “constantly oscillating intersections of various times, spaces, economies [and] constraints” (Simone, 2014, p. 18). To this end, the findings of the thesis reveal how articulations of physical nature and infrastructure are relational and in a constant state of flux, and they mediate and are mediated by the different contexts and settings within which they are used.

Infrastructure is a socio-technical process, rather than something that is solely technical. As authors such as Graham (2001, p. 340) argue, infrastructure is not only technical “engineers stuff” as it can exert power in different ways. In particular, infrastructure can support and deepen inequalities, where “affluent” or “powerful groups” can perpetuate or extend inequalities in space (Graham, 2001, p. 340). The findings of the research reveal the different dimensions of power and how it developed and asserts force through the inclusion of environmental interests, such as those held by civil society or municipal officials. By identifying the role of these actors in the use and (re)conceptualisation of green infrastructure builds on the understandings of infrastructure and how physical nature adds complexity and dominance over how technology and approaches are used in practice.

Last, the findings of the study support the need to explore ‘infrastructure as ethnography’. Exploring physical nature-infrastructure interactions and how they are (re)conceptualised over time, supports the need to explore ‘infrastructure as ethnography’, where it develops and is used as an “embodied” and “embedded” phenomenon (Star and Bowker in Star 1999: 238). While it has been well-established that infrastructure is a socio-political process, the interactions between physical nature and infrastructure illuminate some of the complexity around using infrastructure concepts that bring together a wide range of professionals and actors with diverse backgrounds. Understanding infrastructure as ethnography, therefore, supports a more nuanced study of not only how infrastructure manifests as a socio-political process, but also how environmental interests form part of the everyday or ‘doing’ elements of the city that reveal its embodied and embedded characteristics.

I used Schatzki’s practice theory approach to focus on how meanings of green infrastructure evolve through project level actor understandings of, and engagements with, infrastructure. Focusing on how understandings of physical nature-infrastructure interactions evolve illuminates the unplanned ways that physical nature is drawn on in different ways to meet political agendas around sustainability and resilience, where it forms part of an embedded process rather than under a fixed or static understanding of infrastructure (Shove et al., 2012; Shove, 2016). Consequently, by foregrounding physical nature-infrastructure interactions I highlight the history and politics associated with the use of alternative understandings of infrastructure and the social world.

I explained how the scholars contributing to the broader ‘infrastructural turn’ in sociology illuminate the infrastructure as a socio-political process and how it comes to matter in the city. The use of green infrastructure concepts raises the need for future research around where I consider whether these same arguments ring true for green infrastructure, which has its own politics and inequalities embedded within physical nature-infrastructure interactions. Therefore, by drawing out the multiplicity and capaciousness of the green infrastructure concept and how meaning evolves in practice, it raises the need to consider it what it means for the city in light of the broader literature on the ‘infrastructural turn’.

8.3 Future research

Exploring how participants conceptualised green infrastructure concepts in Johannesburg reveals avenues for future research. In this section, I identify two opportunities for future research that emerge from the thesis where I outline the need to consider how other green infrastructure approaches evolve over time. There is also a need for further research around equity concerns related to the use of river renaturalisation among a range of actors. Both avenues for research support a more focused understanding of the situated and contextually bound features of green infrastructure, where it raises further questions around politics associated with how green infrastructure is practiced (Section 8.2.3).

To start, Bruma Lake and Paterson Park illuminated two projects where river renaturalisation was practiced to address water pollution and flooding. As I indicated in the literature review, there are many understandings of physical nature-infrastructure interactions that can manifest differently across different scales. While the study focused predominantly on an *engineered approach* and how it was conceptualised in Johannesburg, one further avenue for research could be to explore how the *connected landscape* and *ecosystem services approaches* have evolved in Johannesburg. Consequently, investigating other conceptualisations of green infrastructure can reveal where and how they were used, including the range of project level actors and circumstances that influence their use.

As a second avenue for further research, I propose exploring how green infrastructure such as river renaturalisation 'adds up' at the city scale. In other words, by implementing river renaturalisation at Bruma Lake and Paterson Park, what does it mean for other areas that are not located in formerly white suburbs? In addition, how do evolved shared understandings influence infrastructure going forward? As the concepts formed part of policy dialogue (Section 1.1) and project level actor activities (Chapter 6 and Chapter 7), it becomes necessary to reflect on where and how it is used on projects in the city as some actors may benefit or lose according to how green infrastructure is practiced.

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APPENDIX

Appendix 1 Overview of green infrastructure projects identified by city level participants

NO.	PROJECT	DESCRIPTION	CITY LEVEL ACTORS INVOLVED
1	Atlasville flood management project	The project was undertaken to reduce flood risk in Atlasville using green infrastructure, while also providing other services.	City of Ekurhuleni and private sector consultants.
2	Bosmont infrastructure management project	Existing infrastructure does not allow for the efficient draining of stormwater from the site. Green infrastructure solution used (a water diversion pond) to ensure water drains from the site. Insufficient draining of water resulted in flooding.	Johannesburg Municipality, municipally-owned entities.
3	Bruma Lake	Rehabilitation of Bruma lake which was reported to have toxic water. Lake was drained and the then lake and surrounding park were enhanced via the renaturalisation of the lake.	Johannesburg Municipality, municipally-owned entities and members of civil society.
4	Cedar Lofts	Development of Cedar Lofts residential development that developed the site to build resident blocks while also preserving a pre-existing wetland.	Private sector development, with input from Johannesburg Municipality under the development control protocol.
5	Design Quarter gardens and landscaping	Examples of green infrastructure in an upmarket setting to manage stormwater and create aesthetic value.	Private sector development.
6	Diepsloot green infrastructure	Project to provide locally driven stormwater interventions in the informal settlement	Non-profit organisations, with inputs from academia

7	Donnington Drive and Laubscher Parks in Glenvista	Community investment in local parks	Local community in collaboration with municipally-owned entity
8	Greater Kyalami Conservancy	Community-based project to preserve natural landscape and support tourism via equine activities.	Non-profit organisations, with inputs from community members
9	Inner City Partnership	Rejuvenation of Johannesburg inner city to encourage densification and commercial ventures. No clear green element; although it has been discussed as an idea of the participants I have met.	Johannesburg Municipality in collaboration with private sector professionals
10	Kelland wetland	Rehabilitation of the Kelland wetland.	Johannesburg Municipality in collaboration with private sector professionals
11	Klipriviersberg – KEEDZ	Economic development project to support business and the preservation of the Klipriviersberg nature reserve.	Non-profit organisations, local community and businesses
12	Mogale City self-remediation project	The project aims to reduce the pollution of informal and other dwellings around Tembisa on the waste treatment works. This project includes a constructed wetland. Challenges with including and utilising it in project conceptualisation, development etc.	City of Ekurhuleni and private consultants
13	Moroka Dam	Rehabilitation of a silted wetland to manage water at Moroka Dam. The project also included the development of Thokoza Park as a recreational area for residents	Johannesburg Municipality in collaboration with private sector professionals
14	Olifants wetland rehabilitation project	The project aims to reduce the pollution of informal and other dwellings around Tembisa on the waste treatment works. This project includes a constructed wetland. Challenges with including and utilising it in project conceptualisation, development etc.	City of Ekurhuleni and private sector professionals

15	Orlando Ekhaya	Mixed used development with retail, commercial, housing and recreational features. The project also included the development of the park. Park had a wetland which has been preserved, including the building of a bird sanctuary.	Johannesburg City Parks and Zoo and the Environment and Infrastructure Services Department with private sector professionals
16	Ormonde Street Development	River enhancements to Klipspruit in Soweto. The project included the inclusion of a mixed development.	Private sector development with private sector professionals
17	Oxford Park residential and commercial development	Development of the area for high-income tenants (residential and commercial). Development is designed to be 'green' and 'eco-friendly' based on market demands.	Private sector development with private sector professionals
18	Queen's Wetland	Rehabilitation of an existing wetland to improve the water quality of the Jukskei River. Located just upstream of Bruma Lake.	Johannesburg Municipality in collaboration with private sector professionals
19	Paterson Park renaturalisation project	Rejuvenation of local park to enhance stormwater attenuations	Johannesburg Municipality, municipally-owned entities and members of civil society
20	Sandton Gate Precinct development	Development of the area for high-income tenants (residential and commercial). Development is considered green and eco-friendly based on the market. The Braamfontein Spruit flows through this area.	Private sector development with private sector professionals
21	Soweto Greening Project	Project initiated to beautify Soweto for the Soccer World Cup, but also project in its own right.	Johannesburg Municipality, municipally-owned entities
22	Thokoza Park remediation project	Remediation work was undertaken to upgrade Thokoza park and dam.	Johannesburg Municipality, municipally-owned entities and

			members of civil society
23	Urban Rivers Project Alliance	Part of the Green Infrastructure Strategy for City of Johannesburg	Government think-tank
24	Various Green Buildings – Golder, Department of Environmental Affairs (Pretoria) and Standard Bank (Rosebank)	Public, but mostly private. Indicates the upper end of green infrastructure use in Johannesburg. Indicates where GI is used as it is a cheap way to make things green building compliant.	Various public and private sector actors
25	Waterfall residential estate development	Residential housing estate development that has green and sustainable.	Private sector development with private sector professionals
26	Greening Soweto Project	A large-scale tree-planting project tied to the 2010 FIFA World Cup. Johannesburg Municipality aimed to plant more than 300 000 trees in Soweto, where one of the FIFA World Cup stadiums has been built. The project was tied with other interests to invest in physical nature in the Soweto township.	Johannesburg City Parks and Zoo, in collaboration with Soweto residents

Appendix 2 Participant labelling convention

KEY:

Government

FGOVL002 — Unique identity number

Former

Local

ACA - Academics
CIVSOC - Civil Society
CONS - Private sector - consultants
GOV - Government
RINST - Researchers
F - Former
L - Local
I - International

NO.	ID	ROLE	BACKGROUND
1	ACAL001	Academic/practitioner	Architecture
2	ACAI001	Lecturer	Natural science/social science
3	CIVSOCL001	Administrative ward committee member	Architect
4	CIVSOCL002	Environmental consultant	Environmental
5	CIVSOCL003	Community group chairperson	Lawyer
6	CIVSOCL004	Ward councillor	Teacher
7	CIVSOCL005	Small business owner	Construction
8	CIVSOCL006	Hotel manager	Hospitality
9	CIVSOCL007	Developer	Restaurant owner
10	CONSI001	Industrial engineer	Structural engineer
11	CONSI002	Construction engineer	Engineering
12	CONSL001	Consultant	Engineering
13	CONSL003	Facilitator	General academia
14	CONSL004	Facilitator	Town planning
15	CONSL006	Landscape architect	Landscape architecture
16	CONSL007	Environmental engineer	Engineer
17	CONSL009	Architect	Architecture
18	CONSL010	Environmental consultant	Environmental Science
19	CONSL011	Environmental consultant	Environmental Science
20	CONSL012	Landscape architect	Landscape architecture
21	CONSL013	On-site engineer	Engineer
22	CONSL014	Project management	Quantity surveyor
23	CONSL015	Landscape architect	Landscape architecture
24	FGOVL002	Former city official and adjunct professor	Engineer
25	GOVL001	Specialist planner	Planning
26	GOVL006	Assistant director municipal department	Planning
27	GOVL007	Assistant director municipal department	Wastewater engineer
28	GOVL008	Director of unit in municipal department	Town Planning
29	GOVL009	Roads and stormwater management	Stormwater engineer
30	GOVL010	Roads and stormwater management	Stormwater engineer
31	GOVL012	Project manager	Management/environmental control
32	GOVL014	Open space planning management	Planner
33	GOVL015	Acquisitions	Supply chain management
34	GOVL016	Finance and payments	Finance
35	GOVL017	Project manager	Biological science
36	GOVL018	Parks and open space management	Paper production
37	RINSTL001	Professor and senior researcher	Climatology
38	RINSTL002	Researcher	History
39	RINSTP001	Researcher	Economics
40	RINSTP002	Researcher	Geography
41	RINSTP004	Senior Researcher	Environmental planning

Appendix 3 Excerpt of codebook

CODE	TYPE	BRIEF DEFINITION	FULL DEFINITION	WHEN TO USE
ACTORS	Deductive	Actors that have engaged with concepts of urban nature as infrastructure	Actors that have engaged with concepts of urban nature as infrastructure	Apply code to identify the actors involved in the use of urban nature as infrastructure and in which context they are using it.
AGREEMENTS	Inductive	Agreements	Agreements between actors	Apply code where participants indicates there were agreements with other actors, or agreement at points in the project, or on the approach.
APPROACH	Deductive	Approach used by actors to promote green infrastructure	Green infrastructure has been used by an actor or organisation and this has developed into an approach.	Apply code in instances where a green infrastructure or related intervention has become part of the vision of an individual or organisation and this has developed into an approach.
CHALLENGES	Inductive	Challenges to the understanding and use of nature and infrastructure	Challenges to the understanding and use of nature and infrastructure	Apply when participant refers to challenges for the use of nature and infrastructure
COMMUNICATION	Inductive	Communication between actors	Communication between actors	Apply code when participants indicate when and how communication took place, includes platforms.
CONCEPTUALISATION	Deductive	Use of nature and infrastructure in the conceptualisation of projects	Use of nature and infrastructure in the conceptualisation of projects	Apply code when nature and infrastructure has been discusses in the conceptualisation of projects
CONFIDENCE	Inductive	Participant response indicating confidence in green infrastructure interventions	Participant response indicating confidence in green infrastructure interventions	Apply code to instances of confidence and confidence building in infrastructural approaches and use of urban nature.
CREATIVITY	Deductive	Descriptions of creativity in nature and infrastructure	Descriptions of creativity in nature and infrastructure	Apply code to indicate creativity and how it has come about in the development of infrastructure interventions
DEVELOPMENT	Deductive	Use of nature and infrastructure in the development of projects	Use of nature and infrastructure in the development of projects	Apply code when nature and infrastructure has been discussed in the development of projects
DISAGREEMENTS	Inductive	Disagreements	Disagreements between actors	Apply code where participants indicates there were disagreements with other actors, during the project or on approach.
ECONOMIC	Deductive	Economic implications before and after use of green intervention	Economic implications before and after use of green intervention	Apply to references to economic implications either before and after use of green interventions
ELSEWHERE	Deductive	References to the use of green infrastructure concept elsewhere	References to the use of green infrastructure concept elsewhere	Apply code to references to the use of green infrastructure concept elsewhere based on knowledge, interest and use.
EQUITY	Inductive	Equity in the use and provision of green infrastructure	Equity in the use and provision of green infrastructure	Apply code where participants indicate equity concerns and green infrastructure.
FAILURE	Deductive	Participant references to failure	Participant references to failure	Apply code to describe participant descriptions of failure in projects, process or interactions.
IMAGINATION	Deductive	Participant descriptions of green infrastructure vision	Participant descriptions of green infrastructure vision	Apply code to participant descriptions of visions of green infrastructure by them, or other actors.

IMPLEMENTATION	Deductive	Nature and infrastructure used in the implementation of projects	Nature and infrastructure used in the implementation of projects	Apply code when nature and infrastructure has been discusses in the implementation of projects
INDIVIDUAL	Inductive	Individual involvement in the use of green infrastructure	Individual involvement in the use of green infrastructure	Apply code to reference all text which describes the role of the individual incl. their personality, position, and approach in regards to process and how this was changed as a result.
INFLUENCE	Deductive	Influential actors in the use of green infrastructure	Influential actors in the use of green infrastructure	Apply code where participant have influenced processes, or projects.
INFRASTRUCTURE	Inductive	References to infrastructure as problematized, intervened and used.	References to infrastructure as problematized, intervened and used.	Apply code to participant references infrastructure, including instances where nature is considered part of infrastructure. Include blurred lines between infrastructure and nature.
INTERDISCIPLINARY WORKING	Inductive	Actors worked together	Actors worked together	Apply code where actors from different backgrounds worked together to conceptualise, develop or implement green infrastructure.
INTEREST	Inductive	Participant descriptions of interest in green infrastructure approach	Participant descriptions of interest in green infrastructure	Apply code to participant own interests in green infrastructure, including that of others
LOCAL CONTEXT	Inductive	Local parameters	Local parameters the shaped the green infrastructure approach used	Apply code to references to local parameters that defined the use of a green infrastructure approach. Includes participant description of the local context and where they have indicate the local context defined their, or other actors approaches. Refers mainly to physical, or site-specific elements.
MAINTENANCE	Deductive	Participant descriptions of maintenance in the use of nature and infrastructure	Participant descriptions of maintenance in the use of nature and infrastructure	Apply code to participant descriptions of maintenance in the use of nature and infrastructure. Indicate reasons, opportunities and challenges.
MATERIALITY	Inductive	Descriptions of green infrastructure on the ground	Descriptions of physical elements of green infrastructure as they have been implemented in practice.	Apply code to physical descriptions of green infrastructure elements in practice - those which have bene implemented.
MOMENTS	Deductive	Key moments, activities on infrastructure projects which used natural services	Key moments, activities on infrastructure projects which used natural services	Apply code to moments, activities or events that influence the process used to conceptualise, develop and implement infrastructure projects.
NATURE	Inductive	References to nature as problematized, intervened and used.	References to nature as problematized, intervened and used.	Apply code to participant references to nature line the city, as problematized, intervened and used.
NECESSARY	Inductive	Factors necessary for green infrastructure to work	Factors necessary for green infrastructure to work	Apply code to descriptions where participants indicate certain factors are necessary for green infrastructure to be used, or work in practice. This can refer to speculative measures.
OPPORTUNITY	Inductive	Opportunities for the use of green infrastructure	Opportunities for the use of green infrastructure	Apply when participant refers to opportunities which can allow for the use of green infrastructure and related projects or where it can be included in the approach of the city.
ORIGIN	Deductive	Origin of approach	Origin of approaches to green infrastructure	Apply this code to indicate where the green infrastructure idea came from, or where inspiration for the approach has originated
OWNERSHIP	Inductive	Possession of concepts, approach and object	Possession of concepts, approach and object	Apply this code to references to actor possession of concepts, approach or objects.
POLICY REFERENCE	Inductive	Green infrastructure part of policy	Examples of where green infrastructure has been used in policy.	Apply this code when policies are said to refer to green infrastructure in any way.
POLITICAL INTEREST	Inductive	Political interest	Political interest	Apply code when interest is linked directly with local or other levels of politics.
POLLUTION	Inductive	References to pollution	References to pollution	Apply code to all references to pollution where is has implications for projects and actors. This can be a city or project scale and includes all instances of the term.

POWER	Deductive/inductive	Participant references to instances where actors changed process based on their power	Participant references to instances where actors changed process based on their power	Apply code where actors indicate actors, moments, circumstances where actors changes discourse due to power.
PRACTICES	Inductive	Practices used by actors to include green infrastructure	Practices used by actors to include green infrastructure	Apply code to participant descriptions of actors applying their ideas in day-to-day functioning of the city.
PROCUREMENT	Inductive	Procurement processes	Descriptions of procurement processes	Apply code to descriptions of procurement processes including challenges.
PROJECTS	Inductive	References to green infrastructure projects	References to or descriptions of completed green infrastructure projects	Apply code to descriptions of green infrastructure applications.
PUBLIC	Inductive	References to public, or public interests and concerns.	References to public, or public interests and concerns.	Apply code to references to citizen, or community, concerns in relation to policy, process and infrastructure.
RACE	Inductive	References to race	References to race	Apply code to direct or indirect references to race.
REASON	Deductive	Reasons for use of green infrastructure concept	Reason for green infrastructure	Apply this code to instances where participants describe why green infrastructure was used in materiality.
RESPONSIBILITY	Deductive	Participant descriptions of the activities of them and other actors	Participant descriptions of the activities of them and other actors	Apply code to activities and tasks actors are given or assume in the conceptualisation, development and implementation of projects.
ROLE	Inductive	Function of actor in the use of urban nature	Function of actor in the use of urban nature	Apply code to identify the function and part played by an actor in the use of urban nature as infrastructure
SCALE	Deductive	Participant references to scale	Participant references to scale	Apply code to participant descriptions of scale in their exam planation, or failures of projects.
STRIKING	Deductive	Striking features of green infrastructure.	Striking features green infrastructure compared to other applications	Apply code when participants have indicated there is something striking or different in a green infrastructure project.
TECHNICAL	Inductive	Translation of technical concepts into practice	Participant accounts of translation of technical concepts into practice e.g. Engineering descriptions of site, actor's framing of challenges of translating green infrastructure in practice based on technical requirements.	Apply code to instances where participants refer to the use of technical concepts in practice. Instances of use, or challenges. Also includes technical accounts of what was done on site in terms of an innovative technical solution.
TRADE-OFF	Inductive	References to one outcome over another	Participant descriptions of one outcome at the cost of another	Apply code to descriptions where one outcome as reaches, but another was not. This could be the result of a casual relationship or not.
TYPE	Deductive	Type of green infrastructure application	Type of green infrastructure application discussed by participant based on their role. Manly as a result of the local context.	Apply code to descriptions of green infrastructure applications and the kind of green infrastructure used in materiality e.g. References to use of wetlands or storm water based on the local context.
UNCERTAINTY	Inductive	Uncertainty in the use of green infrastructure	Uncertainty in the use of green infrastructure approaches in practice	Apply code to references to uncertainty highlighted by participants in the way that green infrastructure concepts are used in practice.
UNDERSTANDING	Deductive	Participant understanding of green infrastructure	Participant understanding of green infrastructure	Apply code to descriptions that identify the participant's understanding and use of concepts of environment and infrastructure. This also includes uncertainty in the translation of technical concepts.

Appendix 4 Participant information sheet

UCL DEVELOPMENT PLANNING UNIT

ENVIRONMENT, INFRASTRUCTURE AND URBAN MANAGEMENT IN JOHANNESBURG, SOUTH AFRICA

Information Sheet

UCL Ethics Project ID Number: 11725/001

UCL Data Protection Registration Number: Z6364106/2017/07/73

You are being invited to participate in a research project. Your participation is voluntary and it is up to you whether or not you decide to take part. Before you make this decision, it is important for you to understand why the research is being conducted and what your participation will involve. If anything is unclear please let the researcher know.

Research objectives
The research explores how concepts of the environment and infrastructure have influenced the everyday activities of individuals involved in the planning and management of Johannesburg. To investigate this, the project considers in what ways the environment and infrastructure are understood in the city, its importance for service provision, and how it has influenced the ways in which projects, are conceptualised, developed and implemented.

Participants
You have been invited to participate in the project based on your knowledge and expertise of working with, or on, projects related to environment and infrastructure in Johannesburg.

Voluntary participation
Should you decide to take part, you will be required to sign a Consent Form. You can withdraw from the study at any time without giving a reason. This decision will not disadvantage you in any way.

What will happen if I agree to take part?
You will participate in a research interview. The interview involves a series of open-ended questions where you will be asked about elements of your day-to-day work, including your role and contribution to environment and infrastructure projects in Johannesburg. The interview will take approximately one hour to complete.

Confidentiality
Our interview will be recorded on a digital audio device. The audio recording will be typed up as an anonymous text for analysis. Privacy and confidentiality will be ensured in the collection, transcription and processing of your data. No names will be used during data analysis or in the final output, unless agreed with you in person.

All data will be collected, stored and transferred overseas using UCL and EU-U.S. Privacy Shield Framework certified platforms. This is in accordance with the Data Protection Act 1998.

Benefits
While there is no immediate benefit for participants, it is hoped you will gain value from learning more about environment, infrastructure and urban management from an academic perspective.

Potential risks
No risks, inconveniences or discomfort are reasonably expected during your participation.

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Outputs and results
Study results will be published for the purposes of this project, including related articles published by the researcher. Outputs will be accessible on the UCL dissertation online repository, and on related academic platforms. Where possible, the researcher is also willing to share these outputs with study participants.

Funders
Kerry Bobbins is a Commonwealth Scholar, funded by the United Kingdom government. This project is supported by the Royal Geographical Society (with IBG) with a Dudley Stamp Memorial Award.

For further information on this project, please contact the researcher:

Kerry Bobbins (Researcher)
PhD Student
Bartlett Development Planning Unit
34 Tavistock Square
London
WC1H 9EZ
Email: [redacted]

Should you have any concerns about the conduct of the study, please contact the principal researcher:

Dr Colin Marx (Principal researcher)
Senior lecturer
Bartlett Development Planning Unit
34 Tavistock Square
London
WC1H 9EZ
Telephone: [redacted]
Email: [redacted]

Appendix 5 Participant consent form

UCL DEVELOPMENT PLANNING UNIT

UCL

ENVIRONMENT, INFRASTRUCTURE AND URBAN MANAGEMENT IN JOHANNESBURG, SOUTH AFRICA

Consent Form

UCL Ethics Project ID Number: 11725/001

UCL Data Protection Registration Number: Z6364106/2017/07/73

Thank you for your interest in this research project. If you have any questions on the explanation already given to you, please ask the researcher before you decide to participate.

You will be given a copy of this Consent Form to keep and refer to at any time.

I agree:

- To take part in this study based on what has been explained to me.
- To the processing and overseas transfer of my data for the purposes of this research project, and other outputs published by the researcher.
- To my data being shared with the research team consisting of the researcher and their supervisors.
- I have understood how my data will be treated and handled in accordance with the Data Protection Act 1998.
- If I no longer wish to take part in this project, I will notify the researcher and I will be withdrawn from the study immediately.

Participant Signature: ___________________ Name: _____________________________Date: ________

Should you want to discuss any aspect of the study further, please contact: Kerry Bobbins (Researcher), PhD Student, The Bartlett Development Planning Unit, University College London, email: [redacted].

If you have any concerns about the conduct of the study, you can contact UCL using the following details: Dr Colin Marx (Principal Researcher), Senior Lecturer, The Bartlett Development Planning Unit, University College London, telephone: [redacted]

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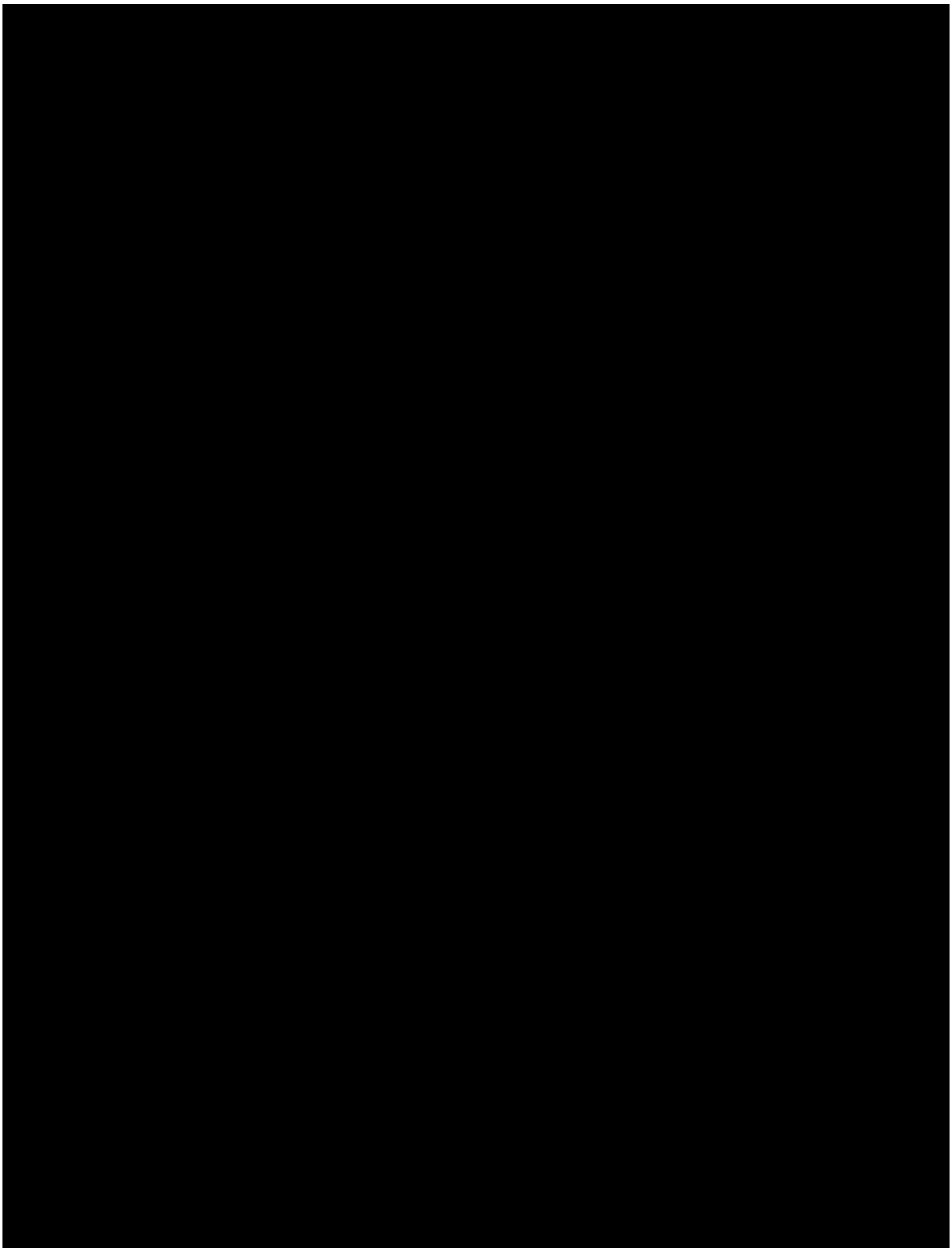
Appendix 6 Bruma Lake technical drawings

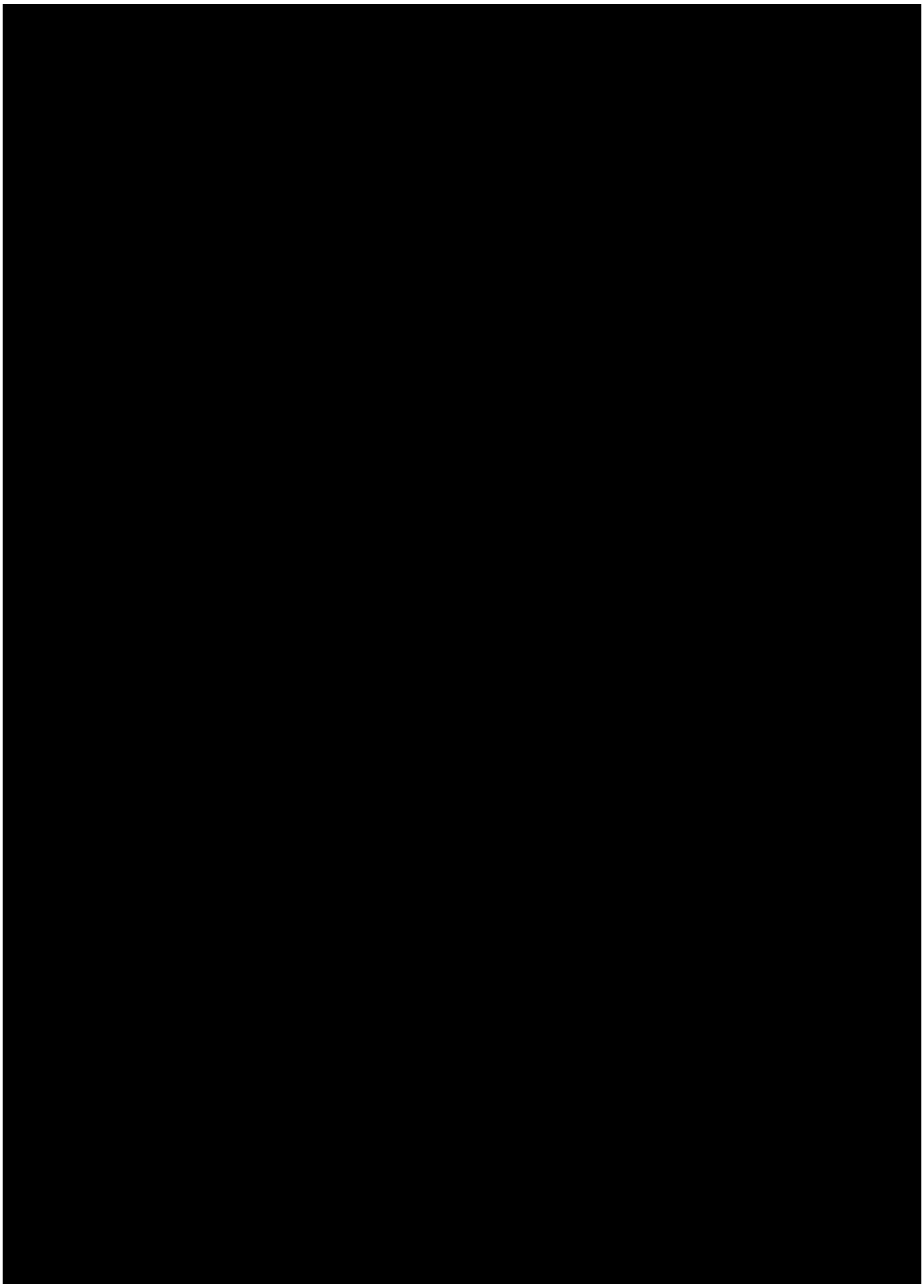
Technical drawings of the Bruma Lake project



Prepared by Chris Brooker and Associates on behalf of City of Johannesburg Municipality.

Appendix 7 Paterson Park technical drawings

Technical drawings of the Paterson Park project



Prepared by Chris Brooker and Associates on behalf of City of Johannesburg Municipality.