Addressing Disease Vectors with Sustainable Drainage Systems in Brazil: The Zika virus in Favelas

By

Rebecca Lewis

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Certificate of Ethical Approval

Applicant:

Rebecca
Lewis

Project Title:

Addressing disease vectors with Sustainable Drainage: the Zika virus in favelas in Brazil

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

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<u>Addressing Disease Vectors with Sustainable Drainage Systems in Brazil: The Zika virus in Favelas</u>

Abstract

As a consequence of urbanisation nearly half of the world's rapidly growing population live in urban areas. The outbreak of Zika virus (ZIKV) in Brazil in August 2015, bought several issues to the forefront of the international health agenda; with researchers establishing cases of neonate microcephaly to be a direct result of maternal ZIKV infection during pregnancy in May 2016. The highest density of ZIKV infections and microcephaly cases were in the northeast and southeast, two of Brazil's most populated areas, which are typically associated with a high prevalence of informal settlements (favelas). These settlements lack suitable infrastructure for effective water management, sanitation and drainage, hence providing suitable breeding environments for the mosquito (*Aedes aegypti)* ZIKV vector.

This research project aims to investigate the potential use of Sustainable Drainage Systems (SuDS) as a method to reduce ZIKV transmission in favelas. Using a mixed-methods approach, both interviews and secondary quantitative data have been accessed to solicit an array of perspectives, including key external stakeholders working with favelas, and favela community members themselves. A series of maps illustrating the epidemiology of ZIKV and microcephaly related to the distribution of favelas have also been produced and discussed. Following analysis and discussion of the key research findings, contrary to the project's initial hypothesis, a conclusive relationship between ZIKV and favelas cannot be established without further additional research. However, other issues were identified relating to housing density, data reporting inaccuracies and lack of adherence to *Aedes aegypti* prevention advice throughout formal and informal (favela) communities. Water and sanitation issues in favelas were also investigated, with findings associated with stormwater, greywater and sewage removal consistent with that of other scholars. Poor management provisions for water supply and solid waste were explicitly raised by participants illustrating the gaps in the current discourse relating to these areas.

Finally, project findings were applied to two novel conceptual frameworks to further understanding and contribute to research in the areas related to the project. Framework (A), identifies the barriers and challenges specific to Rio de Janeiro associated with differences in ZIKV and microcephaly distribution throughout the city. Framework (A) proposes that lack of governance and financial investment are the main contributors to socioeconomic, environmental and health inequalities in Brazil's cities. Secondly Framework (B), proposes that an integrated holistic approach is required to address the distribution of ZIKV and microcephaly. Findings demonstrated that isolated drainage interventions in favelas would be insufficient to reduce ZIKV transmission rates. Therefore, an approach across the whole urban environment is required, to increase public awareness of sanitation and environmental health, improve sanitation infrastructure and provide adequate systems for solid waste management.

Candidate Declaration

I hereby declare that this project is entirely my own work and where I have used the work of others it has been referenced correctly. I can also confirm that the project has been completed in compliance with the University ethics policy and that the information that was supplied with the original ethics document handed in with the project proposal corresponds with the work conducted for the project.

[redacted]

Rebecca Lewis

Acknowledgements

To say the MRes process and completion of this thesis has been smooth would be a lie, in truth it has felt like I've been running several marathons simultaneously from the start to the final submission. To finally be at the end is something I am immensely relieved and proud of and would not have been achieved without the ongoing love and support of my friends, family and supervisory team.

To Hazel Swift & Dr Frank Warwick, thank you for continually believing in me despite the many walls I built to tell myself I couldn't do it. For the many cups of coffee, ongoing encouragement, and an ear to listen when I needed it.

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And finally, to my family. Thank you for putting up with another thing to worry about this year. Only another 4 years until the next thesis is due for submission; here's hoping 2023 won't be quite as eventful.

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List of Abbreviations

DDT Dichlorodiphenyltrichlorethane

GDP Gross Domestic Product

NGOs Non-Governmental Organisations

PPS Permeable Pavement System

SIDS Small Island Developing States

SuDS Sustainable Drainage Systems

UK United Kingdom

UPP Unidade de Polícia Pacificadora (Police Pacification Units**)**

USA United States of America

WHO World Health Organization

ZIKV Zika virus

1.0 Introduction

This chapter details the background areas of study related to the themes of the research. The aim of the project: *to identify the potential for use of Sustainable Drainage Systems (SuDS) as a method to reduce Zika virus (ZIKV) transmission in favelas* is outlined alongside each objective to achieve the aim. Finally, an overview of the thesis structure is provided.

1.1 Background

It is currently estimated that 54% of the world's population live in urban areas (UNHABITAT 2016:2), by 2050 this figure is expected to rise to 70% (UNHABITAT 2017:3). As a result of this rapid urbanisation and population growth, many cities worldwide now face an additional number of issues that place significant pressure on government planning agendas and budgets in the areas of, housing, public health, infrastructure, climate change and poverty (UNHABITAT 2016).

Associated with these issues are increasing numbers of illegal informal settlements in cities, particularly in low and middle-income countries worldwide. In the continents of Africa, Asia and Latin America, 30% of urban populations live in informal settlements on the peripheries of cities (UNHABITAT 2016:14). Furthermore, inadequate provisions of potable water, sanitation, housing and electricity, prevent these communities from having a dignified quality of life. In 2016, the United Nations identified that 844 million people worldwide lacked access to safe drinking water, 2.3 billion people lacked infrastructure for basic sanitation, and 4.5 billion people lacked the facilities to safely manage the disposal of raw sewage; contributing to widespread inequality and poverty in low and middle income-countries – with those living in informal settlements suffering the most (UNDP 2019).

Currently 80% of illness and disease in low-income countries is attributed to water-related issues caused by population growth, increasing demand for water, and climate change (Batterman *et al.* 2009:123). One of the major water-related challenges is that of mosquito-vectors, which account for more than 700,000 deaths globally every year; the highest areas of concern are countries situated in tropical and subtropical regions, where mosquito transmitted diseases such as, dengue, Malaria, and yellow fever negatively impact the poorest populations living with inadequate water and sanitation conditions (WHO 2019).

Furthermore, rising global temperatures, urbanisation, environmental degradation and poverty have enabled mosquito-vectors to establish disease epidemics in new geographical locations and cities worldwide (Aguiar *et al.* 2018; Wilson, Davies and Lindsay 2019).

1.1.1 Research Gap

Whilst conventional vector prevention methods such as insecticide and larvicide are acknowledged to address mosquito-vectors at small-scale localised levels, due to increasing urbanisation and rapid population growth, more wide-scale intersectoral approaches are required, that contribute towards sustainable vector control in the long term (Lindsay *et al.* 2017). The current consensus of a small number of scholars is that improvements in the built environment would contribute a sustainable solution that reduces the abundance of mosquito habitats, as well as addresses the aims of the UN Sustainable Development Goals (Charlesworth *et al.* 2017; Lindsay *et al.* 2017; Wilson, Davies and Lindsay 2019; UNDP 2019). Suggested improvements include, changing patterns of housing design and characteristics, screening of doors and windows, preventing accumulation of water in open areas and providing reliable piped water supplies (Wilson, Davies and Lindsay 2019:53).

1.1.2 Contribution to Knowledge

In order to address these gaps and contribute to further knowledge in these areas, this thesis will evaluate the context of these themes and issues in relation to the 2015-2017 Zika virus epidemic in Brazil.

As a result of the high number of cases reported in Brazil in 2015, a national health emergency was declared by the government (November 2015). This was followed in February 2015 by the World Health Organization (WHO) declaring an international health emergency, due to the rapid spread of the ZIKV into other Latin American countries (see figure 1-1); and the confirmation of ZIKV causing microcephaly in neonates (a condition leading to abnormally small head size and other cognitive impairments). These reasons led to the Zika virus focusing the attention and concern of global health agendas (Lowe *et al.* 2018).

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Figure 1-1: Distribution of confirmed cases of Zika virus per 100,000 population in Latin America (Ikejezie *et al.* 2017:330)

A recent study (Brady *et al.* 2019:12), suggested that 8.5 million symptomatic cases of ZIKV occurred between January 2015 and May 2017 in Brazil. The highest number of Zika virus and microcephaly cases were reported in the Northeast and Southeast (Proenca-Modena *et al.* 2018). However, as 94% of the total Zika virus cases from the epidemic were attributed to the Northeast; published studies have focused on investigating the virus in the Brazilian states of Ceará, Penambuco and Rio Grande do Norte. Therefore, as less research acknowledges the distribution and concentration of ZIKV and microcephaly in the Southeast (to include São Paulo and Rio de Janeiro), this provides a novel basis in which to frame the context and aim of this research.

Rio de Janeiro (Brazil) is well placed as a study location with regards to mosquito-borne disease. Since 1986, Rio de Janeiro has experienced several widespread Dengue epidemics (Heringer *et al.* 2017), and in 2015 the city experienced high cases of both Zika and chikungunya – both virus' that had previously been isolated to other urban areas of the country. With the Olympic games being held in 2016, the city was the focus of media and government campaigns promoting a reduction in *Aedes aegypti* (Arbex *et al.* 2016). Campaigns such as *'Zika Zero'* and *'60 million people are stronger than a mosquito'* were implemented by the Brazilian government, with the president at the time Dilma Rousseff participating in a national Zika prevention day, with 200,000 soldiers inspecting homes and carrying out widespread fogging activities (Brum 2016), illustrated in figure 1-2.

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Figure 1-2: Government officials carrying out fogging inside and outside 'at-risk' homes (Payton 2016)

As the city was at the forefront of these activities and substantial public health investment, this research project is interested in looking retrospectively to identify why high numbers of Zika and microcephaly cases prevailed, despite interventions. Furthermore, at the start of this research project, Rodrigues *et al.* (2018) published a paper focusing specifically on the risk factors associated with new Zika and chikungunya outbreaks in Rio de Janeiro. However, when the authors tried to correlate the distribution of Zika/dengue/chikungunya with risk factors relating to inadequate water supply, sanitation and drainage their results proved inconclusive; thus, highlighting the need for additional data and research to be undertaken focusing on mosquito-borne disease in Rio de Janeiro.

1.2 Aims & Objectives

In the context of the background provided, the following research aim has been identified. To achieve the aim, three objectives have been established.

Aim: To identify the potential for use of SuDS as a method to reduce ZIKV transmission in favelas.

Objectives:

1) To identify is there is a connection between ZIKV and favelas.
2) To investigate current water management issues in favelas.
3) To evaluate the feasibility of SuDS approaches in favelas.

1.3 Structure of the thesis

The thesis is arranged into the following chapters and sub-chapters:

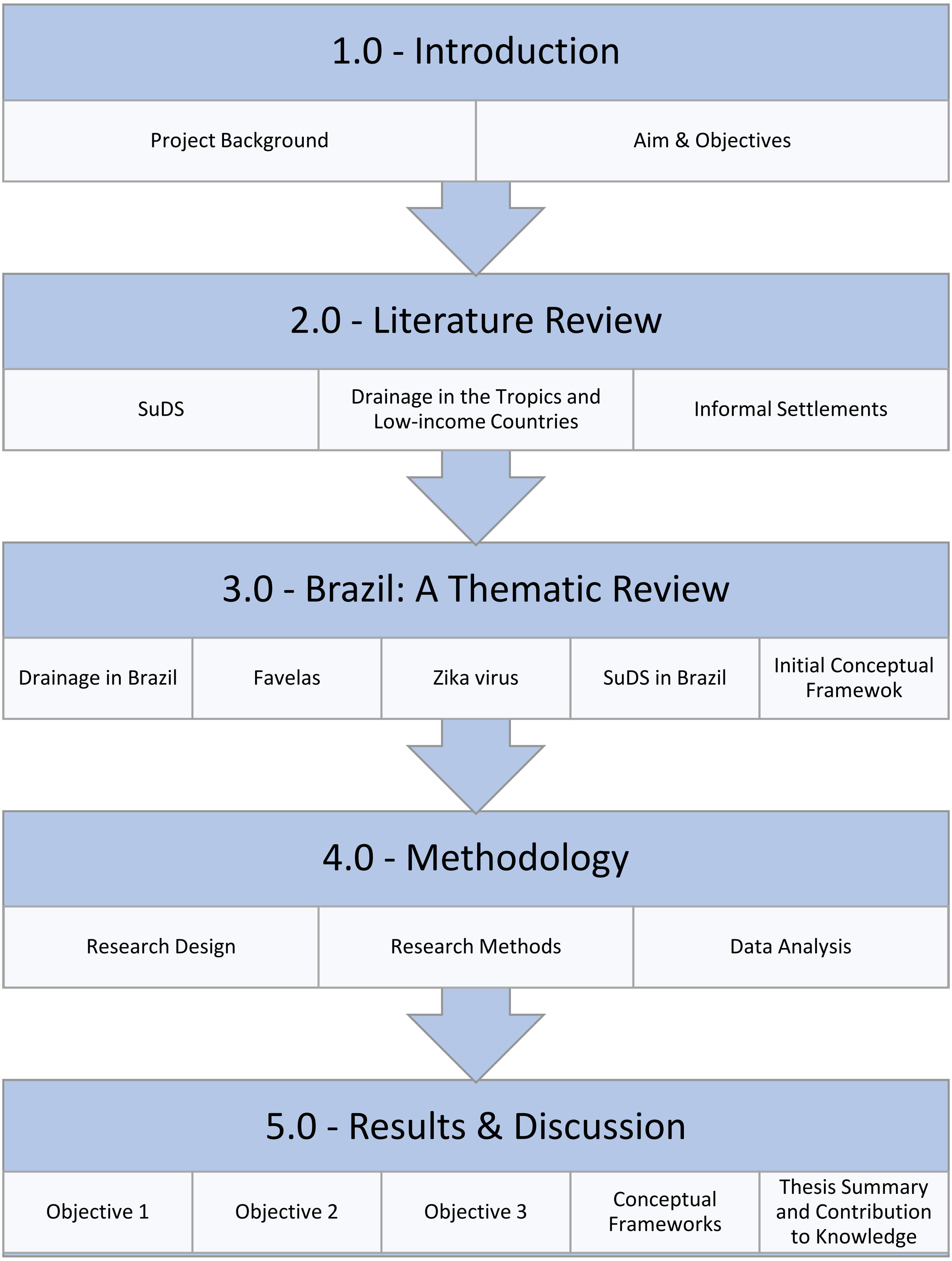

Figure 1-3: Thesis Structure

The contents of each chapter can be summarised as follows:

- Chapter 1: Introduction. Provides the background and context of the research that has been conducted and outlines the project aim and objectives;
- Chapter 2: Literature Review. Explores and examines relevant literature related to the concepts of sustainable drainage, drainage in tropical low-Income countries and informal settlements. Identifying the gaps in the literature to apply these concepts to the context of the research project.
- Chapter 3: Brazil: A thematic review. Applies findings from the literature review to Brazil's urban areas and identifies the major challenges related to drainage provisions, favelas, Zika virus and the implementation of SuDS in Brazil. Presents and explains an initial conceptual framework combining the concepts and context outlined in Chapters 2 and 3, to synthesise understanding.
- Chapter 4: Methodology. Outlines the research approach and design, as well as methods for data collection and analysis to generate results.
- Chapter 5: Results and Discussion. Integrates the results and discussion to outline and examine the findings of the project related to existing discourse, alongside novel contributions.

2.0 Literature Review

2.1 Introduction

The aim of the chapter is to synthesise current literature in the three conceptual areas of the research project – SuDS (2.2), urban drainage approaches in low-income countries (2.4) and informal settlements (2.5). Relevant literature underpinning the current extent of SuDS approaches and methods in both temperature and tropical environments are presented, with the underlying intention to understand and adapt climate specific SuDS parameters in the context of Brazil's favelas (2.3). In addition, urban water management challenges and techniques in cities of low-income countries will be outlined and critiqued, with a focus on the potential to apply new and innovative methods and approaches in the urban environment (2.5.2, 2.5.3). Finally, current global examples of community-designed drainage systems operating in informal settlements will be illustrated with their implications and key design features discussed (2.5.4). As well as natural and practical considerations, social concepts such as community engagement, participation and ownership will also be outlined; establishing a basis of literature in which to address objective three: *To evaluate the feasibility of SuDS approaches in favelas*.

Having synthesised the key concepts, challenges and actions, the literature review will guide Chapter 3, in providing a basis to contextualise current understanding and approaches regarding surface water management in Brazil's favelas (objective two). As well as discussing the potential approaches and SuDS techniques suitable for implementation in the climate and context of Brazil's favelas (objective three).

2.2 Sustainable Drainage Systems

Established as an alternative method to conventional pipe-based drainage approaches, Sustainable Drainage Systems (SuDS) are designed to mitigate ongoing problems caused by surface water flooding and the conveyance of stormwater in the urban environment; by mimicking the natural drainage environment (Charlesworth, Warwick and Lashford 2016). SuDS is a multi-faceted approach that encourages the infiltration and detention of surface runoff at the point of origin, in turn complementing and enhancing the capacity of conventional drainage systems and preventing unnecessary discharge of accumulated surface or stormwater into watercourses (Charlesworth, Harker and Rickard 2003; Charlesworth 2010; Charlesworth and Booth 2017; Coupe *et al.* 2014; Jones and Macdonald 2007; Woods Ballard *et al.* 2015).

As presented in table 2-1, there are several different SuDS devices available to perform varying functions. Broadly speaking there are two main types of SuDS approaches, hard or soft. Hard SuDS comprise devices such as pervious paving, whereas soft SuDS include rain gardens, wetlands or vegetated devices. Despite this distinction, the most successful application of SuDS often combines several devices to create a smaller drainage sub-catchment, in which water passes through each device to create a SuDS treatment train (Charlesworth, Warwick and Lashford 2016; Coupe *et al.* 2014; Woods Ballard *et al.* 2015).

Table 2-1: An overview of SuDS devices and functions
(Charlesworth, Warwick and Lashford 2016:2)

SuDS Device Grouping	**Function**	**Example Devices**
Source Control	Slowdown, store and treat run off at the location close to where rain has fallen. Water can be released gradually or utilised for non-potable purposes.	Green Roof; Rainwater harvesting; Pervious paving; Sub-surface storage; Trees; Rain garden; Disconnected downpipe
Infiltration	Runoff storage and infiltration into the ground to recharge groundwater.	Soakaway; Infiltration basins; Infiltration trench
Detention and Retention	Basins with temporary or permanent storage or runoff. Removal of pollutants to improve water quality.	Detention basin; Retention basin; Pond; Wetland
Filtration	Slow down flow and treat runoff to remove pollutants.	Sand filter; Filter strip; Filter trench; Bioretention device
Conveyance	Channels that convey runoff. Can also store and infiltrate water into the ground.	Swale ; Rill

There are numerous benefits of using SuDS alongside or separate to conventional drainage, including reducing stormwater loading and peak flows and the removal of diffuse pollution (Jones and Macdonald 2007). These benefits were initially expressed in the 'SuDS triangle' (Charlesworth 2010), however a more up to date version is now utilised (Woods -Ballard *et al.* 2015) which expresses these benefits as a square (see Figure 2-1). In addition to the original components of the 'SuDS triangle' (water quantity, water quality and amenity), the model now considers biodiversity to be an additional benefit of SuDS approaches. Although biodiversity was an original component of *amenity*, the 'SuDS square' (2015) now emphasises the equal importance of both amenity and biodiversity highlighting the positive impact of SuDS systems on both people and nature.

Figure 2-1: The SuDS square (after Woods Ballard *et al.* 2015:6)

Despite SuDS contributing to an improvement in the natural environment and quality of life for people living in urban areas (Charlesworth 2010), the uses and benefits of SuDS are often misunderstood by local communities; with local authorities in the UK often facing opposition to their implementation – either as schemes associated with new housing developments, or to individual proposals for retrofitting SuDS into existing areas. As such, it is essential to provide communities with enhanced understanding about the functions of SuDS devices and their wider impact on catchment drainage - to gain community buy-in from the outset (Everett 2017).

As the focus of the research project is to identify the challenges of attaining effective water management systems and the potential for implementation of SuDS devices in favelas, the subsequent sections will focus on SuDS project examples and drainage approaches implemented in locations with conditions similar to Brazil. The following key factors are included and discussed: climate (section 2.3), level of development (section 2.4) and the specifics of informal settlement communities (section 2.5).

2.3 Drainage in the tropics

Owing to ongoing challenges posed by increased precipitation, prevalence of impermeable surfaces and inadequate planning regulations, many cities in the tropics have identified a need for new and innovative approaches to complement existing piped infrastructure systems. As such, methods that combine both conventional drainage systems with SuDS devices to reduce problems caused by inadequate hydraulic capacity, the frequency of urban flooding events and potential options for greywater disposal and reuse are particularly relevant (Parkinson 2003; Zevenbergen and Pathirana 2018). In addition to the benefits already represented in the SuDS square (figure 2-1), SuDS devices already implemented in the tropics, have proven to be effective at mitigating the urban heat island effect (see the US Virgin Islands, 2.3.1), as well as managing and adapting to extremes in weather and climate (Charlesworth and Mezue 2017).

Across high-income countries like the United Kingdom (UK) and United States of America (USA) water management infrastructure is an integrated system, whereby services are consistently provided to service-users, with relevant institutional planning and investment that ensures a regulated system is delivered by utility companies (Larsen *et al.* 2016). Nevertheless, efforts from local authorities and regulatory bodies, are often limited by resource restrictions, availability of public funds, environmental challenges and significant uncertainty surrounding future changes to climate in their locality (Zevenbergen and Pathirana 2018). Despite ongoing efforts to upgrade, maintain and connect new households to sewerage networks, it is estimated that only 36% of African and 44% of Asian populations will be connected to a piped sewer network by 2050 (Drecht *et al.* 2009) - illustrating the need for enhanced planning and consideration of household and stormwater management throughout tropical regions.

For SuDS to be effective in tropical environments, there are several factors that must be considered and adapted when designing SuDS devices (table 2-2).

Table 2-2: A summary of SuDS implementation challenges in tropical environments. (Charlesworth and Mezue 2017; Maksimovic, Todorovic and Braga 1993; de Silveira, Goldenfum and Fendrich 2001).

Factor	Challenges	Impact on SuDS Devices
Rainfall intensity	High volumes of precipitation over a short time period – increases erosion and transportation of sediment.	Hydraulic loads have high sediment composition – potential blocking of devices. Multiple pollutants entering devices.
Volume of Rainfall	Daily rainfall during rainy season. High loading in storm sewers.	Needs capacity for high loading volumes. Infiltration/detention/filtration necessary. High stormwater quantity, increased pollutant quantity.
Temperature	Annual temperatures of 18°C and higher. Potential for water-borne disease, and disease vectors. Higher evaporation rates.	Efficiency of treatment/removal capacity necessary. Sub-surface infiltration/detention devices should be considered.
Population Density	Rapid urbanisation due to poor planning control, increase of impermeable surface use. Greater household demand and consumption of water.	High stormwater and wastewater volumes. Higher levels of urban pollution and contaminants entering SuDS devices.

2.3.1 Examples of SuDS worldwide

Although the majority of successfully implemented SuDS systems are in the UK, USA, Australia and Europe, numerous attempts have been made to implement SuDS-like systems worldwide; in both tropical and sub-tropical cities. The following section will outline successful SuDS examples from China, Malaysia and The US Virgin Islands and the different stakeholders involved.

Malaysia

Designed specifically to address stormwater management in tropical climates (Ghani *et al.* 2008), BIOECODS are similar in operation to Swales, as a SuDS conveyance device (see Table 2-1). The main difference between BIOECODS and Swales is that accumulated runoff is stored and conveyed sub-surface, preventing surface water ponding during intense rainfall events and reducing opportunities for vector breeding (Charlesworth and Mezue 2017). Typically, BIOECODS are designed using native vegetation and comprise three main SuDS device elements: ecological swales, biofiltration storage and ecological ponds. Each device works in series to form a SuDS treatment train (see Figure 2-2), that captures runoff at source and reduces the hydraulic volume and pollutants from stormwater loads – with conveyed stormwater discharged back into the surrounding catchment area or into recreational ponds utilised for public leisure activities (Ghani *et al.* 2008).

Figure 2.2: Outline of SuDS train adopted in Kinta District, Central Malaysia (Ghani *et al.* 2008:8).

The US Virgin Islands

As Small Island Developing States (SIDS) in the US Virgin Islands, St Croix, St Thomas and St John (see Figure 2-3) experience ongoing problems due to excess stormwater – with the highest number of issues occurring during the annual tropical storm season (June – November).

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Figure 2-3: The British and US Virgin Islands (VInow 2019)

For relatively small isolated islands, the damage caused by hurricanes and flood events results in significant economic and livelihood devastation, alongside impacting the tourism and business sectors severely (UN-OHRLLS 2009). Owing to ongoing coastal inundation (due to sea level rise) coupled with frequent surface water flooding, efficient prior planning and infrastructure is vital in SIDS such as the Virgin Islands (UNHABITAT 2015).

In St Croix, St Thomas and St John the impact of these issues has encouraged the implementation of different SuDS devices across the islands, to support conventional drainage systems and provide added hydraulic capacity and efficiency that current piped drainage infrastructure lacks. SuDS devices utilised include permeable pavement systems (PPS), green roofs, green pavers and vegetated bio-swales (Monrose and Tota-Maharaj 2018; NOAA 2014). Whilst proving efficient at managing regular precipitation events, the devices have also shown a reduction in air temperatures, and a minimisation in the urban heat island effect - due to a decrease in the radiating capacity of concrete and asphalt surfaces (US EPA 2008).

China

Unlike the previous examples, China experiences problems caused by both excess and scarcity of water – with flooding attributed as China's most destructive natural hazard (Jiang, Zevenbergen and Fu 2017). To resolve this, China has implemented 30 nationwide 'Sponge Cities', utilising nature-based drainage methods that infiltrate accumulated surface water, for either groundwater recharge, or for retention, storage and reuse – therefore responding to both water scenarios in parallel (Roxburgh 2017; Zevenbergen, Fu and Pathirana 2018). Whilst not dissimilar to the SuDS concept, the 'Sponge City' approach also takes advantage of the warm humid climate and creates additional opportunities for restorative ecological processes as well as hydrological restoration. This is achieved by incorporating vegetated drainage devices that enhance opportunities for evapotranspiration, treatment and infiltration of captured surface water (see Figure 2-4a and 2-4b) (Zevenbergen, Fu and Pathirana 2018). Unlike SuDS, the 'Sponge City' concept is a city-wide system and therefore is only achievable by top-down policy, implementation and funding – whereas SuDS schemes in the US and UK generally operate at a much lower level (catchment) with less local authority involvement (Lashford *et al.* 2019).

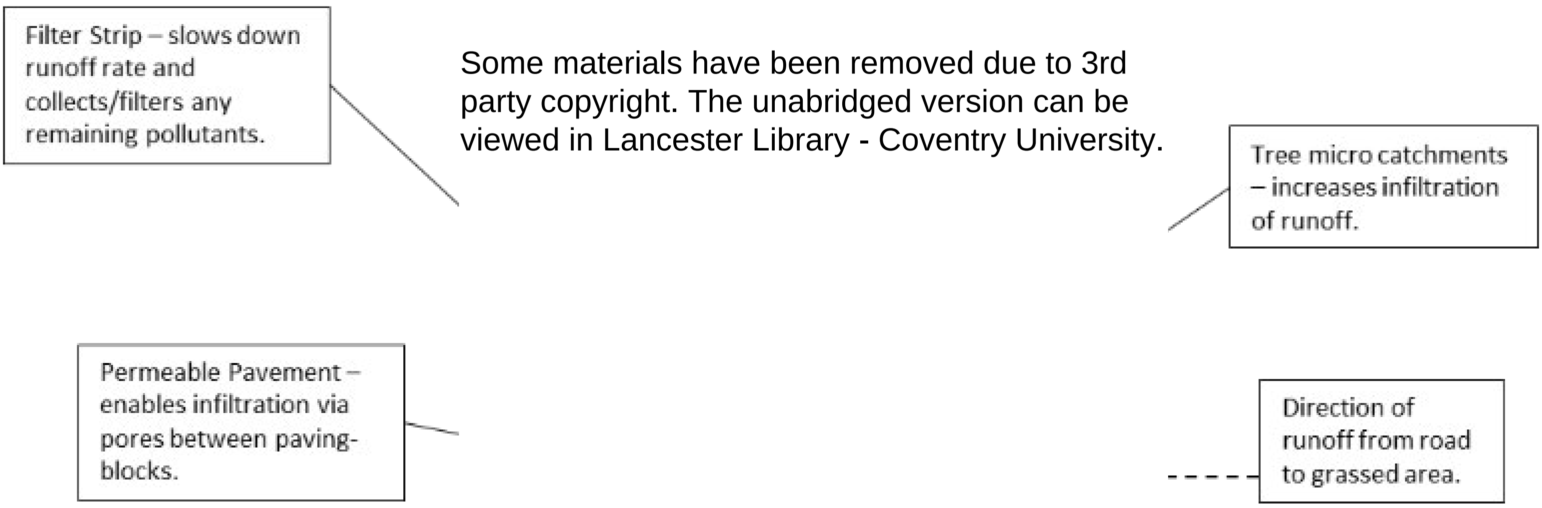

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Figure 2-4a: PPS in Lingang District – Southern Shanghai, China (Roxburgh 2017).

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Bridges, paths and recreation areas for leisure use and to increase green urban areas.

Constructed wetland – designed for full or partial inundation during storm events

Vegetated devices appropriate for partial or full inundation using wetland plant species.

Figure 2-4b: Yanweizhou Wetland and Leisure Park, Jinhua City – Eastern China (AHBELAB n.d.).

2.4 Drainage in low-income cities

For this research project UNCTAD's (2014) country classification will be followed, whereby countries are grouped into the categories high-income, middle-income and low-income, based upon Gross National Income (GNI) per capita. However, in the case of low-income countries, GNI is amalgamated with data from the human assets index and economic vulnerability indicators (UNCTAD 2014:144). According to the World Bank (2019), high-income countries are classified at GNI per capita of US$12,056 compared to US$995 for low-income countries.

Owing to international commitments to achieve the United Nation's Sustainable Development Goals (SDGs), there has been growing interest in urban water management (Larsen *et al.* 2016) - with specific emphasis on addressing SDG6: 'Clean water and sanitation' (UNDP 2019). However, in both the SDGs and the United Nations Convention of Human Rights, drainage and wastewater management is not explicitly mentioned despite the overarching emphasis being on the 'right to *access* clean water and sanitation' (Charlesworth *et al.* 2017). Only through efficient water management infrastructure and institutional systems can the term *access* be truly achieved by policymakers; and realised by communities lacking these services. In addition, whilst also addressing SDG6, providing correct drainage and wastewater disposal infrastructure should ensure: a reduction in vectors (such as mosquitoes, flies and rats) and water-borne disease, effective management of water quality, and a reduction in flooding events and climate change impacts (Ajibade and Tota-Maharaj

2018). Hence despite not being at the forefront of the United Nations water agenda, there is a growing consensus amongst academics, engineers, scientists and practitioners that SuDS are a viable option for cities in low-income countries (Armitage 2011; Charlesworth *et al.* 2017; Reed 2004).

Although SuDS in the context of low-income cities seems to be a logical long-term approach to address existing and future drainage challenges, there is still significant work to be done to encourage inclusion in global and national agendas (Charlesworth and Mezue 2017). Many low-income cities throughout the world are faced with out-of-date and inadequate infrastructure, owing to rapid urbanisation (Mguni, Herslund and Jensen 2016). Furthermore, fluctuations in governance and lacking institutional capacity has meant that many cities have expanded in an uncontrolled manner with no regard to urban planning and policy regulations, leading to widespread settlement on unsuitable land; such as flood plains, wetlands and steep hill slopes (see 2.5.1) (Lindell 2008; UN HABITAT 2011).

2.4.1 Benefits of using SuDS in the cities of low-income countries

One of the main benefits of SuDS when compared to piped-drainage systems, is the versatility of SuDS infrastructure; as it can be retrofitted alongside existing infrastructure to enhance capacity and can also be designed into new locations throughout cities (Swilling *et al.* 2013). This is an extremely desirable design feature owing to the high prevalence of informal settlements on the peripheries of many cities (such as; Dar es Salaam (Tanzania), Nairobi (Kenya), Rio de Janeiro (Brazil), Mumbai (India) etc.) many of which have no existing connections to formal water management infrastructure (Pastore 2015).

In Dar es Salaam, detention ponds and river bank stabilisation measures have been implemented as part of a 'Metropolitan Development Project'; aimed at controlling and managing stormwater runoff in upstream areas during periods of heavy precipitation, as well as reducing the frequency of fluvial flooding (Bald 2014). Although this is a positive example of a local government implemented SuDS project in a low-income context, there is still significant work to be done to encourage replication in other cities and locations in tropical regions.

One of the major hindrances to the success of future SuDS implementation, and existing conventional drainage methods is the prevalence of uncollected solid waste throughout cities. In many locations, day-to-day drainage issues are aggravated by solid waste that blocks drains, enters pipes and ditches, and subsequently reduces hydraulic capacity (Parkinson 2003). For future drainage efforts to be effective, reliable solid waste removal and wastewater disposal need to become integrated at the policy level to ensure any newly implemented systems can work efficiently and correctly (Mguni, Herslund and Jensen 2016).

Following studies by Bryld (2003) and Simon (2012), it has been suggested that one approach to support implementation of SuDS in low-income cities is to encourage a reversion in current planning policy, which renders the use of urban green spaces by low-income communities for agriculture as illegal. There are numerous reasons why these practices should be encouraged; firstly, in cities such as Kampala (Uganda) and Dar es Salaam (Tanzania) urban agricultural practice supply 50% of the food consumed across the whole city (Bryld 2003:79). Furthermore, alongside these benefits to food security and the local economy, maintaining and optimising urban green space is an effective method of natural flood management; that is, to provide flood buffer zones that enhance the infiltration of stormwater during heavy rainfall events. Similarly, in peripheral vegetated areas not utilised for crops, additional SuDS devices such as ponds or BIOECODS (see 2.3.1 - Malaysia) could be implemented, creating additional capacity for surface water management and to enhance biodiversity (de Zeeuw *et al.* 2011).

2.4.2 Use of SuDS in refugee camps

As well as being a new method utilised in urban areas of low-income countries, SuDS approaches have recently been applied as a method to improve poor drainage in refugee camps – with exemplary cases located in the Kurdistan Region of Iraq, Bangladesh, Kenya and South Sudan (Ajibade and Tota-Maharaj 2018; Arup 2019; Charlesworth *et al.* 2017).

Owing to the locations of refugee camps, surface water flooding is a constant challenge (see figure 2-5). Furthermore, with the number of refugees worldwide continually increasing there is a constant challenge to maintain camp infrastructure to respond to increasing population pressures from the community already housed inside camps, and from newly arriving populations (UNHCR 2017). Many of the problems associated with surface water arise from greywater and stormwater ponding, the proliferation of disease vectors (e.g. mosquitoes) and the mixing of stormwater and potable water, increasing opportunity for water-borne disease such as typhoid and cholera (Ajibade *et al.* 2016).

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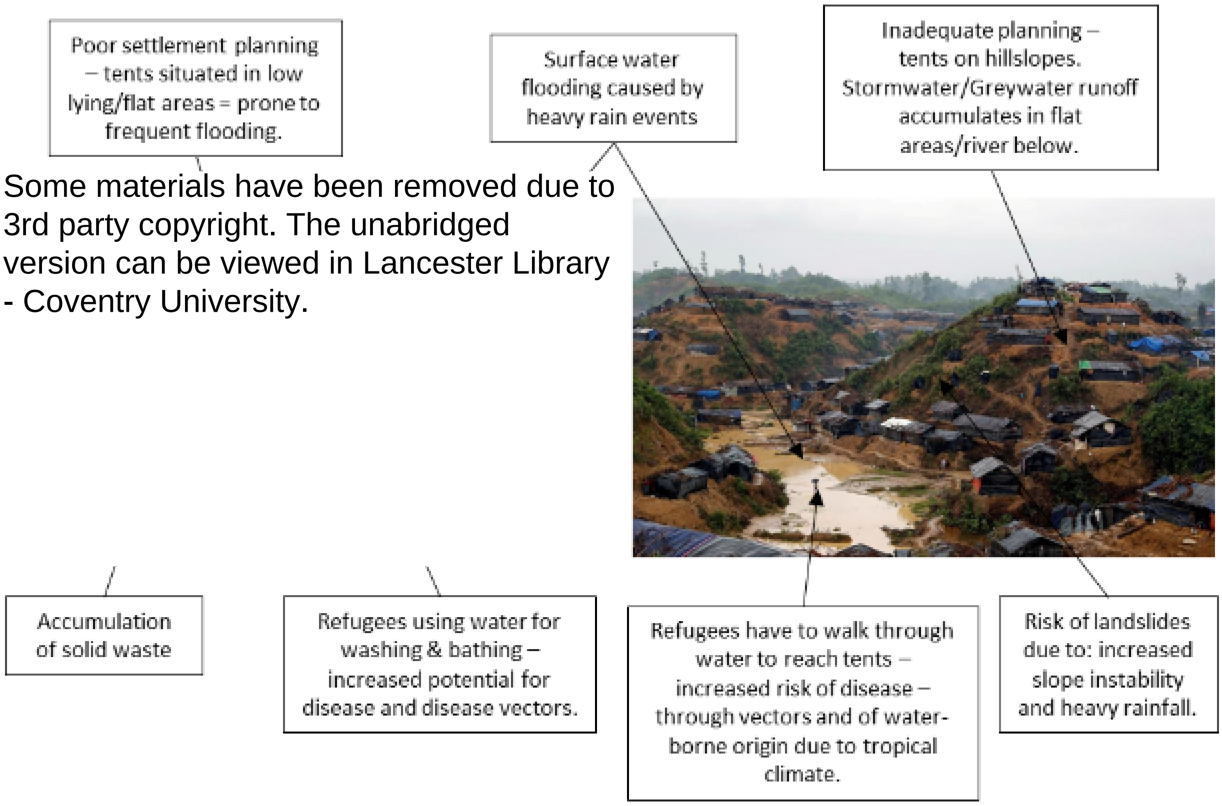

Figure 2-5: Surface water management issues in refugee camps
(L) 2008 flooding in Al Tanf a Palestinian refugee settlement in Syria (UNHCR 2015) and (R) A Rohingya refugee camp in Cox's Bazaar, Bangladesh (Human Rights Watch 2018).

All the challenges mentioned above create ongoing issues for those living and managing Bentiu camp (see figure 2-6):

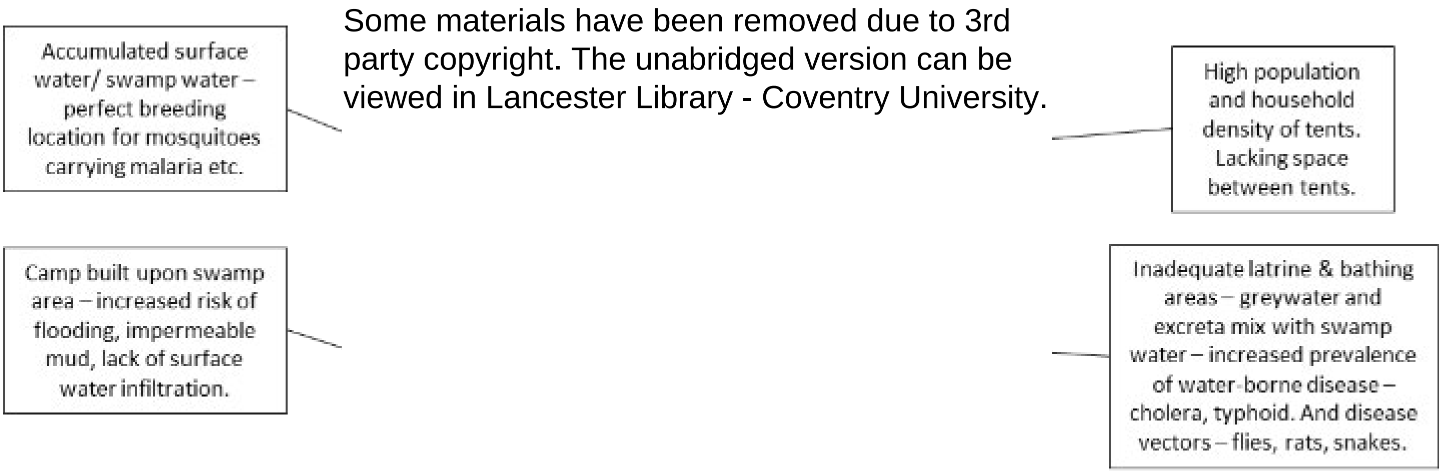

Figure 2-6: Bentiu Camp (Floodlist 2019)

Bentiu Refugee camp situated in the north of South Sudan, currently houses approximately 113,000 refugees across a swampland site of 1.6 million m^2 (400 acres) (Reliefweb 2018). Following severe flooding in 2014, levees and drainage canals (hard engineering approaches) were constructed on the perimeter of the camp to pump excess water away from dwellings. However, due to expensive pumping and installation costs, these methods cannot be considered truly sustainable (Ajibade *et al.* 2016). Ajibade and Tota-Maharaj (2018) propose that implementation of filter drains throughout the camp, and a series of wetland ponds on the exterior would act as a more efficient method for stormwater and greywater management. An additional benefit of this approach is that each device they propose has further treatment capabilities, therefore whilst being efficient at removing excess surface water, the devices will also enable additional capacity for treatment and water storage and thus further opportunities for greywater reuse in the camp.

2.5 Informal Settlements

2.5.1 Defining informal settlements

Although the phrase 'informal settlement' may appear homogenous, informal settlements are instead rather contrasting in terms of their layout and cultural origins worldwide. Similarly, many different synonyms are utilised in different regions when referring to informal settlements (see figure 2-7).

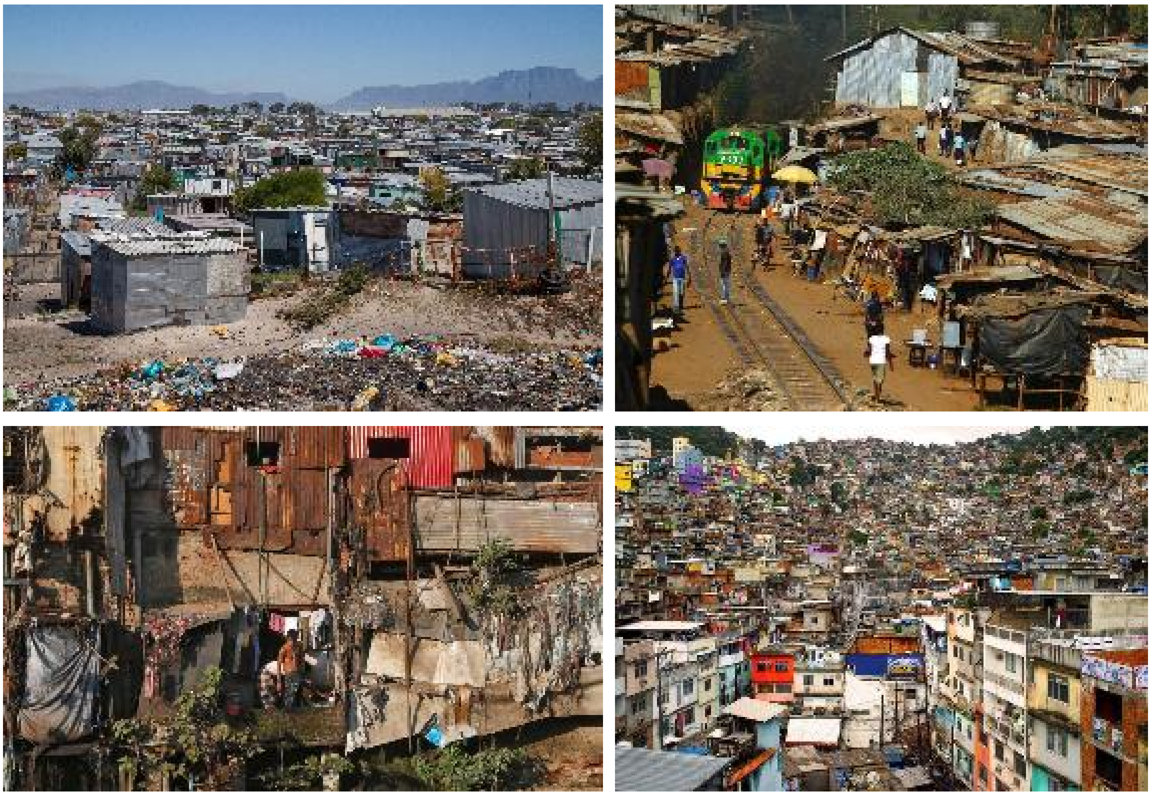

Figure 2.7: Examples of informal Settlements

Top: (L) Marikana Shanty Town – Cape Town (South Africa) (Groundup 2017) & (R) Kibera Slum – Nairobi (Kenya) (The Star 2018). Bottom: (L) Dharavi Slum – Mumbai (India)(ABC 2017) & (R) Rochina Favela – Rio de Janeiro (Brazil) (Favelatour n.d.)

Typically, informal settlements are situated on unused wasteland that is deemed inappropriate for formal housing development, with dwellings built from reclaimed construction materials and scavenged scrap; such as bricks, corrugated iron and cardboard (Cities Alliance 2012; Jiusto and Kenney 2016; Tucci 2001; Wekesa, Steyn and Otieno 2011). Whilst lifestyle and quality of life varies, it is universally agreed that most informal settlements are rooted in the socio-economic inequalities present in the urban environment (David *et al.*

2007). As such, prohibited access to power and resources inhibit the rights of people living in these communities (Mitlin and Satterthwaite 2004). As defined by Huchzermeyer and Karam (2006), informal settlements are regarded as settlements of the urban poor established by unauthorised land occupation, as such for clarity this is the definition that will be adopted throughout this research project.

2.5.2 Drainage challenges in informal settlements

In informal settlements located on the periphery of cities, the problems of inadequate drainage are exacerbated even further. Between 1990 and 2014, there was a 28% increase in informal settlement populations, rising from 689 million to 881 million people (UN HABITAT 2011). Current estimates suggest that more than a billion people worldwide live in informal settlements (UN HABITAT 2016), with many settlements lacking the necessary infrastructure for solid waste disposal, potable water and removal of sewage (Huchzermeyer 2004; Parkinson 2003). The locations where these settlements are often situated further adds to drainage challenges, with communities choosing to illegally-occupy steep mountain sides, riverbanks, and flood plains – all with their own associated hydrological challenges (Satterthwaite 2011). Despite this, the advantages of living closer to employment opportunities overrule the realities of living in a poorly drained location, and as such, many communities continue to settle in precarious locations for this reason (Parkinson 2003).

There are many water management issues that arise in informal settlements, with major contributors being sewage, greywater and solid waste (Katukiza *et al.* 2012). Therefore, with no proper disposal infrastructure or services, wastewater is often discharged into improvised open drainage channels, nearby watercourses or thrown into the street - creating puddles and contributing to significant environmental health issues (Parkinson, Tayler and Mark 2007). These common disposal practices result in reduced groundwater quality, owing to contamination originating from organic matter, micro-pollutants, and pathogens (Clara *et al.* 2005; Mara *et al.* 2007). Furthermore, in settlements where communities practice open defecation or excreta disposal in uncovered drainage channels, there is a significant risk of water-borne diseases such as cholera, dysentery and typhoid (Jiusto and Kenney 2016; Patterson *et al.* 2005).

Accounting for an average of 65-75% of household water consumption, the disposal of greywater is an issue for communities in informal settlements. Generated from cooking, laundry and personal hygiene activities, is it common for households to use between 20-30 litres of water per person each day (Eriksson *et al.* 2002, Katukiza *et al.* 2012). Despite cooking and laundry activities not appearing to be direct sources of contamination, it is common to find both *E. coli* (an enteric bacteria) and biodegradable organic matter in water utilised for personal washing and cooking – providing the opportunity for growth of pathogens and detrimental consequences to human health (Christova-Boal *et al.* 1996). Therefore, irrespective of the greywater's original composition, it is toxic within 24 hours of production (WHO 2006). For this reason, greywater is often regarded as being the most polluted variant of surface water (Katukiza *et al.* 2012).

Even when sewage and greywater are correctly disposed of and sanitation infrastructure is provided, there is still a potential risk to human health due to the accumulation of solid waste and pooling of stormwater around the settlement (Katukiza *et al.* 2012). This is particularly evident following intense rainfall events; resulting in runoff composed of accumulated greywater, solid waste and sediment – that once settled attracts disease vectors such as mosquitoes, flies and rats which carry a host of diseases (for example, Lyme Disease, Weil's disease and malaria) (Armitage 2011; Jiusto and Kenney 2016; Larsen *et al.* 2016; Maksimovic and Tejada-Guibert 2001).

2.5.3 Approaches to drainage upgrading in informal settlements

As a necessary step in the reduction of global poverty and disease, the implementation of water, drainage and sanitation infrastructure in informal settlements is a vital step to improve the quality of life for vulnerable urban communities. However, achieving this will not be without challenge, owing to the many secondary factors associated with sewage, greywater and stormwater (Jiusto and Kenney 2016; Mara *et al.* 2007). In addition, there are several issues unique to informal settlements that make the design and construction of infrastructure harder, these include: the density and lack of space between dwellings, proximity to external formal infrastructure, land tenure and lacking willingness of community members to engage with sanitation improvements (David *et al.* 2007; Pegram *et al.* 1999; Katukiza *et al.* 2012). As a result, centralised drainage infrastructure already utilised in urban areas is therefore inadequate for replication in informal settlement environments for these reasons (Imparato and Ruster 2003). Thus, providing an opportunity for application of SuDS devices owing to their scalability and adaptability in different contexts.

Another key factor that needs to be considered is the perceptions and views of the communities, which can work for or against upgrading activities in informal settlements (Adegun 2015; Cities Alliance 2012; Jiusto and Kenney 2016). To counter this impacting negatively, the project and its anticipated outcomes should be developed in partnership with the community - ensuring that the chosen design and its benefits are understood and accepted by both the project initiators and the community (Imparato and Ruster 2003; UNEP 2002). Furthermore, unless institutional measures are in place to ensure regulatory adherence and upkeep of the infrastructure, it is important to consider the long-term sustainability of the solution if it is to be left as the responsibility of the community (Katukiza *et al.* 2012; Pegram *et al.* 1999; Tucci 2001).

Should the upgrading project not be supported by a local authority or regulatory body, it may be necessary to design a scaled-down solution that uses low-cost readily available materials in a more holistic manner; whereby solid waste, wastewater treatment and wastewater disposal all complement each other (David *et al.* 2007). In addition, opportunities for wastewater reuse could also be explored to provide income-generating activities (generation of sellable goods by recycling solid waste) and to produce renewable energy for the community (Katuiza *et al.* 2010; Mara *et al.* 2007). In Nigeria, Reed *et al.* (2013) found that community members had self-initiated the maintenance of formal drainage infrastructure, to solve the problems caused by frequently blocked drains. Community teams would work together and regularly clear the silt and sand blocking the drains; having dried out the sand they then sold it on to construction workers and generated income.

Nonetheless, despite many academic papers promoting community engagement methods, there is minimal literature that outlines how to best apply these methods to informal settlements (Tucci 2001). As such, of the few sanitation projects that have been written about, there is very little analysis as to the success of innovative infrastructure in the long-term; neither is there a critical appraisal of the approaches utilised when engaging with the community (Adegun 2015; Fitchett 2017).

2.5.4 Current wastewater strategies in informal settlements

Resulting from poor governance, inadequate finances and the contention of land illegality, there is a lack of interest from governing authorities to implement projects relating to wastewater management in informal settlements (Larsen *et al.* 2016). Despite this, there are several examples of solutions that informal settlement communities have initiated themselves to manage wastewater problems and increase internal coping strategies (Jiusto and Kenney 2016). Whilst the effectiveness of each solution is yet to be evaluated, it is positive to see a collection of low-cost, local technological approaches being utilised to manage wastewater at a household-level (Jiusto and Kenney 2016; Katukizia *et al.* 2012; Reed 2013).

The largest body of urban drainage literature in informal settlements relates to South Africa (Adegun 2015; Armitage 2011; Armitage *et al.* 2013; Fitchett 2017; Winter 2017). Common to all examples are the materials used for each infrastructure solution, in that they are all locally available materials, such as sand, fruit stones/coconut shells, discarded construction material and old tyres (Jiusto and Kenney 2016; Parkinson 2003; Reed 2013). In both Monwabisi Park and Langrug Settlements (near Stellenbosch, South Africa), residents have designed ad-hoc solutions by building drainage ditches, and erecting steel or wooden flood barriers around the perimeter of their homes (figure 2-8); they have also constructed areas for soakaways to encourage infiltration of surface water and to support groundwater recharge (Jiusto and Kenney 2016).

Figure 2.8: Techniques to manage surface water in South Africa

(L) Sand filled-tyre flood barriers, Monwabisi Park & (M) Corrugated iron and wooden fence flood barriers around shack perimeter, Monwabisi Park (Button *et al.* 2010). (R) Improvised plastic pipe drainage channel between dwellings, Langrug (Harris *et al.* 2011).

Whilst the examples provided demonstrate community-initiated techniques; these approaches predominantly focus on stormwater management. In contrast, Kulabako *et al.* (2009) and Zuma *et al.* (2009) provide examples of activities involving greywater reuse in both Uganda and Grahamstown, South Africa (figure 2-9). Both methods shown in Figure 2-9 are designed for household use, by using locally available materials and to support the reuse of greywater to aid agricultural practices, either integrated with the greywater tower (figure 2-9 (R)) or separate - by using the recycled water to irrigate small home gardens (Katukiza *et al.* 2012).

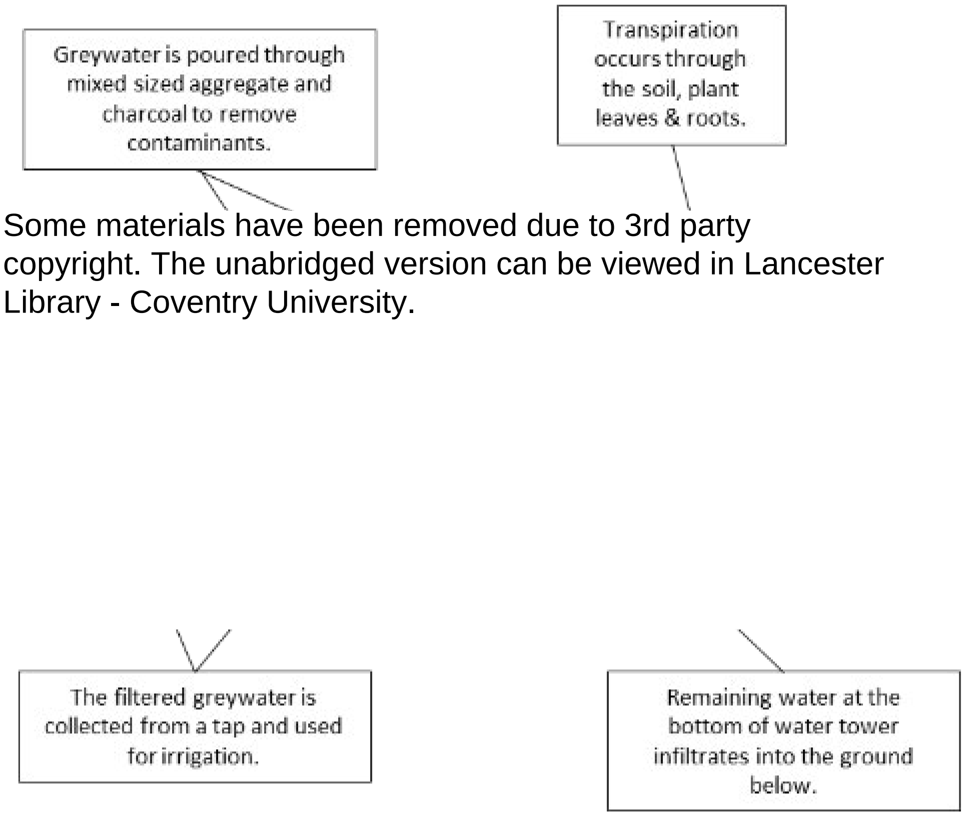

Figure 2-9: (L) Greywater tower (R) Greywater tower used for growing onions and tomatoes (Katukiza *et al.* 2012:975)

The findings are also interesting when reviewing social science studies that account for community perception of surface water management in informal settlements. Studies conducted by both Parkinson (2003) and Stephens, Patanaik and Lewin (1994), identified that day-to-day surface water issues are often not a priority of communities; with many failing to link poor surface water management to other challenges they experience. Despite lacking emphasis on surface water, communities do list 'flooding' as a burden they frequently experience, citing the inconvenience caused in terms of damage to the home (Parkinson

2003). In contrast Stephens, Patanaik and Lewin (1994) found that a community in Indore (India) accepted flooding as a day-to-day part of life, therefore placing greater desire for problem-solving to address low frequency, high impact events instead of daily 'routine' challenges.

As outlined in section 2.5.1, if informal settlements are to be regarded as heterogeneous, then so must the proposed drainage solutions. It is for this reason that whilst the methods and solutions highlighted in section 2.5.4 have been successfully adopted into communities; this may not always be the case in other locations. Furthermore, whilst the versatility amongst the different SuDS devices makes them suitable for use in an informal settlement context (see section 2.1, Table 2-1), long-term effectiveness is dependent on how well the method and its results are presented to the community. Therefore, it is often more effective to support a community to enhance existing techniques and practices to ensures longevity (via community maintenance and operation), rather than designing and implementing a new solution that is not adapted to the specific, social, economic and environmental context (Jiusto and Kenney 2016).

2.6 Conclusion

In conclusion, having thoroughly discussed and considered the scholarly discourse related to the conceptual areas of SuDS, urban drainage approaches in low-income countries and informal settlements, additional scholarly contribution and further research is necessary.

Although high-income countries can design and implement SuDS devices that complement existing drainage systems (section 2.2), in many of the low-income countries discussed in section 2.3, the current drainage infrastructure is either inadequate or completely lacking. Therefore, when coupled with the ongoing challenges caused by climate change, urbanisation and poor planning regulations at a city-wide scale, implementation of SuDS devices as a first step in providing sanitation infrastructure will prove insufficient in addressing these challenges simultaneously. Furthermore, existing examples of SuDs devices implemented in tropical environments (such as: BIOECODS, PPS, swales, and rain gardens) demonstrate that implementation is only possible where urban policy and public-private partnerships work collaboratively, and with the adequate resources and funds to ensure completion (see 2.3.1).

Despite the international development agenda advocating for improvements in the built environment in low-income countries, lacking accountability mechanisms enable governments to avoid implementing policy and structures for better water, sanitation and drainage infrastructure – despite the wider benefits on health, wellbeing and climate change (see 2.5.2). Furthermore, in many of the low-income countries discussed in section 2.4, urbanisation has occurred at an uncontrollable rate, therefore decades of investment in both policy and finance are required to resolve the issues caused by population demands on water, and increased use of impermeable surfaces and grey infrastructure. However, whilst engagement is lacking from low-income country governments, several academic and community-initiated examples addressing drainage challenges exist; in both refugee camps and informal settlements – demonstrating both positive results and the need for further investment and design ideas for these communities (see 2.4.2, 2.5.3,2.5.4).

This is particularly evident in informal settlement communities, whereby issues of housing density, proximity to formal infrastructure, the legality of land ownership and the community themselves causes numerous problems related to sewage, greywater and solid waste management alongside inadequate disposal practices and infrastructure. Furthermore, owing to the spread of vector-borne disease and wider livelihood challenges associated with informal settlements, it is even more evident that investment in improved infrastructure is required to ensure communities have a dignified way of living.

For these reasons, implementing SuDS in informal settlements to address surface water – such as greywater and stormwater could be considered a feasible option. The primary reason for this is the adaptability and scalability of each individual SuDS device itself. Furthermore, the potential to design low-cost, low-scale versions of certain devices, that informal settlement communities themselves could design, build and implement using locally available resources and material; at minimal additional cost to them. Nevertheless whilst a reduction in surface water would ensure a more visually appealing community and amenity, the positive implications on environmental and public health improvements could be significant with regards to waterborne (e.g. Cholera, typhoid), water-based (e.g. schistosomiasis), and water-related (Zika, dengue and malaria) disease transmission (Annenberg Foundation 2017). By providing better understanding and capacity to manage greywater and stormwater correctly, pollution of river courses would reduce, alongside improved water quality and biodiversity. However, whilst in principle this may appear a logical concept, as discussed in section 2.5.4, when implementing any new project in a new environment there must be adequate engagement and involvement from the community themselves. This is even more important in cases where there is lacking governmental policy and finance to implement infrastructure upgrading or retrofitting activities, thus for SuDs in the concept of this project to be feasible and successful the community must be engaged and willing for their implementation.

Therefore, when applying these key conceptual discussions to the aim of this research project: *To identify the potential for use of SuDS as a method to reduce ZIKV transmission in favelas*, it is apparent that both the academic discourse and practical examples illustrated in this chapter align with the overall aim of the project. As a result, this lays the foundation in to apply these concepts in the context of Brazil and the response to the ZIKV. As alluded to in section 2.5.1, Chapter 3 will outline the heterogeneity of Brazil's informal settlements, and illustrate current approaches to water, sanitation and drainage infrastructure in both the wider urban environment and also favelas.

3.0 Brazil: A thematic review

3.1 Introduction

This chapter will contextualise the literature and concepts outlined in Chapter 2 relevant to the context of Brazil, and regarding the ZIKV and SuDS. Following the presentation of both scholarly and practitioner discourse in Brazil, each section will be summarised. Summaries of findings from Chapters 2 and 3 will then be combined to establish a basis of knowledge in which to create a conceptual framework that underpins the whole project (see 3.6).

There are several key texts that outline and discuss key challenges related to SuDS and urban drainage in low-income countries (Jiusto and Kenney 2016; Parkinson, Tayler and Mark 2007; Parkinson 2003). However, many of these approaches whilst broadly applicable in Brazil, fail to acknowledge the diversity of informal settlement communities, as well as the wider inter-sectoral benefits associated with improved water and waste management using SuDS-based approaches. This chapter will identify the gaps in the current discourse and propose solutions to promote an integrated and holistic approach between sectors.

3.1.1 Introduction to Brazil

As the largest landmass in South America and the 9th largest economy worldwide (World Bank 2018), Brazil has experienced several decades of rapid urbanisation with 84% of Brazil's population now living in urban areas (da Silva and Cerquiera 2016). However, with an estimated population of 210 million people, the country now faces several challenges in terms of infrastructure and public service provisions; with government policies associated with health, housing, education and sanitation significantly outdated (EIU 2019; Xavier and Magalhães 2003).

Figure 3-1: Map of Brazil, showing major cities and different topographic regions (WorldAtlas 2019)

With the coastline on the Atlantic Ocean and varying topography throughout the country (see figure 3-1), Brazil's climate varies across its five regions, with a tropical climate in the North to a temperate/semi-arid climate in the South (Aguiar *et al.* 2018). Furthermore, frequent fluctuations in global climate have meant that increasing temperatures and longer periods of heavy rainfall now persist for 7 months each year (Reed 2013). As a result, urban water management infrastructure is particularly overstretched, owing to frequent flooding and droughts, alongside sanitation systems with inadequate hydraulic capacity to manage both household water and stormwater (Britto *et al.* 2018; Dias *et al.* 2018).

3.2 Urban Drainage in Brazil

3.2.1 Current approaches to drainage

Although Rio de Janeiro was the third city in the world to have a piped sewage network and lead international knowledge and understanding on efficient urban drainage systems (Sale and Norris 2016), owing to poor governance, unequal distribution of public funds and frequently changing political agendas; Brazil has numerous issues related to water supply sanitation and drainage (Soares, Parkinson and Bernardes 2005). Significant pressure is also created by high population density, increasing impervious surfaces and high demand for, and hydraulic discharge into, existing water, sanitation and drainage utilities (Miguez and Veról 2017).

Although the creation of individual state bodies for Sanitation Works in 1962 aimed to strengthen the provision and quality of sanitation nationally, it is currently estimated that 27 million homes are not connected to the sewage or drainage network – equating to nearly 100 million individuals. Furthermore, a study by the Instituto Trata Brasil found that in the low-income communities of São Paulo and Rio de Janeiro, there was a positive correlation between inadequate sanitation and negative health outcomes, such as dengue, diarrhoea and leptospirosis (Dias *et al.* 2018).

In major metropolitan areas such as Rio de Janeiro, these issues are further amplified. Despite the existence of a State Sanitation Body, in 1989 Rio-Aguás was established as an additional water authority for the city; with the aim to specifically address challenges relating to the management of rainwater, sewage and sanitation (Sale and Norris 2016). However, owing to lack of financial investment at federal and municipal levels, several water management issues exist in the city, these include: inadequate hydraulic capacity and loading rates of sewage infrastructure, poor maintenance of combined-sewer systems, and a lack of wastewater treatment facilities - cause severe pollution to waterbodies and the environment (Silveira 2002; Soares, Parkinson and Bernardes 2005). Finally, infrequent water supply regularly results in droughts and storage of potable water inside each household as reserves (Dias *et al.* 2018; Miguez and Veról 2017; Sale and Norris 2016). In Rio de Janeiro, whilst 95% of the city is connected to the public water supply system, due to pollution caused by sewage discharging into water bodies, Rio de Janeiro's potable water must be piped into the city from the Paraiba do Sul River Basin (˜100km away) (Kelman 2015). The basin additionally supplies Nova Iguaçu, Duque de Caxias, Petropólis (see figure 5-4 5.2.2b pg. 116) as well as São Paulo and other large cities across São Paulo State; therefore, the water supply is often infrequent with restrictions regularly imposed by local authorities (Britto *et al.* 2018).

3.2.2 Governance and legislation

Federal Law 11,445 (2007, c.1) outlines necessary provisions for sanitation, waste and water supply (Sampaio, Kilgerman and Junior 2009). The main principles are to encourage universal access to utility services, the availability of drainage services across all urban areas and integration of infrastructure services to ensure the efficient management of water. The law also provides a national planning framework that ensures regulations are achieved by State and Municipal governments in the areas of, water supply, sewage, solid waste, rainwater management. Furthermore additional considerations are made that ensure ongoing infrastructure maintenance and improvements to promote increased environmental health (Miguez, Veról and Rezende 2016). To ensure local authorities adhere to regulatory planning, the following regulatory acts further define and outline their responsibilities (Miguez and Veról 2017): The Federal Urban Land Parcelling Act (1979), National Water Resources Policy (1997), City Statute Act (2001).

3.2.3 Governance, maintenance and operation issues

Despite numerous legislation and regulatory guidelines, there are several governance issues preventing the implementation of adequate sanitation in Brazil. Many of the issues are grounded in Brazil's decentralised governance structures; therefore, although national laws are underpinned by federal constitutions and policy documents, very little of the national policy agenda is applicable or replicated in local areas - whether in urban or rural contexts (Dias *et al.* 2018). This issue was identified by Bridge and Brandão (2014) in Belém (Pará State, North Brazil). The authors identified that a lack of coordination between the Metropolitan and Municipal authorities meant that constant tensions arise between housing and environment planning agendas - as a result subsequent drainage projects are poorly designed and implemented.

Another issue inhibiting adequate governance is a lack of technical knowledge and resource capacity at the municipal level; as a result, operation and maintenance costs are often not factored into project budgets (Tucci 2005). Consequentially many municipal urban water management efforts are focussed around addressing flooding (Miguez and Veról 2017; Poleto 2011), and therefore ongoing investment in day-to-day systems is not prioritised or sufficiently funded (Dias *et al.* 2018; Tucci 2001). Although this is acknowledged to be a current governance issue, Knauer *et al.* (2010) outlines that similar flood-prevention drainage approaches were previously adopted in Brazil from the 1970s-1990s. Techniques implemented during this time included lining of river channels and constructing numerous closed drainage systems. However, due to the recession in the 1990s and the subsequent impact on public spending (Soares, Parkinson and Bernardes 2005), the increasing costs of maintaining and building such heavily engineered systems meant that many systems fell into disrepair and thus had no impact on flood reduction (Knauer *et al.* 2010). This has created many challenges in terms of retrofitting, replacing and maintaining out-dated ineffective drainage systems throughout Brazil, with drainage inlet blockages and low scale drain overflows frequently occurring (Reed 2013; Tucci 2001).

In many areas, it is challenging for those constructing new or retrofit systems to adapt earlier infrastructure where environmental degradation has occurred, for example channelisation of canals which has increased the frequency of overtopping flood events (da Silva and Cerqueira 2016). Similarly, a lack of historic or current data relating to both hydrological (flow rates, catchment permeability) and planning components (inadequate records of infrastructure networks) regularly prevents integrated management, operation and maintenance of drainage systems (Bridge and Brandão 2014; Marhulis and Unterstell 2017). Not only does this impact on existing drainage systems but it is also a major challenge in the implementation of new systems (Soares, Parkinson and Bernardes 2005). Municipal planners often adopt a generic drainage system design, as they are unable to create location-specific models due to the lack of local data (Nascimento, Baptista and Kuark-Leite 1999).

To adhere to regulations requiring new water and sanitation infrastructure, municipal prioritisation is then waived at the expense of addressing past problems in existing drainage systems (da Silva and Cerqueira 2016). A primary example of this is the inadequacy of existing sewage treatment works (owing to lack of legislation). Rather than implementing new sewage treatment facilities and monitoring urban wastewater discharge, authorities are instead investing money into piping potable water from remote sources that are less contaminated (Hupferr *et al.* 2013). In Belo Horizonte 92% of residents are connected to the sewage network; however, there is no infrastructure to transport household wastewater to a sewage treatment works, which creates additional challenges to water supply and the maintenance of adequate public and environmental health (Knauer *et al.* 2010).

3.3 Informal Settlements in Brazil

Despite widespread reductions in poverty from 2004-2015 by President Lula's Workers Party, informal settlements continue to proliferate many of Brazil's urban areas. Informal settlements (locally referred to as favelas) are typically situated on illegally occupied land on the suburban fringes of Brazil's major cities, such as Rio de Janeiro, São Paulo, Fortaleza, Belo Horizonte, Recife etc. (IMF 2017:4). For this reason, favelas are associated with numerous issues that impact both the favela community itself and the surrounding communities of the city. This section (3.3) will outline some of these challenges in the context of housing and sanitation infrastructure and discuss the opportunities for further research.

3.3.1 What are favelas?

Characterised by poor housing, sanitation and structural quality of infrastructure, Brazil's favelas are home to approximately 26.4% (c.2010) (Snyder *et al.* 2017; UNHABITAT 2011) of the population. Owing to low socioeconomic status and social vulnerability, many favela communities lack basic utilities; including provisions for drinking water, sanitation, drainage and solid waste management – all with their own associated health impacts (Shetty 2011). Furthermore, individual dwellings are precariously built using a variety of low-cost, reclaimed materials such as iron sheeting roofing, discarded bricks and concrete from construction sites creating subsequent environmental and public health concerns (Tucci 2001). In addition, owing to their location on steep slopes, floodplains, and riverbanks availability of land is minimal, dwellings are often incredibly densely packed, and the houses themselves are typically overcrowded (see figure 3-2 below) (Dovey and King 2011). Therefore, despite the community’s best attempts at illegally tapping into regulated provisions, such as electricity and drinking water; often the characteristics of their location prevents action being taken by the government to incorporate them into the formalised regulated system (O’Hare and Barke 2002).

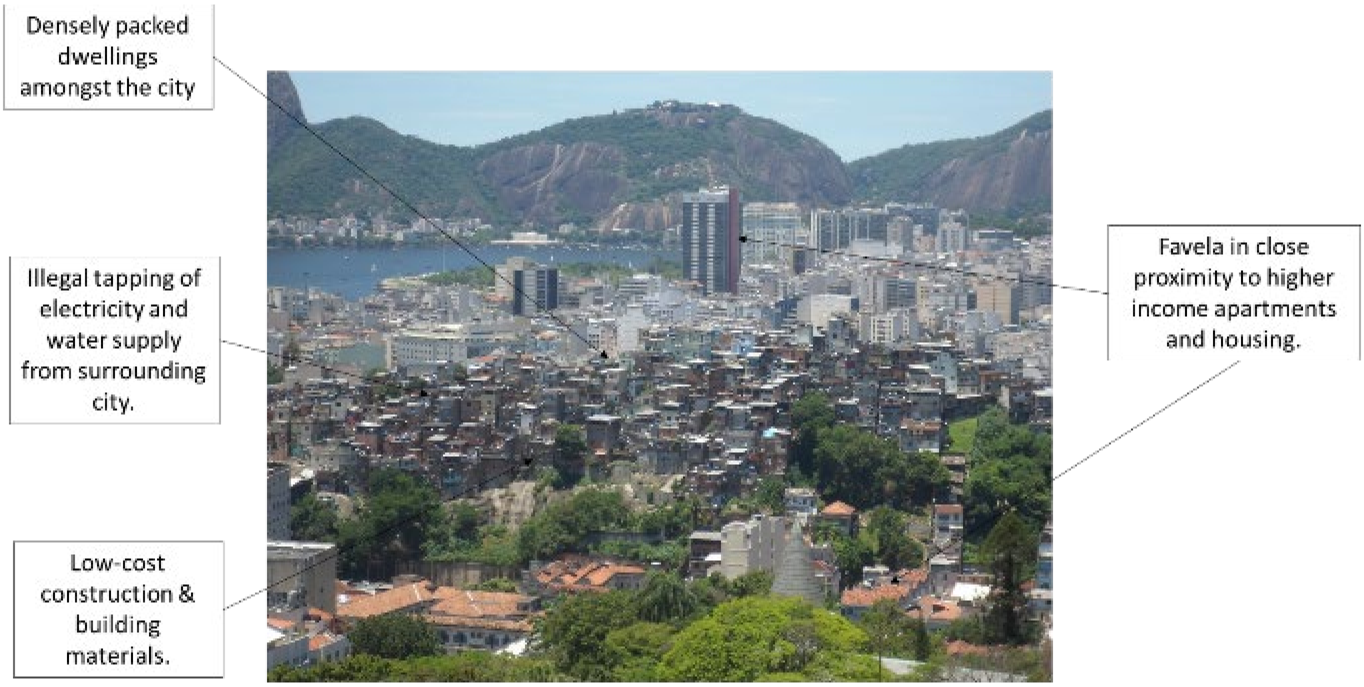

Figure 3-2: Favela community in Rio de Janeiro city’s Santa Teresa district (Photo taken by the author, November 2018)

In the most part, favelas are home to the most vulnerable individuals, many of whom are rural to urban migrants reliant on informal sector job opportunities, such as trash picking, working on building sites and tourism (see figure 3-3) (Dovey 2015). For this reason, access to education, health care and wider social services is a challenge. Ultimately whilst these communities continue to live in illegal, unrecognised areas even if individuals had the funds to access public services, lack of a recognised address prevents access to social security funds or other government social support schemes (UNHABITAT 2003).

Figure 3-3: View of Copacabana Beach, Rio de Janeiro and the proximity to favelas (Photo taken by the author, November 2018)

In Brazil no single definition for favelas exists, thus several definitions have emerged, these are summarised in table 3-1:

Table 3-1: Definitions associated with favela communities.
(Xavier and Magalhães 2003:8-13)

Classification Name	**Definition**
Aglomerado Subnormal (Subnormal Agglomeration)	'Groups of 50 or more housing units located in a dense and disorderly manner.'
Favelas	'Highly consolidated invasions of public or private land with self-built buildings… lacking infrastructure and any kinds of plans.'
Loteamentos Irregulares (Illegal Subdivisions)	'Illegal land that lacks infrastructure and does not comply with planning rules.'
Invasões (Invasions)	'Irregular occupation of public or private land … takes place in environmentally

	fragile areas – riverbanks, swamps, hills or in residual areas of public infrastructure.’
Cortiços	‘Social housing formed by one or more buildings located in a single plot, or shared rooms in a single building.’

Although the table above summarises the key terminologies used in both Brazilian literature and the national census, they share many common themes that relate to the informal settlement definition chosen for this project in 2.5.2: ‘settlements of the urban poor established by unauthorised land occupation (Huchzermeyer and Karam 2006).’ For this reason, with the exception of Cortiços, (which will be referred to as relocated housing), the term ‘favela’ will be used in this thesis to collectively refer to each of the terms outlined above.

3.3.2 Government regulation and legislation on favelas

Since the end of military rule in Brazil in the 1980s, public opinion and governance approaches regarding the integration of favela communities frequently fluctuated from positive integration to complete removal by forced eviction (Cities Alliance 2012). Following the creation of Brazil's new constitution in 1988, there was a significant emphasis on urban development by the national government to include: sanitation, housing and transportation (Samora 2016). This resulted in widespread efforts in municipal plans to promote 'slum-upgrading' and resettlement, however a lack of federal legislation related to favelas meant that implementation of positive approaches was based on the goodwill of each authority, rather than widescale positive actions (Cities Alliance 2012). Cities supporting upgrading included Rio de Janeiro, São Paulo and Recife where policies promoted the legal protection of favela residents' rights, with tenure rules giving land ownership to residents after five years of continuous illegal occupation (Ren 2018). In 2001 the federal government mandated the City Statute Law, based on Lefebvre's (1968) *Right to the city,* the statute encouraged legal tools and programs to address the issue of inequality in urban areas (Samora 2016). At all governance levels (federal, state, municipal), the statute resulted in the creation of projects and availability of public funds to improve infrastructure and the integration of favela communities into the city (Fortes and Cobbett 2010). Some of these programmes are outlined in table 3-2.

Table 3-2: Brazilian programmes in-support of favela upgrading

Programme Name	Duration of Programme	Implementing Authority	Sector/s	Location	Achievements	Citation
Favela Barrio	1988 - 2008	Federal - with funds from International Development Bank	Infrastructure, Sanitation, Public Spaces	Rio de Janeiro	Construction of sewage systems, implementation of social spaces e.g. park. Improvement of public spaces.	(Perlman 2010) ;(Ren 2018); (Samora 2016);
PAC-UAP	2007	Federal & Municipal	Housing, Sanitation, Infrastructure, Social Services	National	$33 billion Brazilian *reals* invested in project. 3,113 housing interventions	(Denaldi *et al.* 2016); (Samora 2016).
Slum Upgrading Programme	2008-2013	Municipal	Housing, Sanitation	São Paulo	130,000 families included. Replacement of 10,00 homes located in areas high risk to flooding and landslides.	(Pisani and Bruna n.d.)
Morar Carioca	2008-Ongoing	Municipal	Housing	Rio de Janeiro	Intended achievements: to integrate all favelas in Rio de Janeiro as an Olympic legacy by 2020.	(Ren 2018)
Minha Casa, Miha Vida	2009-Ongoing	Federal	Housing	National	Intended achievements: construction of 3.4 million homes for low-income families	(Denaldi *et al.* 2016; Healy 2014)
PAC-UAP (2)	2010	Federal	Housing, Infrastructure	Rio de Janeiro & São Paulo	$17 billion reals. 415 Project planned.	(Samora 2016)

Although the outlined programmes have contributed to improvements in some areas, there is still widespread prejudice against favela communities as well as little evidence of successful implementation of the intended achievements (Ren 2018). Therefore, whilst efforts have been made to improve infrastructure, these have been criticised due to the lack of socio-economic development in favelas as a result (Cerqueira and da Silva 2016). Similarly, in the case of projects such as *PAC-UAP (2)* and *Morar Carioca* that were aligned with the Olympics and World Cup legacies, owing to wide-spread corruption, many of the intended community outcomes were never fulfilled with finance diverted to other aspects of the sporting event's budgets (Sampaio Freitas 2017).

3.3.3 Drainage, water and environmental health issues in favelas

Despite some interventions being implemented by the programmes in table 3-2, there are still numerous issues associated with water and waste (sewage, solid waste) management in favelas. Many of the reasons favelas still lack improved infrastructure is because of corruptions, widespread prejudice and a lack of local-level government impetus to enact federal policy.

An example of this issue is in Rio de Janeiro State, where two public-private water companies are responsible for the provision of water and sanitation systems, CEDAE (the state company) and RioAguas (municipal). However, due to high levels of crime and violence in favelas, CEDAE sanitation projects have only been attempted in favelas where there is an ongoing presence of state police and military to ensure peace (referred to as UPP, Police Pacification Units) (Adler *et al.* 2017). However, CEDAE's approach is futile as only 264 (8%) of Rio de Janeiro City's favelas are covered by UPP (Malleret 2018), meaning many communities have received no sanitation investment or upgrading at all.

Owing to little investment and inclusion in formal systems, the community improvises solutions to deal with water and waste management. This often results in raw sewage being discharged into nearby rivers or watercourses, solid waste being tipped/thrown down hills or into rivers, potable water being collected from nearby pipes and stored in the home, and household greywater being taken and thrown outside (Dias *et al.* 2018). It is projected that these conditions apply to approximately 11 million people across Brazil (Dias *et al.* 2018:1344), and whilst many communities accept these improvised solutions, there are several detrimental consequences both to the community themselves, as well as to the proximate and wider urban environment. Some of these issues are presented in the photos below, taken in Ouero Preto community, Nova Iguaçu (see figure 5-4, 5.2.2b. pg. 116).

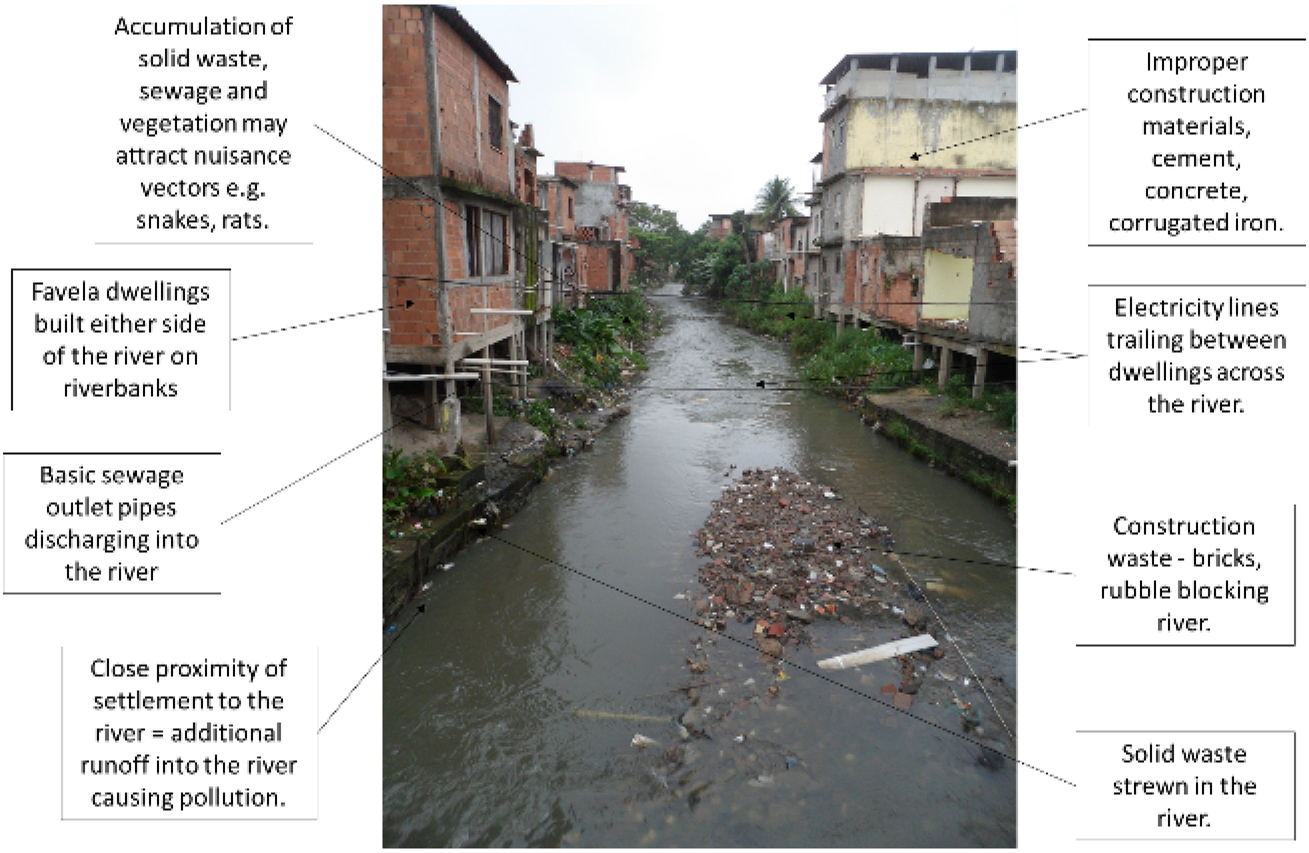

Figure 3-4: Watercourse pollution caused by favelas.
(Photo shared with the author by Participant 5).

Many of these day-to-day issues shown figure 3-4 have associated factors negative to public and environmental health (see 2.5.2). As this thesis is concerned with applying SuDS to address the ZIKV (see 3.4), it is particularly important to identify parameters suitable for mosquito vectors. Favourable breeding locations for *Aedes aegypti* (the vector of Zika, dengue, chikungunya and yellow fever virus' in Brazil) include: open areas with any standing or stagnant water and collected water in solid waste such as discarded food packaging, car tyres, water storage containers, plant pots/leaves (Snyder *et al.* 2017; Wilson, Davies and Lindsay 2019). Figures 3-5 and 3-6 show suitable *Aedes aegypti* breeding locations in Ouero Preto.

Figure 3-5: Blocked drain nearby favela community.

(Photo shared with the author by Participant 5).

Figure 3-6: Solid waste disposal issues in favelas.

(Photo shared with the author by Participant 5).

3.4 Zika virus

3.4.1 Zika virus background

The Zika virus (ZIKV) is primarily transmitted to humans by the bite of the female *Aedes aegypti* mosquito. However, the virus can also be transmitted in-utero from pregnant mother to child, via blood transfusions and through sexual intercourse (Boyer *et al.* 2018). Whilst *Aedes aegypti* is the main vector of ZIKV, recent studies have shown that *Aedes albopictus* is also capable of transmitting the virus (Aguiar *et al.* 2018; Lowe *et al.* 2018). Furthermore, some research suggests that *Culex quinquefasciatus* should be considered as a third ZIKV vector, however evidence to support this is minimal (Guedes *et al.* 2017).

In the case of *Aedes aegypti,* the quality of the peri-domestic environment and high population densities are particularly important factors associated with life cycle of the mosquito. Estimates suggest that *Aedes aegypti* travels between 100-500 meters in its 1-month lifetime, meaning both feeding and breeding locations must be in close proximity (see figure 3-7) (Aguiar *et al.* 2018; Lowe *et al.* 2018; Snyder *et al.* 2017).

Figure 3-7: Mosquito lifecycle (Biogents 2018)

Typical locations for *Aedes aegypti* oviposition (egg laying) in the peri-domestic environment are illustrated in figure 3-8 (below). Although domestic habitats such as those outlined below are preferred, mosquitoes are also able to lay eggs in anything of natural origin that holds up to a teaspoons volume of water, e.g. water collecting on the leaves of plants, and in stormwater puddles (Boyer *et al.* 2018; Government of Bermuda n.d.).

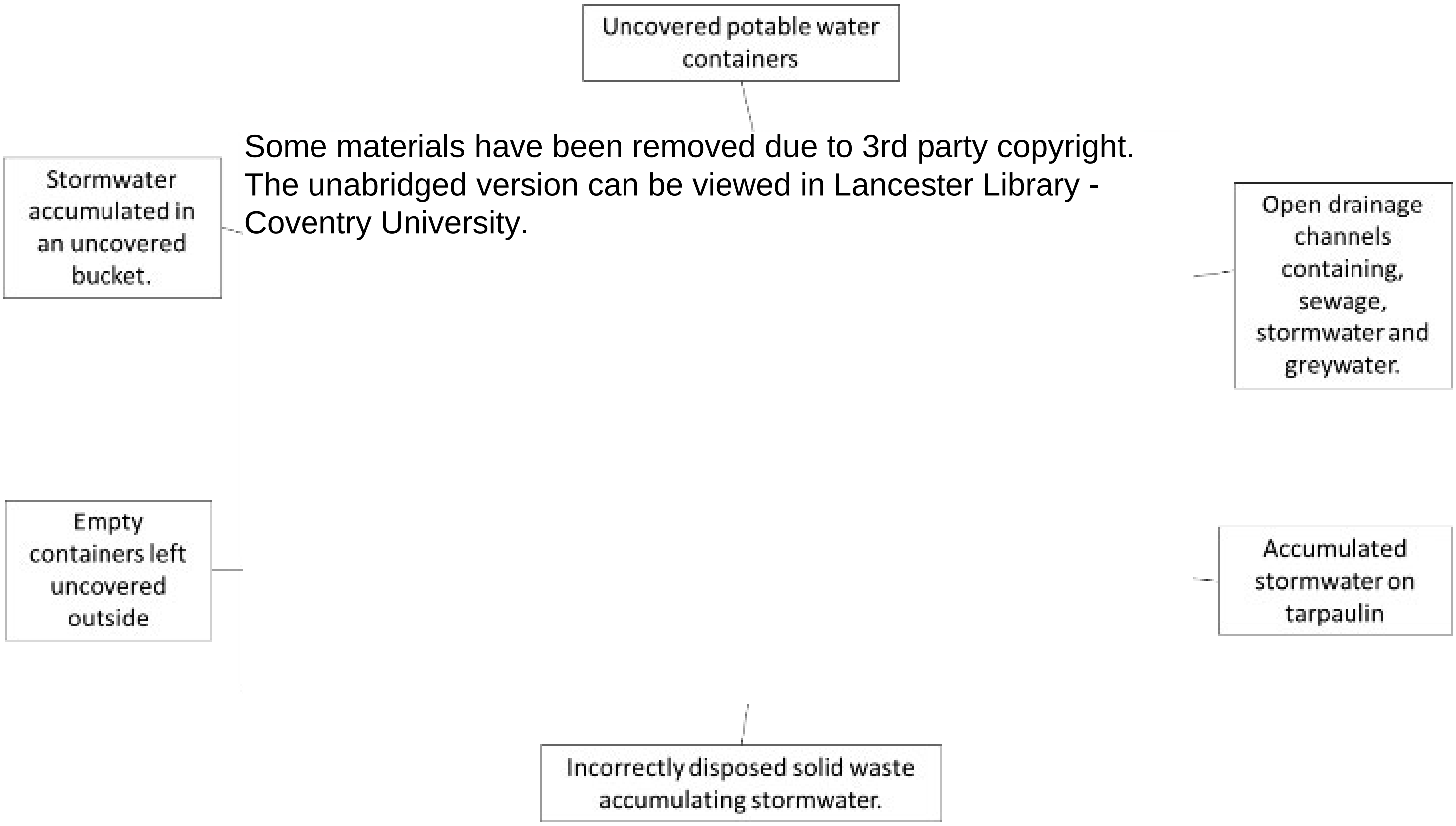

Figure 3-8: Peri-domestic oviposition sites of *Aedes aegypti* (Getachew *et al.* 2015).

One of the major challenges inhibiting ZIKV understanding is that 80% of those infected are asymptomatic, therefore medical intervention is required only in severe cases. For this reason, tracing the distribution and coverage of ZIKV is only possible during large epidemics, therefore relatively little is known about ZIKV when compared with other mosquito-transmitted diseases (Lowe *et al.* 2018). This issue was exemplified in 2013 and 2014 when Guillain-Barré syndrome (a condition causing limb weakness and paralysis in adults) was connected to ZIKV following outbreaks in Polynesia and Micronesia. Yet previous ZIKV epidemics in Uganda (1947) and The Yap Islands, Micronesia (2007) did not result in any connection being made to Guillain-Barré syndrome (Boyer *et al.* 2018; de Souza *et al.* 2018).

Aedes aegypti is typically found inhabiting densely populated urban areas in tropical and subtropical regions worldwide, to include South America, Sub-Saharan Africa and parts of Asia. Whereas *Aedes albopictus* prefers more temperate climates, such as that of the US and Northern Europe – where the mosquitoes typically inhabit vegetated or forested areas. It is estimated that over 2 million people worldwide live in locations suitable for ZIKV transmission, illustrated by the red areas in figure 3-9 (Messina *et al.* 2016). Many of these areas with confirmed ZIKV cases include Lagos (Nigeria), Kolkata (India), Bangkok (Thailand) and Manilla (The Philippines) – each with populations greater than 10 million people and are popular tourist destinations (Young 2019).

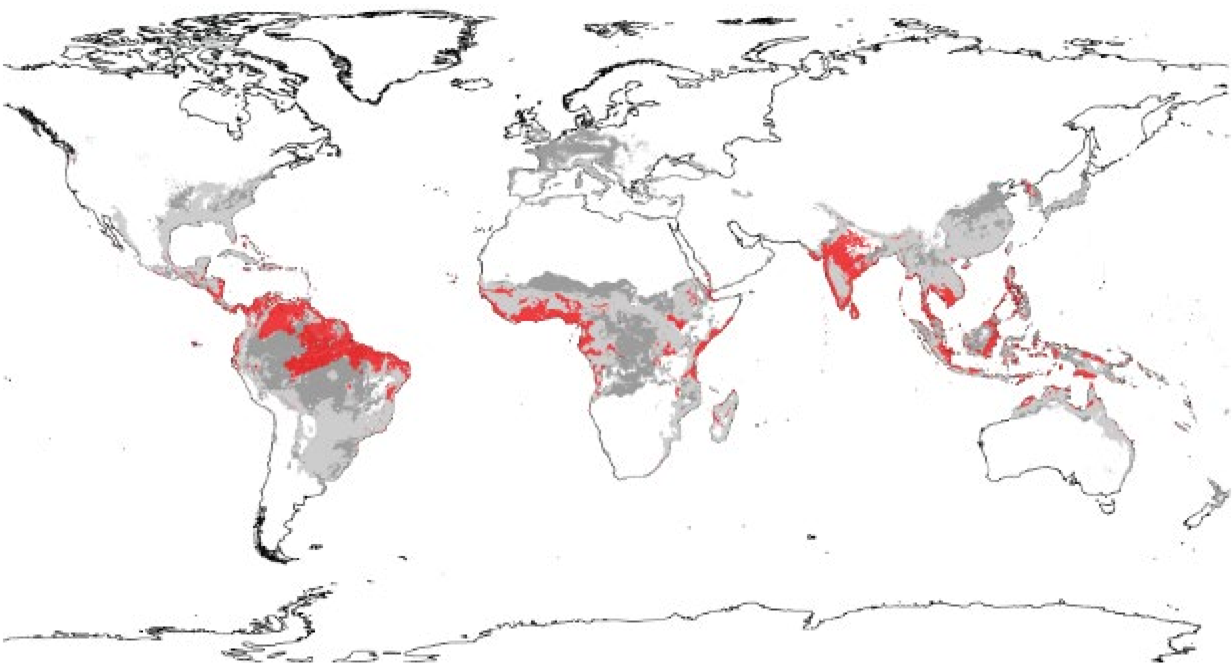

Figure 3-9: Current ZIKV distribution (in red) compared with 2050 ZIKV distribution projections (in grey) (Carlson, Dougherty and Getz 2016:11).

With increasing evidence suggesting the distribution of *Aedes aegypti* will exceed the current distribution of the *Anopheles* mosquito attributed to Malaria (Braack 2019), it is vital that research attempts focus on novel prevention methods to halt future epidemics (Lowe *et al.* 2018; Mittal *et al.* 2017).

3.4.2 2015-2017 ZIKV epidemic in Brazil.

Distribution

Despite media attention attributing the ZIKV epidemic to the 2014 Brazilian Football World Cup (Arbex *et al.* 2016), it is thought that the ZIKV arrived in Brazil in 2013 and remained undetected until 2015 when several ZIKV cases were identified in Camaçari, (Bahia State) and Natal (Rio Grande do Norte State) in North-East Brazil (Campos *et al.* 2015; Zanluca *et al.* 2015). One of the issues with the initial ZIKV outbreak was a lack of understanding about the virus. Public health officials initially tried to model its spread on past dengue outbreaks, which proved futile as ZIKV became widespread in urban areas over several months – from the Northeast to the Southeast (see figure 3-10). Whereas dengue took several decades spread (1980s-2010), placing significant pressure on public health provisions (Lowe *et al.* 2018; Proenca-Modena *et al.* 2018).

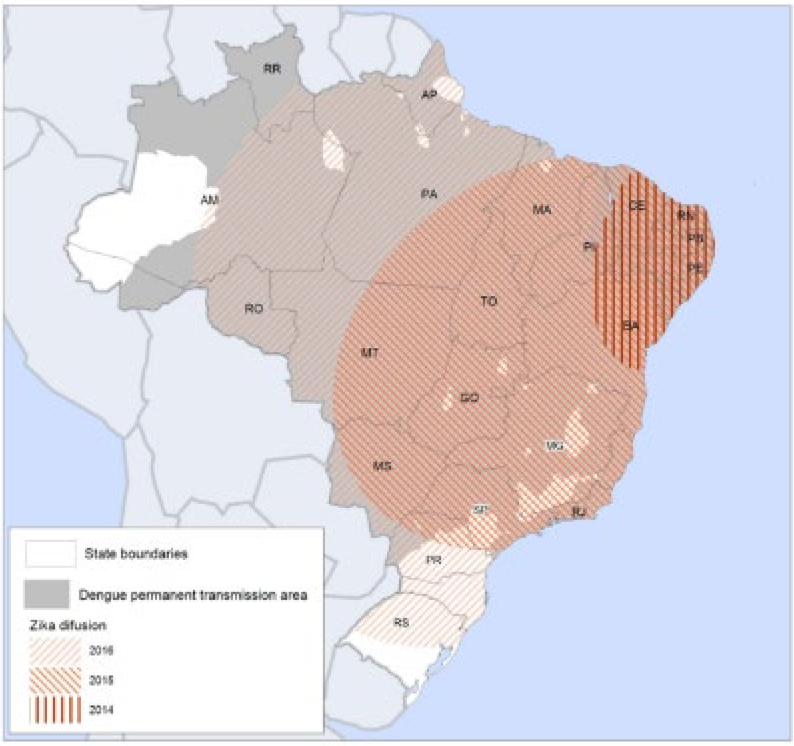

Figure 3-10: Spatial diffusion of ZIKV (Lowe *et al.* 2018:2)

Since the ZIKV outbreak in 2015-2017, researchers have identified *Aedes aegypti* species in 94% of the country, coinciding with most populous cities on both the Northeast and Southeast coastlines, including Fortaleza, Recife, Rio de Janeiro and São Paulo (Nunes *et al. 2018*).

Diagnosis and Monitoring

In Brazil, alongside the ZIKV, *Aedes aegypti* also transmits chikungunya and dengue fever, therefore because of breeding habits and each virus having similar symptoms, case diagnosis can only be confirmed and distinguished from laboratory tests (Lowe *et al. 2018)*. Therefore, despite sources claiming to reveal ZIKV statistics and infection rates, questions have been raised regarding the reliability of data owing to the lack of diagnostic capabilities and inconsistent health coverage throughout Brazil (Arbex *et al.* 2016; Brady *et al.* 2019; Mittal *et al.* 2017; Snyder *et al.* 2017).

ZIKV only became a notifiable disease in February 2016 (11 months after the initial outbreak in Brazil), when an international emergency was declared by the WHO (PAHO 2017). Therefore, data from the 11-months prior is sporadic with many inconsistencies between Municipal and State held records (Boyer *et al.* 2018). Up until June 2017, 218,931 ZIKV cases were recorded nationally by the Brazilian Ministry of Health (Secretaria de Vigilância em Saúde 2017). However, with 80% of cases being asymptomatic and an estimated 98.6% of Brazil's population living in urban areas present with *Aedes aegypti*, it is likely that the actual number of infected individuals would have been much higher (Aguiar *et al.* 2018; Proenca-Modena *et al.* 2018).

Microcephaly

One of the long-term challenges associated with ZIKV is microcephaly, caused by in-utero transmission of ZIKV from mother to child. Microcephaly is a condition defined 'in neonates whose occipital-frontal head circumference is smaller than expected for their gestational age and gender' (see figure 3-11) (Arbex *et al.* 2018:717).

Figure 3-11: Head size comparison between a typical neonate and neonates presenting with microcephaly (Centres for Disease Control and Prevention 2018).

Microcephaly is not a uniform congenital birth defect and each case presents very differently. More recently other symptoms and indicators have also been identified and attributed to a wider condition acknowledged as 'Congenital Zika Syndrome' (Centre for Disease Control and Prevention 2018; Schuler-Faccini *et al.* 2016).

Although microcephaly cases were identified as early as August 2015, owing to a lack of understanding and formal attribution to ZIKV, many cases were not formally recorded, thus in the early stages of the outbreak access to, and recording of reliable data was a significant problem. A recently conducted study (Brady *et al.* 2019) proposes that 2,791 cases of microcephaly were diagnosed during 2015-2017. Owing to the long-term health implications associated with severe developmental delay and the financial burden of treating and monitoring the condition, it is vital that the Brazilian government considers additional approaches to prevent further microcephaly epidemics.

3.4.3 Understanding of mosquito-vector distribution in Brazil

Access to adequate water supply, sewage treatment and solid waste collection are all factors associated with the prevention of mosquito-borne disease (Rodrigues *et al.* 2019). Recent studies focusing on *Aedes aegypti* in Brazil have found there to be conflicting schools of thought regarding the correlation between arbovirus outbreaks and urban socio-environmental conditions (Teixeira and Cruz 2011).

Several scholars acknowledge the potential for socioeconomic and environmental variables (such as housing quality and 'improved' sanitation infrastructure using closed or covered systems) to impact arbovirus epidemiology (see table 3-3). With each paper discussing varying attributes related to vector transmission and the spatial distribution of infection cases across numerous geographical boundaries (national, regional, state, city-wide, etc).

To address objective 1 of this project, six papers (summarised in table 3-3) will be reviewed to form a basis of understanding reflecting the geospatial associations between arbovirus distribution and urban socioeconomic and environmental characteristics.

Table 3-3: Research projects findings related to arbovirus distribution and socioeconomic and environment conditions.

Citation	Region	Location	Arbovirus	Summarised key findings
(Souza *et al.* 2018)	Northeast	Recife, Pernambuco State	Zika	Lack of sewage system and garbage collection correlated with higher microcephaly incidence.
(Rodrigues *et al.* 2018)	Southeast	Manguinhos Community, Rio de Janeiro Municipality	Zika, dengue, chikungunya	Difference in risk of disease not explained by water and sanitation indicators. Inadequate adherence to prevention activities more likely – applied to both low- and high-income areas.
(de Souza *et al.* 2018)	Northeast	Recife, Pernambuco State	Zika	139/142 cases of microcephaly in study area directly associated with favelas with poor sanitation and housing infrastructure.
(Kikuti *et al.* 2015)	Northeast	Salvador, Bahia State	Dengue	Dengue infection dependent on social status and proximity to health services.
(Teixeira and Cruz 2011)	Southeast	Rio de Janeiro Municipality	Dengue	Highest incidences occurred in areas with precarious infrastructure and sewage systems.
(Flauzino *et al.* 2009)	Southeast	Niterói Municipality, Rio de Janeiro State	Dengue	Persistent occurrence of dengue in slum areas with poor sanitation and solid waste management across all epidemic periods studied.

The six papers were selected based upon the region of the study and the time periods of their data. Brazil's Northeast and Southeast regions were particularly of interest, as both these areas experienced the highest number and density of ZIKV infections in 2015 (see section 3.4.2 & figure 3-9). Similarly, whilst there were numerous academic outputs published during and after the Zika epidemic, many were written in the field of medicine and therefore not suitable as they do not consider geospatial associations. In addition, as the 2015-2017 outbreak was the first major ZIKV outbreak in Brazil, there is a limited amount of academic literature regarding geospatial epidemiology of the virus, therefore the principle papers that address this as their main research aim are, de Souza *et al.* (2018), Rodrigues *et al.* (2018) and Souza *et al.* (2018).

Owing to the few papers addressing the geospatial attributes of ZIKV, a comparison was made with 'historic' data relating to other *Aedes aegypti* transmitted diseases. Dengue has been an established virus in Brazil since the mid-1800s (Figueiredo 2003), with a significant number of papers seeking to identify the associations between urban conditions and the spread of the virus. For this reason, both Texeira and Cruz (2011) and Flauzino *et. al* (2009) studies have been included due to their focus on dengue in Rio de Janeiro.

The following lists the key findings that align with objective 1 of this project:

- Observational studies concerning specific locations (de Souza *et al.* 2018; Souza *et al.* 2018; Teixeira and Cruz 2011) found associations between increased dengue risk and demographic, socioeconomic and environmental characteristics.
- Higher cases and frequency of dengue outbreaks coincided with areas that had inadequate solid waste collections, and irregular water supply (Kikuti *et al.* 2015).
- Rodrigues *et al.* (2018) suggest that the distribution of vector breeding sites is not directly related to poverty but to diverse housing characteristics and management of urban space.
- All papers agreed that 'individuals in vulnerable families are at greater risk infector via mosquito-vector' (Rodrigues *et al.* 2018:12).

Although the quality and impact of sanitation infrastructure were not quantifiably measured in any of these papers, sanitation factors such as water supply, stormwater and sewage management were included as wider issues of concern associated the distribution of arboviruses and as well as contributing to vulnerability. As such, it is important to ensure governments and international bodies continue to develop and identify key policies and approaches that consider the wider urban environment, as well as access to health care facilities – thus increasing awareness of public health challenges and reducing disease transmission rates.

3.4.4 *Aedes aegypti* prevention strategies in Brazil

Since 1947 there have been numerous strategies and policies aimed at reducing *Aedes aegypti* populations, throughout South America. In Brazil, prevention efforts began in 1947 using Dichlorodiphenyltrichloroethane (DDT) insecticide sprays inside homes. This was then shortly followed by the creation of the '*Aedes aegypti* eradication programme' run by the Pan American Health Organization, WHO and supported by the Brazilian Ministry of Health. Several integrated approaches to monitor, control and manage the spread of Dengue fever were subsequently adopted (Araújo *et al.* 2015). However, due to increased resistance to DDT and larvicides, as well as inadequate programme management and coordination, it was ineffective in reducing mosquito populations in the long term - despite being initially successful. Hence as discussed by Gubler and Trent (1994) by the middle of the 90s, *Aedes aegypti* had a distribution across Central and South America similar to its prior distribution before eradication efforts (Gubler and Clark 1996, Scliessman and Calheiros 1974).

Table 3-4 lists the methods used and being developed by *Aedes* aegypti prevention programmes. These methods have been initiated both using bottom-up (community-led) and top-down (organisation/policy-maker-led) methods to varying degrees of success (Gubler 1989). Most of the adopted bottom-up approaches were created with the intention of enabling communities to manage mosquito prevention from within, such as involving communities in the removal of larval habitats from inside and outside homes as well as encouraging the frequent application of larvicide to water-storing containers. However due to lack of participatory engagement in the project planning and intervention design stage, community support was withdrawn from the projects and the programmes did not continue to be maintained by the government, despite the threat of fines levied on residents (Gubler 2011, Gubler and Clark 1996).

Table 3-4: An outline and critique of current Aedes aegypti reduction methods.
(Araújo *et al.* 2015, Chandra *et al.* 2008, Weaver *et al.* 2016, Winch *et al.* 2002, WHO 2016).

Methods	Description	Critique
Elimination/protection of water-storing items.	Ensuring either the removal or covering of items and objects both internally and externally to the home capable of holding water. For example, covering of drinking water containers or water butts and correct disposal of solid waste e.g. building materials, old tyres.	Current advice in Brazil suggests covering items containing only potable water – Ae*des aegypti* breeds in both clean & dirty water. Only a short-term solution, long-term approach needs to address water supply, thus preventing the ***need*** to store water.
Application of insecticides/larvicides.	The use of chemical compound sprays/aerosols/drops to kill airborne adult mosquitoes or mosquito larvae present in water.	Success is reliant on regular application and income to purchase sprays which are often expensive. See above critique - if only treating clean water this action is ineffective.
Use of larvivorous species.	Species which feed on the larvae of mosquitoes. Such as certain fish and dragonfly species. For example, integration of fish species in household outside pots with aquatic plants and fish – common practice in India and across Asia.	Introducing unfamiliar cultural practices may have the opposite impact and encourage mosquito's and other vectors/nuisance animals if implementation is not adhered/correctly explained.
Emerging scientific trials and research.	Wolbachia – a bacterium that lives in the gut of the mosquito which inhibits the replication of the vector-borne viruses in the mosquito, preventing transmission to humans. Genetically Modified Mosquitoes - carry a faulty gene that when given to offspring prevents them from surviving to maturity.	Ongoing trials are very expensive. As emerging research no long-term awareness yes of the effectiveness of these methods, or other wider impacts to the local ecosystem, biodiversity.

Knudsen and Slooff (1992) identify that the most effective projects are those that are created alongside communities. Initially top-down to raise awareness and understanding about *Aedes* aegypti and the diseases it transmits, followed by community-led consensus on the best approach to respond to the issue utilising resources, ideas and leadership of the chosen community – thus creating a higher likelihood for sustainable longevity (Gubler and Clark 1996). By fostering this approach, a change in community mind-set is often achieved as communities are then able to understand that the removal of larval habitats is in their best interests and hence regular activities such as applying larvicides and insecticides, as well as protecting water storage containers are routinely carried out (Gubler and Clark 1996, Tapia-Conyer, Betancourt-Cravioto and Médes-Galván 2012, Knudsen and Slooff 1992).

3.5 SuDS in Brazil

3.5.1 Background

Since the 1990s, there have been numerous efforts to integrate SuDS systems across Brazil (Genz and Tucci 1995; Nascimento *et al.* 1997; Pompêo 1999) with initial advocacy and suggestions compiled via working-groups of academics, policy-makers and practitioners. However, despite these key stakeholders working collaboratively, many of the suggested and implemented designs failed to engage with sustainability and made no consideration in their design features of future challenges posed by rapid urbanisation (Miguez and Veról 2017). In 2006, the Brazilian federal Ministry of Cities published a proposal for the widespread implementation of SuDS (Ministério Das Cidades 2007), advocating adoption of Low Impact Design and SuDS techniques in the urban environment to complement existing conventional (piped) drainage infrastructure (Goldenfum *et al.* 2007; Miguez, Veról and Rezende 2016). As a result of these guidelines and ongoing work by academic institutions across Brazil, several SuDS techniques and projects can be found in the country's major urban environments, including Rio de Janeiro, São Paulo and Belo Horizonte. Adopted techniques include detention basins, wetlands, green roofs, rain gardens and rain barrels (local term, alternatively referred to as waterbutts) (Köhler, Schmidt and Laar 2003; Miguez and Veról 2017; Nascimento *et al.* 2016; Wilkinson *et al.* 2017).

3.5.2 Example of current SuDS techniques in Brazil

The most common use of SuDS in Brazil is the implementation of large-scale detention reservoirs, which are then connected via pipes to inner-city canals (Peroni and do Nascimento Teixeira 2019). These reservoirs act as temporary storage points for stormwater, which is then discharged back into the canals and surrounding catchment areas after periods of heavy rainfall (Herzog 2016). Examples of these basins can be found in all three of the cities identified above, due to extensive flooding occurring multiple times per year. Furthermore, each project uses a collaborative approach with the location and citing of these basins decided by academic flood modellers, the basin itself built by the municipal or private water company and the municipal or federal government financing the project itself.

Figure 3-12 illustrates the typical design and surrounding environment of these detention reservoirs for a project in the neighbourhood of Pacaembu, São Paulo city, unlike many other detention- designs, the basin itself is in fact integrated into a park, acting as a lake and improving amenity and providing recreational areas for the local community (Miguez and Veról 2017). In other cases, detention basins are often concealed underneath sports pitches, children's playgrounds and market squares with drain covers to collect and convey stormwater into the basin (Miguez, Veról and Rezende 2016).

Figure 3-12: An artist's impression of a stormwater detention reservoir prior to implementation in Pacaembu, São Paulo (Miguez and Veról 2017:323).

Although other devices such as rain gardens, green roofs, rain barrels and wetlands are being widely researched, trialled and advocated for by Brazilian academics, there a lack of impetus from municipal authorities to implement these devices on a widespread scale owing to their lesser impact on flood reduction. As a result, largescale grey infrastructure approaches such as detention basins are favoured and receive the most government funding for implementation, and whilst this is a slight move forward in addressing flooding in a more holistic manner (by promoting stormwater recharge into the existing catchment), there is still more work needed to implement SuDS approaches aimed at truly restoring the urban environment to as close to natural catchment conditions as possible (Charlesworth, Harker and Rickard 2003). Furthermore, it is noticeable that at present neither conventional drainage methods or SuDS-like devices consider the resultant impacts on the downstream areas in the cities.

3.5.3 Sanitation interventions in Rio de Janeiro's favelas

Owing to the choice of Rio de Janeiro as the study location (see 4.3.1) the following subsection reflects specific intervention examples in Rio de Janeiro State. Although improved sanitation/SuDS related projects in favelas are few, several collaborative partnerships between academic institutions, Non-governmental organisations (NGOs) and favela communities themselves have been created to address this. Both examples chosen (below) have been designed in partnership using technology, materials and skills appropriate for community-led construction, maintenance and future replication.

Integrated Biosystems in Vale Encantado

Vale Encantado is a low-income community of around 120 residents situated on the peripheries of the Tijuca National Park (see figure 3-13).

Figure 3-13: Location of Vale Encantado (circled), in Alto da Boa Vista district, Rio de Janeiro City (Nidumolu 2015).

Located on a steep hillslope, there are many issues associated with disposal of sewage, rainwater runoff and greywater disposal. Although the community are included in government provisions for solid waste collection, there are no plans for the municipal implementation of improved systems for sewage and sanitation. In partnership with NGO

Viva Rio and the Pontifical Catholic University of Rio de Janeiro, a biodigester (for the anaerobic treatment of raw sewage) and constructed wetland (for nutrient absorption) have been designed, constructed and collaboratively implemented; enabling application of fertiliser and irrigation of fruit trees. The design uses tyres and bricks and is constructed using basic masonry and ferrocement techniques, see figure 3-14 (Adler *et al.* 2017).

Figure 3-14: Biodigester being constructed in Vale Encantado (L) Community member building the internal tank structure using bricks and cement. (R) Finished biodigester with inlet chamber on the right and outlet pipe ready for the construction of the wetland (Lepercq 2015).

Evapotranspiration Tanks in Praia do Sono, Paraty

In Praia do Sono (see figure 3-15 (L)), a series of evapotranspiration tanks have been implemented in a low-income community to increase agricultural productivity and reduce the risk of disease associated with untreated raw sewage (figure 3-15 (R)). The tank itself treats greywater, food waste and raw sewage, to generate biomass (for fertiliser use) and enable irrigation of crops and fruit trees growing in the soil layer above the tank via evapotranspiration from each input waste (Atunes 2018).

Figure 3-15: (L) Locating Praia de Sono in Rio de Janeiro State (Seixas *et al.* n.d.) & (R) Example of one of the evapotranspiration tanks in Praia do Sono (Atunes 2018:25).

As shown by the examples provided in this section, there is potential for up-scaling and retrofitting of SuDs-like water and waste management systems in Brazil. Although widespread replacement of conventional sanitation infrastructure is unlikely, retrofitting SuDS devices alongside existing systems or as standalone SuDS systems at small-scale catchment areas could be a more effective approach; reducing the issues associated with historic infrastructure and frequency of flooding (see 3.2.1, 3.2.2). Despite these practical considerations, barriers of governance and community perception must be considered to raise greater awareness of the benefits linked to improvements in water and sanitation.

3.6 Conceptual Framework

Conceptual frameworks are a fundamental tool when combining the various aspects of multidisciplinary research projects, enabling themes and their connections to be visualised and grounded in the unique context of the project (Bryman 2012; Herod and Parker 2010). Figure 3-16 presents the concepts (chapter 2) and context (chapter 3) of this project as a novel conceptual framework on which the project was initially based, to respond to the literature gaps and address the research aim (represented by a '?' in the model).

Project Aim:
To investigate the potential use of SuDS as a method to reduce ZIKV transmission in favelas.
?

ZIKV:
i. Epidemic in Brazil during 2015-2017.
ii. Objective 1 is to identify if a connection exists between ZIKV and poor sanitation in favelas (<- - ->)

Sanitation:
i. Includes water supply, sewage removal and stormwater management.
ii. Existing literature acknowledges poor sanitation provisions in favelas – Objective 2.
iii. Relationship with the government and societal attitude influence the availability and quality of sanitation provisions in favelas.

Favela:
i. interventions are influenced by the relationship between the favela community and the government (←→).
ii. Health and Sanitation are indicators of vulnerability in favelas – with issues associated to environmental health.

Governance:
i. Encapsulates everything owing to the influence of the self-governed favela and the government run state who hold power over policy and decision-making.

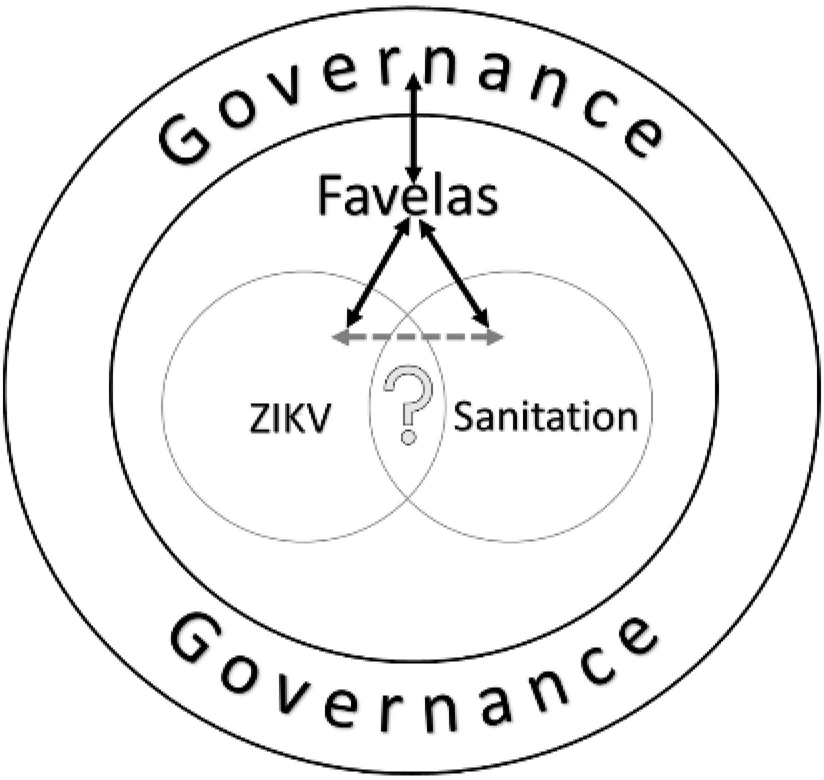

Figure 3-16: Preliminary Conceptual Framework with supporting justification

There are many issues associated with conventional drainage infrastructure in Brazil, including infrequency of water supply, lack of treatment for household sewage and inadequate capacity to deal with excess stormwater, attention is therefore diverted away from basic sanitation rights in favelas (Dias *et al.* 2018). Owing to the frequency of large-scale flooding events, most government sanitation interventions finance installation of additional grey-infrastructure, rather than funding routine improvements to existing sanitation systems (Miguez and Veról 2017) (see 3.2.1). Furthermore, as minimal regulation and mechanisms for accountability exist between governance bodies and the sanitation companies, there is a reluctance to invest in conventional drainage systems where there would be no profit for the company – further isolating low-income favela communities from future improvements (da Silva and Cerqueira 2016).

As favela communities typically lack access to basic utilities such as potable water, electricity and sewage disposal, there is an opportunity for investment and development in improved sanitation infrastructure which addresses the issues caused by inadequate management of stormwater, greywater, and sewage (Jiusto and Kenney 2016). Owing to challenges of terrain, the favela's proximity to existing formal infrastructure, and the complex relationships between the government and favela communities, facilitating connections to formal sanitation systems may not be possible, therefore alternative approaches must be considered (see 3.3). These issues whilst illustrating a lack of access to basic human rights, are also connected to wider issues associated with environmental protection and public health, by providing habitat opportunities for disease vectors such as mosquitoes and causing lasting environmental damage through pollution and degradation of waterbodies (see 3.3.3).

Poor sanitation infrastructure encourages improper storage of potable water and the accumulation of stormwater and greywater in open areas, therefore encouraging *Aedes aegypti* to inhabit areas where these favourable breeding conditions exist (Souza *et al.* 2018; Texeira and Cruz 2011). However, owing to a lack of sufficient literature examining the epidemiology of ZIKV in relation to indicators of poor sanitation in favelas (see 3.4.3), it is not yet possible to directly correlate these factors in the context of the ZIKV outbreak from 2015-2017. Therefore, this project will contribute further understanding of the association between ZIKV and favelas in order to discuss the potential for SuDS techniques to mitigate the poor sanitation conditions favourable to *Aedes aegypti*.

3.7 Conclusion

This chapter has examined the themes of governance, sanitation, favelas and ZIKV in the context of favelas in Brazil, with both academic literature and practical examples reviewed and critiqued. Findings have identified further research in this area is needed, specifically associated with the management of water and sanitation, and ZIKV. Having identified these key areas, a novel conceptual framework (figure 3-16) has been created as an appraisal of findings from chapters 2 and 3, and the current relationships between each theme. Chapter 4 takes a mixed-methods approach in order to address the aim and to investigate the multiple aspects of the projects, to wider understand this area of research and provide information related to both the current discourse and additional knowledge.

4.0 Methodology

4.1 Introduction

The purpose of this chapter is to outline the research approach and the processes adopted to produce results and fulfil the aim and objectives outlined in chapter 1.

An overview of the whole process is represented by figure 4-1, in which the decision-making process adopted when designing the methodology for the project is presented. Key decisions are presented in bullet points. Although figure 4-1 implies a step-by-step process, as research is a cyclical and reflective process, it was often necessary to alternate back and forth between stages and prior decisions when designing both methodological tools and analytical techniques.

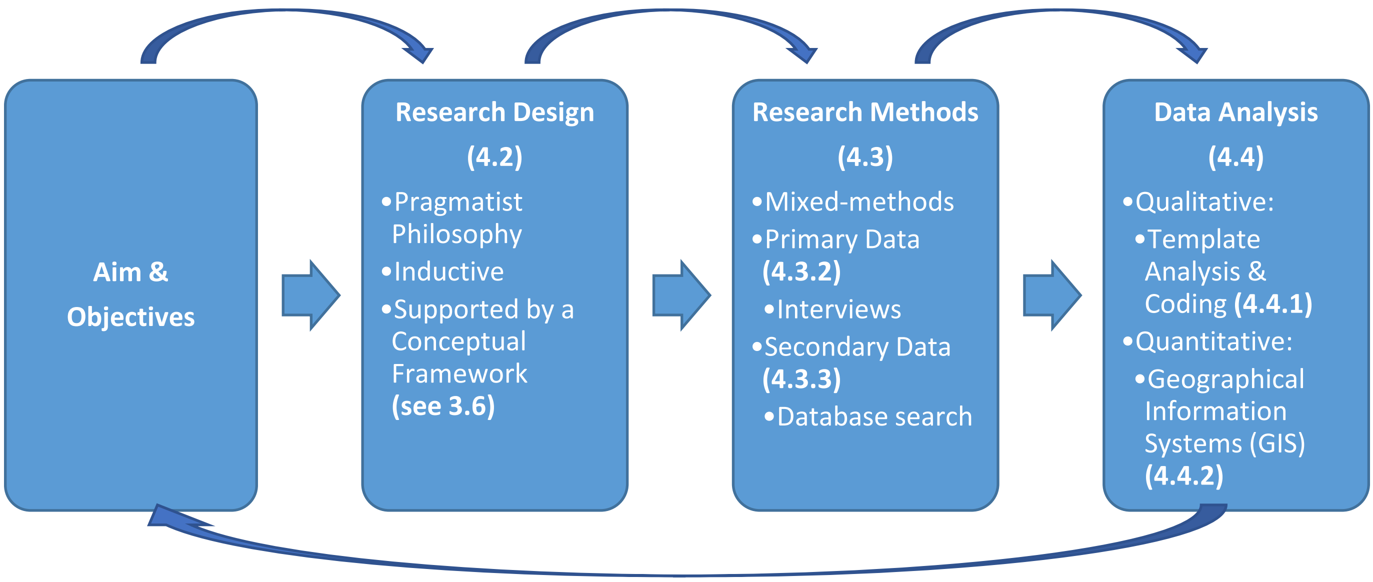

Figure 4-1: The methodology design process applied to this research project.

To sufficiently discuss each element, Chapter 3 will be split into three sections. The preceding section (4.2) will discuss the philosophical, theoretical and conceptual design features of the research project. In section 4.3, a rationale for each data collection method will be outlined along with a critical review of its application and benefits. Finally, the latter part of this chapter (4.4) will give further detail regarding data analysis choices and methods when reviewing primary and secondary data obtained during desk and field-based data collection.

4.2 Research Design

4.2.1 Research Philosophy

As the project seeks to explore the interaction between humans and the natural environment, this approach aligns itself best to the philosophy of pragmatic research (Patton 1990; Tashakkori and Teddlie 1998). Pragmatist research approaches adopt suitable methods and techniques that are best placed to respond to the needs of the unique research question. This is unlike research philosophies such as interpretivism or positivism which advocate for specific methodological approaches and methods to be utilised by researchers (Saunders, Lewis and Thornhill 2012). In most cases pragmatist researchers identify with both positivist (empirical, quantitative values) and interpretivist (subjective, qualitative data) approaches, acknowledging that by using varying data types and methods, the research is more rigorous, and findings are more substantiated (Keleman and Rumens 2008).

As pragmatist research questions are designed to gain a broad perspective on different themes or concepts, this often results in the adoption of a mixed-methods research approach. This is particularly relevant owing to the multidisciplinary nature of this research project, in which natural science and social science concepts are being applied to identify the feasibility for SuDS implementation, the wider impacts of ZIKV and inadequate water management in favelas. Therefore, as per a mixed-methods approach (Creswell 2003), the following data types and origins have been selected: primary qualitative data from subject experts and favela community members, and quantitative secondary spatial data and raw data representing the epidemiology of ZIKV.

The research methods and decision-making process adopted for this project are highlighted in table 4-1; with the most appropriate data and methods selected due to their suitability in line with the research aim, alongside being achievable in the timescale of the project.

Table 4-1: Situating a mixed-methods approach alongside the projects' research objectives

Research Objectives	Qualitative data?	Quantitative data?	Chosen methods
1) To identify if there is a connection between ZIKV and favelas.	Y	Y	Semi-Structured Interviews, Secondary Data Review, Database Searches for health data and spatial data.
2)To investigate current water management issues in favelas.	Y	Y	Semi-Structured Interviews, Secondary Data Review, Database Searches for socio-economic and spatial data.
3)To evaluate the feasibility of SuDS approaches in favelas.	Y	N	Semi-structured interviews, Secondary Data Review.

In the context of this project, by choosing interviews and health and spatial data to generate results, the project is utilising complementary methods adopted by both social science and natural science disciplines; thus, applying a more rigorous approach when responding to the research question (Bloomberg and Volpe 2012; Bryman 2012).

4.2.2 Research Approach

The initial inspiration for this project was generated following a discussion around the conditions in favelas that colleagues observed on a previous trip to Fortaleza in 2017 (Ceará State, Northeast Brazil – see figure 4-2), in which two favela communities were visited.

Figure 4-2: Map of Brazil with Fortaleza and Ceará State circled (Gage 2017)

In both Maracanau and Rosalina favela communities, several significant water management issues were identified; these issues are illustrated and annotated in figures 4-3 and 4-4.

Photo provided by : Sue Charlesworth

Figure 4-3: Maracanau community, Fortaleza (November 2017)

Photo provided by : Sue Charlesworth

Figure 4-4: Rosalina community, Fortaleza (November 2017)

In addition, around this time, two key papers were published that suggested a possible correlation between the epidemiology of the ZIKV and living conditions in favela/slum areas; owing to a higher number of confirmed ZIKV and microcephaly cases in favelas, when compared with the wider urban environment (de Souza *et al.* 2018; Snyder *et al.* 2017). Similarly, articles published by *The Guardian* (Brum 2016; Watts 2016) and other online sources at the height of the outbreak in 2016, also discussed this phenomenon with favelas being blamed for the spread of the virus. As outlined in 3.4.3, despite the virus being attributed to favelas, the written material of academics and journalists failed to discuss or link infrequent water supply and inadequate surface water management conditions to the preferred breeding sites of the mosquito; such as: uncovered containers storing drinking water and accumulation of surface water in the peri-domestic environment (tyres, solid waste, road/pavements).

For these outlined reasons the initial premise of the project was centred on the observations generated by the media and academics as well as observations made by colleagues - that there are a higher number of ZIKV and microcephaly cases in favelas; thus, demonstrating traits of an inductive research approach (Neuman 2014). As such, having identified the 'observation', the chosen research methods will adopt inductive reasoning to identify the theories, frameworks and concepts, that connect the epidemiology of the ZIKV and the characteristics of favelas together; this whole process is represented in figure 4-5.

Figure 4-5: The Inductive Research Approach (Adapted from Bryman 2012; Holt-Jensen 1988; Lodico, Spaulding and Voegtle 2010).

As a complementary research tool for pragmatist, mixed-methods approaches (see 4.2.1), adopting an inductive approach further enhances the quality of the research as it enables a combination of field research and desk-based study to obtain findings that best address the projects aim (Saunders, Lewis and Thornhill 2012).

4.2.3 Ethical Approval

Prior to commencing the research project and before commencing fieldwork ethical clearance was sought and approved by Coventry University's Ethics Committee (Appendix 6). As the project is based on Brazil's favelas, there were several health and safety considerations in place to ensure personal security when undertaking fieldwork.

4.3 Research Methods

4.3.1 Study Location

Rio de Janeiro city is regarded by many as the gateway to Brazil's wealthiest region (see figure 4-6) (O'hare and Barke 2002), however Rio de Janeiro is in fact a city of contrasts in terms of socio-economic conditions and the physical environment - with mountains, forested areas and beaches making up the varied landscape of the city (Teixeira and Cruz 2011).

Figure 4-6: Map showing the states and cities of Southeast Brazil (Hansen 2011)

Furthermore, despite the Southeast generating 60% of Brazil's Gross Domestic Product (GDP_ (Grosse 2019:13) and hosting a population of 80 million (IBGE 2010), it is acknowledged as having the 2nd highest level of housing deficit in Brazil (Habitat for Humanity 2019). As a result, overcrowding and illegal land occupation by favela communities is one of the major challenges facing many cities in the Southeast. For these reasons and other more practical factors (to be identified below) this influenced the selection of Rio de Janeiro as the main study area for this research project.

Rio de Janeiro Background

Rio de Janeiro consists of three main administrative areas, Rio de Janeiro State, Rio de Janeiro Metropolitan Region and Rio de Janeiro Municipality (city). Figure 4-7 (below) identifies each of these three areas and their respective boundaries.

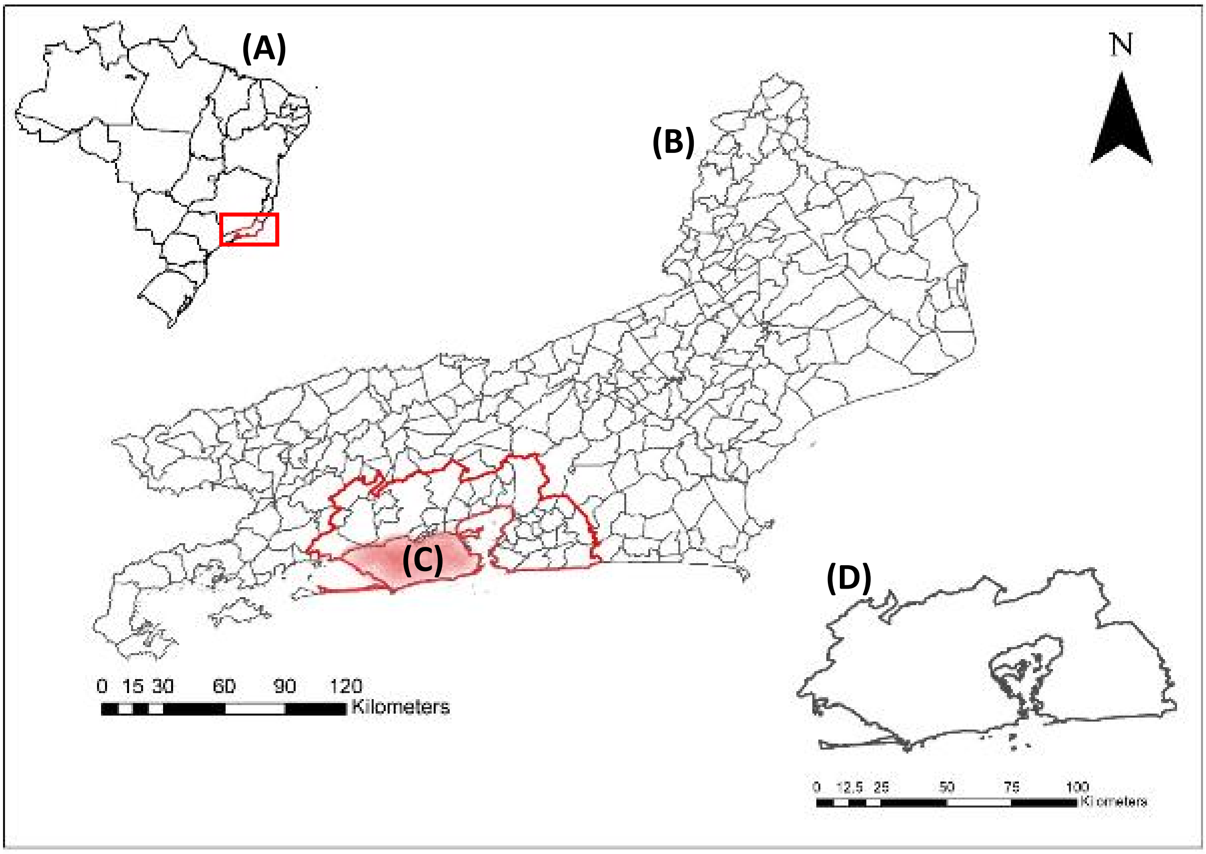

Figure 4-7: GIS Maps generated by the author outlining the administrative areas of Rio de Janeiro. A) Brazil with Rio de Janeiro State outlined B) Rio de Janeiro State with Rio de Janeiro Metropolitan Area outlined C) Shaded area of Rio de Janeiro Municipality (city) & D) Rio de Janeiro Metropolitan Area (IBGE 2019b).

With a population of 13.3 million distributed throughout the Metropolitan Area (Figure 4-7 (D)) (CIA 2018), the issues created by socio-economic inequalities and poor environmental management are further exacerbated owing to both high housing, population and favela densities – with 2,990 favelas located in Rio de Janeiro (IBGE 2019c; Teixeira and Cruz 2011). Consequently, inadequate housing conditions and poor management of water, sanitation and drainage infrastructure cause many ongoing environmental and health issues all with their own wider implications; one of which is that they are deemed suitable for mosquito breeding habitats (Guha-Sapir and Schimmer 2005).

Data Collection Considerations

Alongside the contextual factors outlined above, several practical factors also influenced the choice of Rio de Janeiro as the study location. As the Masters by Research (MReS) process encourages data collection to be facilitated inside a 12-month timeframe, to ensure this could be achieved potential considerations for both primary and secondary data had to be weighed against the time taken to both collate and analyse data, as well as the overall quality of the data to be obtained. These considerations are outlined, with further elaborations cross-referenced to appropriate sections of this chapter.

Primary Data Considerations:

1. Despite Rio de Janeiro not being the political capital of Brazil, it is where many influential government bodies, public institutions and NGOs are located. Therefore it was decided to be the most appropriate location to have access to a sufficiently diverse background of participants for the project, but also who are equally credible in their own fields and have an involvement with or influence policymaking - thus are able to provide a realistic appraisal as to the potential for SuDS investment and their ability to address and reduce proliferation of disease vectors in Brazil (as per the research aim and title).
2. As discussed further in section 4.3.2 - *Primary Data Collection,* my supervisory team and other departmental colleagues at the Centre for Agroecology, Water and Resilience (Coventry University) had a number of existing networking connections with academics situated in Rio de Janeiro, who were then able to act as either key informants or participants themselves (see pg.84).
3. Finally, ZIKV data from 2015 onwards was mostly centred in the Northeast of Brazil, concerning the states of Ceará, Pernambuco and Bahia (see figure 4-2) focused around disease transmission rates and monitoring (see 3.4.3). Creating a literature gap for new and complementary qualitative data exploring ZIKV epidemiology and the implications of inadequate water, sanitation and drainage.

Secondary Data Considerations:

1) Limited open access health data due to ethical considerations, government epidemiology data released periodically by Ministry of Health, broad focus not at micro-level.
2) In early stages of the ZIKV outbreak in Brazil, many questions of reliability and accuracy of data:
    - In a recent paper (Brady *et al.* 2019:5), the author states 'we only considered Zika data as reliable after the 08/12/15.'
3) Open access data appropriate for the project was identified (Brasil 2016 cited in Vissoci *et al.* 2018).
    - Data deemed credible and reliable having been published in a peer-reviewed journal.
    - Available data adhered to Brady *et al.'s* (2019) recommendation above – recording cases from January-December 2016.
    - The data is representative of all three administrative areas of Rio de Janeiro as discussed in section 4.3.1 - *Rio de Janeiro Background* (pg.82).

Having outlined throughout section 4.3.1, the numerous factors and considerations that influenced and underpin the reasoning and choice of Rio de Janeiro as a study area, it is clear to see that data has been collected by utilising both complementary methods alongside quantitative data representative of different geographical scales. Therefore, whilst ZIKV is not the sole focus of this research project, its distribution is a key factor when addressing research objective 1. As such, GIS will be used to display secondary empirical data, alongside presenting a discussion of key primary data findings obtained via interviews with research participants – both methods shall be discussed further in sections 4.3.2 and 4.3.3.

4.3.2 Primary Data Collection

Interview Schedule Design

By applying the conceptual framework (see 3.6) interview questions were developed alongside and aligned to the themes of the conceptual framework, with the intention to solicit individual perceptions and context-specific data from participants regarding the four thematic components of the project (Governance, Favelas, ZIKV and Sanitation) as well as the aims and objectives of the research project (Babbie 1992; Rhoads and Wilson 2010). In addition, two complementary interview schedules were designed to suit the contrasting backgrounds of intended participants: external stakeholders (such as university academics, government representatives, those involved with favela projects via NGOs/public sector) and favela community members themselves (participant backgrounds are discussed further on pg.90 (*Selected* Participants' Backgrounds*)*. An example of both interview schedules can be found in Appendix 1 and Appendix 2.

Both interview schedules maintained a semi-structured format, in which there was a provisional order of questioning. This allowed for the participant to lead the conversation based on their own knowledge and enabled the generation of additional lines of questioning to further explore any points of interest (Dunn 2005; Longhurst 2010). The only stylistic difference between the two interview schedules was the type of open-ended questions asked – either to obtain a short response or a more comprehensive answer (Hay 2016). This was a carefully considered factor, to ensure potential language challenges were addressed and to enhance the comfort of each participant. With regards to favela community members, the questions required short response answers on a range of topics relevant to the participant's everyday life – for example: "Where do you collect water from?". Whereas with external stakeholders, broad, open-ended questions were predominately utilised. Instead of soliciting the reality of life in a favela, the main aim was to have a thorough understanding of key factors such as government policy and scholarly research findings; in addition to the participant's individual perspectives on the challenges and barriers to adequate infrastructure and environmental health in favelas. An example of this questioning style is: "What do you think is the reasoning behind consistently higher infection rates in favelas, in comparison to the wider urban environment?"

Language Considerations

As alluded to previously, owing to the international focus of the project it was important to pre-empt and consider any potential challenges that might arise due to differences in spoken-language between the researcher and participants; for this reason, two key measures were implemented. Firstly, a translator was available and present for the duration of the interviewing processes, enabling participants lacking confidence in or knowledge of spoken English, to participate in their native language Portuguese. Similarly, in the case where participants were interviewed solely in English, having a translator present meant that any confusion caused by mistranslation (either by the researcher or participant) could be clarified, ensuring accurate representation of the participants thoughts in both the recording of the interview and from the perspective of the researcher. Furthermore as discussed and defined fully in the subsection *Recruiting Participants* (pg.87), the translator themselves was an initial key informant for the project, therefore they already held a rapport with several of the projects participant's and therefore put both myself (the researcher) and the participant at ease by facilitating a relaxed and open environment for discussion.

Secondly, another important language consideration was to ensure that each question was written in a style and format appropriate for translation and for the type of response required to complement the dataset (Longhurst 2010; Smith 2010). This was facilitated by design of each open-ended question as discussed above, either to obtain a short or more comprehensive response. However, whilst this ensured the comfort of and style appropriate to participants, this created an additional challenge in terms of the subsequent analysis as participant responses were often not replicable and therefore made drawing comparison between participants difficult - an example is provided in Table 4-2.

Table 4-2: Example of analytical challenges due to language

P1 – External Stakeholder Q: How well does public information about the prevention of ZIKV/chikungunya/dengue reach favela communities? *A: 'I cannot see a change in behaviour […] for you to change you have to do improvements that having a low income does not allow. … people do not link inadequate sanitation to disease […] so it is difficult to unite people in a good cause to demand solutions.'* -- *P15 – Favela Community Member* Q: In your community do people pay attention to ZIKV prevention? A: 'The president of the building's community association is very aware about this. He always tells people to not throw out their trash or store water in open containers.'

Benefits of using Interviews as a research method

Despite outlining the challenges of preparing and conducting interviews in the preceding section, there are numerous benefits to using interviews as a research method. The primary benefit is the opportunity to obtain a variety of perspectives from those involved in the direct context of the research – either through lived or career-based involvement (Hay 2016). This is unlike most quantitative approaches, whereby a statistically significant sample must be achieved; instead qualitative researchers concern themselves with understanding how participants experience and make sense of their lives and the subject matter of the research (Longhurst 2010).

Having varying perspectives is also a vital aspect of research projects where the researcher is not native to the context of the research (in this instance Brazil), as interviewing participants allows the researcher to gain a comprehensive understanding of key concepts both from a contextual basis and from differing subjective perspectives (Nash 2000). Additionally, by obtaining a variety of perspectives (both from community members themselves and external stakeholders), it ensured triangulation between primary and secondary data findings could be achieved; and therefore, enhanced the overall quality and credibility of the research project (Lincoln and Guba 1985; Valentine 2005).

Recruiting Participants

The main recruitment technique adopted during fieldwork was snowball sampling (Bryman 2012; Secor 2010; Valentine 2005). This snowballing approach is shown in figure 4-8, whereby a key informant connects with potential participants, who then through their own network of contacts then continue to connect the researcher to additional participants.

Figure 4-8: Visualising the Snowball Sampling technique (Bhat 2019)

Furthermore, once connected to interested parties via a key informant, purposeful sampling was utilised to select the most appropriate participants for the project. This second sampling method was followed by building a profile of each proposed participant's current and previous backgrounds, and then assessing how well they related to one or more of the conceptual themes of the project (ZIKV, Sanitation, Governance, Favela/s) (Cameron 2005; Gilchrist and Williams 2012).

Owing to the one-year timeframe of the research project, utilising existing contacts as initial informants meant the participant recruitment process was sped up, as they were able to vouch for the credibility and trustworthiness of the research project and any information, they may share with me as the researcher. Furthermore, having an initial endorsement from each informant meant that potential participants in their own networks would be more likely to participate in the project themselves.

To summarise, the participant recruitment process using snowballing and purposeful sampling methods involved (Cameron 2005; Gilchrist and Williams 2012):

1. Brazilian academics connected to Coventry University were contacted by email and supplied with the intended aim, objectives and data collection methods for the project.
2. Informants then distributed the details of the project amongst their own networks (as illustrated in figure 4-10, above).
3. Interested participants made contact with the researcher either directly or via the informant and their suitability for inclusion was discussed by prior discussion; if deemed suitable, a time, date and location for the interview was scheduled (see *Interview Procedure*, Steps 1&2 pg. 91).

Recruitment Challenges

Whilst many researchers and projects find participants with ease, it is commonly acknowledged that this is not always the case, especially when specific target audiences are being sought for inclusion (Gomez and Jones 2010). This was the case when trying to identify, recruit and access favela participants during fieldwork. Owing to the Brazilian Presidential election results being announced on the 28th October 2018 (three days prior to planned fieldwork), there was an increased possibility of heightened violence in favela communities throughout Rio de Janeiro for the duration of the trip. This meant that access to favela participants in-situ was not possible due to safety and security concerns (see Appendix 3). (see Appendix 3).

To ensure an internal perspective on favela conditions remained, a complementary technique called 'on-site recruitment' was adopted to recruit two favela participants – involving the identification and inclusion of participants who are available near to, or at similar locations to the participants already confirmed for inclusion (Krueger 1988). In the case of this project, both participants were sought due to intersecting roles or routine activities at locations that were also visited to conduct interviews with external stakeholders – hence the name 'on-site recruitment'. However, to adhere to Coventry University's ethics protocol and to maintain the anonymity of all participants it would not be appropriate for these locations to be named.

Selected Participants' Backgrounds

A variety of different participants were sought for their contrasting backgrounds, due to their complementary and multi-disciplinary benefit to the research project; this included a variety of external stakeholders and favela community members. These contrasting backgrounds are shown in table 4-3:

Table 4-3: Summary of research participant backgrounds

Background	Participant Identifier	Total Participants
Social Science:		
- Health Management Analyst	P2	3
- Public & Environmental Health Researcher	P4 & P5	
Natural Science:		
- Public Health Technologist	*P1 & P6*	7
- Arbovirus Specialist	*P9*	
- Sanitary Engineer & Microbiologist	*P11*	
- Sanitation and Environmental Health Researcher	*P12 & P14*	
- Lab Technician	*P13*	
Health Workers:		
- Community Health Agent	P7	2
- Nurse	P8	
Government Employees:		
- Ministry of the Environment Specialist	P3	2
- Social Welfare Technician	P10	
Favela Community Members	P15 & P16	2
		= 16

In total 16 face-to-face interviews were conducted with an array of participants from different backgrounds, disciplines and careers; this was to ensure that the four conceptual areas of the project (ZIKV, governance, favela/s, drainage) could be addressed from different perspectives, as well as being directly represented in the projects' sample size. Furthermore, whilst not a primary consideration in the initial inclusion of participants, there was a balanced representation of gender, with 9 females and 7 males respectively.

As outlined in the previous section (see *Recruitment challenges*), due to the diverse array of participants being sought for inclusion, as well as the short timeframe to conduct interviews (4 days), this resulted in a small sample being obtained. Although achieving a statistically significant sample size is not typical of qualitative research (Longhurst 2010), owing to the multidisciplinary nature of this project it is important to be aware of the challenges associated with small sample sizes when attempting to make claims to knowledge. Nevertheless, as qualitative data is not the sole data-type used in this project, the results obtained from both primary and secondary data collection have been triangulated against one another to validate findings and enhance the overall credibility of the research presented in this thesis (Valentine 2005; White 2010).

Interview Procedure

Interviews were conducted over 4 days, during fieldwork activities in Rio de Janeiro. Each interview lasted on average 1.5-2 hours per participant. There were several stages to the interviewing process, these were as follows:

1. Prior to each interview participants were provided (by email/in-person) with a summary sheet of the research project along with a *Participant Information Sheet* and *Participant Consent Form* – as per Coventry University's ethics regulations. Simplified versions of both ethics' forms were given to those who expressed concern with their comprehension of English.
2. Time and location agreed with the participant, translator and researcher. Participant interview timetable drawn up.
3. Prior to commencing interviews with participants, time was spent with the translator to outline the interview schedule and to confirm that concepts were correctly understood to enable facilitation of accurate translation.
4. On the day of each interview, the interview schedule was reviewed by the researcher and translator to ensure each interview included topics relevant to the participant's area of expertise, and to encourage free-flowing discussion with participants.

5. Participants were met as previously agreed at a chosen location– mostly in their own offices to ensure comfort and a quiet environment (Denzin 1970). Formal introductions were made with the participant, and any prior questions about the research project were addressed.
6. In cases where the participant spoke minimal English, the interview maintained the format of researcher, translator, participant, translator and researcher (repeat) – with either the researcher or translator interjecting to seek clarification from the participant; either to improve the accuracy of the translation or to gain additional information.
7. The formal process for each interview was as followed;
    a. Project detail, intended interview outcomes, and ethical considerations discussed with the participant. *Participant Consent Form* signed by the participant and researcher*;*
    b. Consent gained from the participant for the interview to be audio recorded;
    c. The formal interview began with participants asked to outline their previous and ongoing work, this ensured rapport was built between participants and researcher and aligned subsequent questioning to their relevant expertise (Longhurst 2010);
    d. Questions were asked by the researcher as per the interview schedule, allowing for the order of questioning to be directed by the participant. Additional questions were asked to seek clarification/enhance understanding;
    e. At the end of the interview, the interview schedule was reviewed, any thematic areas of the research project omitted from the discussion were then re-addressed with the participant;
    f. During stages c. - e. supporting notes were taken by the researcher, to record discussion points of interest and to clarify the spelling of Portuguese place names/phrases relevant to the project (Longhurst 2010);
    g. The interview was concluded, key concepts raised by the participant were summarised and reviewed to ensure accurate comprehension by the researcher; participants were then given the opportunity to add anything additional they felt to be relevant;

    h. The interview ended, and the recording device turned off. Participants were thanked for their involvement and given contact details of the researcher for follow-up.

8. Interview notes were reviewed and typed up on the day of each interview and filed alongside the corresponding audio recording on both a Coventry University OneDrive account and a password-protected memory stick.

4.3.3 Secondary Data Collection

To ensure both a theoretical and practical basis for the project, it was necessary to make use of both qualitative and quantitative secondary data sources (see, Table 4-1., 4.2.1) (Robbins 2010). As the project takes a practical-oriented approach, scholarly journal articles, grey literature such as; government/organisational reports and technical papers, as well as online media sources (websites/news articles) were reviewed, which aided the construction of a thorough literature review representative of both the academic discourse and context-specific material.

Qualitative Data

Although the use of qualitative secondary data enables researchers to quickly gather contextual material from a wide range of sources to understand the previous and current discourse in relation to their own research project, there are also several unique issues identified when using this data collection technique. The main challenge is that the researcher cannot customise this secondary data to the needs of the project, therefore data replication is problematic; requiring additional primary or secondary sources to verify and triangulate the data (Clark 2005). Furthermore, when searching for and reviewing academic papers, it was also necessary to ensure the credibility of each article and the journal it is published in. This was achieved by referring to journal and author metrics, alongside identifying and selecting articles for inclusion in the project that were sought via reputable scholarly databases, such as Scopus, Science Direct and PubMed (Radhika 2018).

Another unanticipated challenge encountered when searching for context-specific secondary sources, was the lack of Brazil-specific articles and reports published in English. Similarly, grey literature including Brazilian government legislation was also only available in Portuguese -

therefore both document types required *Google Translate* to comprehend. For these reasons, the scope of the thematic review (Chapter 3) was therefore limited, as most academic databases collate English-language papers only. To address this, a search of ‘Google Scholar’ and the ‘Academic Search Complete’ databases was undertaken, using Portuguese search terms generated by *Google Translate*. However, this approach resulted in *Google Translate* providing a literal translation rather than ‘colloquial’ terminology and yielded few search results, with many of these results often not directly related to this research at all – see figure 4-9 below.

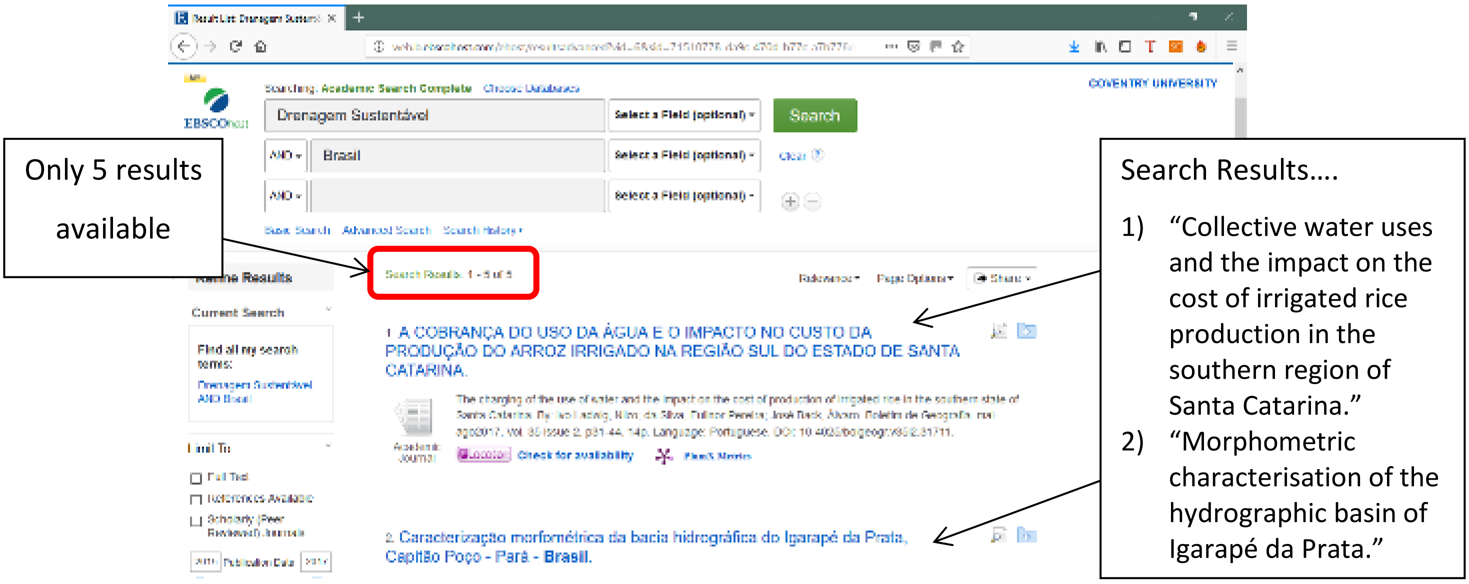

Figure 4-9: An example of database search results when using the search terms ‘Drenagem Sustentável (Sustainable Drainage)’ and ‘Brasíl (Brazil)’ in Portuguese.

Consequently, many of the Portuguese-language texts included throughout the project were recommended by Brazilian subject experts and interview participants as key reference documents. Whilst these suggested documents proved useful and aided the finding of other similar resources; through in-text citations, specific organisations mentioned, or the phrasing of specific themes in Portuguese, it was necessary to use *Google Translate* to fully understand their contents and to enable their inclusion in both chapter 2 and 3 - as a reflection of the wider body of current literature.

Quantitative Data

To address research objective one: *To identify a connection between the ZIKV and favelas*; it was necessary to search online quantitative databases, to gather raw numerical data to support the demonstration and discussion of an association between ZIKV and favelas – with data being sought that represents the location of favelas, and the number of ZIKV and microcephaly cases respectively. In addition, by generating additional lines of quantitative enquiry, a complementary mixed-methods approach was achieved, that allowed for conformational triangulation between both the primary and secondary datasets obtained during fieldwork (White 2010).

To suitably address research objective 1 in the 1-year timeframe of the project, open access quantitative databases were a vital resource; whereby raw data is collated by other academics and presented in a clear and consistent manner, rendering it suitable for different presentation types or statistical analysis methods. In the case of this project, the availability of georeferenced spatial data reflecting disease epidemiology and the location of favelas lent itself to being manipulated and visualised using Geographical Information Systems (GIS) software (see 4.4.2, pg.102) (Batty 2010; Martin and Pavlovskya 2010).

Whilst secondary databases enable time to be saved during data collection, there are several disadvantages; therefore it is important to acknowledge the confines of the obtained secondary data, due to the methodology and definitions of variables being constructed by someone else (Martin and Pavlovskya 2010). This issue is typically found in government census questionnaires, whereby socio-political and economic factors often influence the construct of questioning; with an underlying intention to skew data to present idealistic outcomes rather than the reality. As a result, these constraints often directly impact on the creativity of analytical choices and approaches – thus limiting the true scope of the research project (Hoggart *et al.* 2002; Scott 1990).

This was a vital consideration when deciding to use government produced data in this project with the reliability of each dataset considered prior to selection. Furthermore, in the context of Brazil the government are reluctant to present the true extent of favelas due to their illegality, and to avoid pressure to improve services and facilities in informal settlement areas

(Snyder *et al.* 2017); for this reason, favelas are often extensively underrepresented in government records.

Whilst census data and geospatial data is readily available on Brazilian government websites, due to ethical challenges, locating open-access health data was much harder. Fortunately, Vissoci *et al.* 2018's paper provided access to the raw secondary data, that authors obtained via the Brazilian Ministry of Health (Brasil 2015 cited in Vissoci *et al.* 2018) – documenting both ZIKV and microcephaly cases. However, despite the availability of the data, it is only a reflection of 11 months of data in the middle of the Brazilian ZIKV outbreak (Jan-Dec 2016) and can be criticised in that it does not fully demonstrate the longevity of the outbreak and true epidemiology of ZIKV. Further discussion and explanation regarding the application and analysis of the data to produce results can be found in 4.4.2 (pg. 102).

4.4 Data Analysis

4.4.1 Qualitative Data Analysis: Introduction

To achieve results from qualitative data, a process of consolidation and categorisation of data must occur, that enable the key themes and patterns to emerge from the dataset. Once data analysis is complete, instead of providing a narrative between researcher and participants, research outputs should reflect a rounded interpretation and discussion of findings alongside the existing literature, that supports the generation of new ideas (Neuman 2014). As summarised by Crabtree and Miller (2012:166) the full analysis process should involve:

a) 'creating a code manual or coding scheme; (see *Primary Analysis Process*, step 2, pg. 99)
b) hand or computer coding the text; (see *Primary Analysis Process*, step 3 , pg. 99)
c) sorting segments to get all similar text in one place, and; (see *Primary Analysis Process*, steps 4- 6 ,pg. 99)
d) reading the segments and making connections that are subsequently corroborated and legitimised.'(see *Primary Analysis Process*, steps 6-8, pg. 100)

Qualitative Data Analysis Background

Coding

The most common initial output of the qualitative analysis is a collection of 'codes.' It is then from this collection of codes that the researcher can then organise, rank and evaluates research findings to build key areas for discussion (see Appendix 4) (Charmaz 2008; Cope 2010; Saldana 2013). Typically, generated codes are either short phrases or single words that infer meaning, which the researcher uses to make sense of and highlight key findings from often large datasets (Crang 2005; Huberman and Miles 1994; Neumann 2014).

There are several different ways to approach and conduct qualitative data analysis (Saldana 2013), with the coding process evolving depending on the demands of the research being undertaken. For this reason, there is no single agreed analytical method that can be rigidly followed and reproduced by qualitative researchers – this is unlike analysis methods adopted in quantitative studies (Crang 2005; Cope 2010). Whilst coding is a way to organise rich data material; codes are not the final output of the analytical process despite the common misunderstanding that they are an 'explanatory framework in themselves' (Crang 2005:224).

At a basic level codes often represent the key themes of a research project, however as the coding process becomes more iterative it is common for sub-codes and sub-themes to be created and as such a hierarchy of key findings and categorisation emerges (Bryman 2012; Crabtree and Miller 2012; Lewins and Silver 2007; Moules *et al.* 2017). As the researcher becomes fully submerged in the analytical process, generated codes eventually become more substantial; and if data collection has been successful, the output should be a collection of codes linked to the wider conceptual framework of the project (see Appendix 4, pg.180)(Cope 2010).

Template Analysis

As one of many coding approaches, Template Analysis is a specific approach to analysis and coding that allows the researcher to fully immerse themselves in the analytical process, whereby specific themes are being sought from a dataset (Crabtree and Miller 2012; King 2004). The main benefit of conducting 'Template Analysis' is that the coding process begins with predefined *a priori* codes, that are specifically tailored to the research project and used to develop a holistic conceptual framework; either prior to or after data collection (see 3.6) (Brooks *et al.* 2015; King 2004; Wainwright and Waring 2008). Utilising *a priori* codes enables researchers to focus on specific elements of the dataset and ensures that related parts of the text are simultaneously analysed earlier on in the process; aiding thorough analysis of themes and for identification of subsequent connections to occur rapidly (Brooks *et al.* 2015; Crabtree and Miller 2012; Huberman and Miles 1994). As such, the Template Analysis approach is focuses specifically on generating theory from the data, by adopting a thorough analytical approach, as such it aligns well to inductive research projects such as this (Bryman 2012).

Advantages and Disadvantages

As one of the main methods that qualitative researchers adopt, qualitative data coding faces two key criticisms. The main challenge is that by generating short, concise codes, the initial narrative of the dataset is lost, with any additional supporting contextual elements that are subsequently coded with different terms (Bryman 2012; Coffey and Atkinson 1996). Although output codes and their categories do not provide a comprehensive description of participant views, to address this issue a glossary of key quotes was generated – that enhanced the quality of analysis and support discussion of findings. Similarly, issues of reliability have also been raised, owing to individual subjectivity of the researcher's analytical and coding choices. However, this is contradicted by King (2004:256), who identifies that Template Analysis encourages the researcher to be flexible and ensure multiple angles of analysis are considered - by reviewing transcripts and coding hierarchy several times to ensure a 'rich description of the data is obtained.' Similarly, by aligning the *a priori* codes to the project's conceptual framework, this allowed for there to be a clear focus on each theme and identification of the relevant relationships or attributes to be coded (Rudestam and Newton 2007).

Primary Analysis Process

To analyse qualitative data obtained from face-to-face interviews (see 4.3.2, pg.84), and in line with the Template Analysis approach, the following steps were carried out:

1. Transcription and consolidation of each interview and any handwritten notes to establish a broad overview of initial interview findings (Crang 2005).

2. An initial set of *a priori* codes based on the project's conceptual framework were identified – to include; governance, sanitation, favela/s and ZIKV (Brooks *et al.* 2015; Crabtree and Miller 2012; King 2004; Huberman and Miles 1994).
3. With the initial 4 *a priori codes*, interview questions were aligned to the most applicable code. This began by splitting transcripts by hand and creating piles of similar transcript excerpts per question (Crabtree and Miller 2012).
    i) It is common for Qualitative Data Analysis Software*;* such as NVIVO to be utilised from this phase onwards. Due to time constraints and unfamiliarity with the software, it was decided coding would be conducted by hand using Microsoft Office programmes (Word and Excel) to support notation of codes (Crang 2005).
4. Following editing and then sorting transcript text into comparable segments, responses were re-read and redacted to remove any unrelated information, and participant discussion points were reassigned to better-aligned questions – this process was repeated until all transcripts and questions had been reviewed, with key quotations added to a quote glossary for cross-referencing in the later analytical phases (Crabtree and Miller 2012).
5. With the re-ordered and multi-participant responses, the coding process was undertaken by identifying key recurring themes or interesting insights from the text, assigning a short-hand description and then creating subsequent codes. This process is illustrated in table 4-4.

Table 4-4: An example of the coding procedure applied to this project; from transcript to codes.

Transcript	Short-hand description	Codes
"The federal level states that sanitation is fresh water supply, sewage collection and treatment and drainage systems. But at the local level each municipality can choose what they want to do. They have their own independence and autonomy." [P1]	Government sanitation priorities. Federal Vs Local (Municipality) agenda. Municipality decide agenda.	FEDERAL SANITATION POTABLE WATER SEWAGE REMOVAL SEWAGE TREATMENT MUNICIPALITY INFRASTRUCTURE AGENDA
"There is no piped infrastructure in favelas the sewage and waste is often put into the river by the community. Communities should be taught how to recycle greywater, so less waste is put into the river. In communities, the education is what is lacking so many people will see greywater and sewage to be the same thing. There are also problems with pathogens in the water which cause to disease. A social project is needed to mobilise and teach the people about the important concepts relevant to your research project, before the implementation of infrastructure so they can work with you." [P4]	Lacking infrastructure in favelas. Raw sewage/greywater discharged into rivers. Lacking awareness amongst community – education is necessary to solve these issues and engage community.	NO SANITATION INFRASTRUCTURE DISCHARGE WASTEWATER INTO RIVER LACKING AWARENESS OF ENVIRONMENTAL ISSUES HEALTH CHALLENGES EDUCATION/AWARENESS BUILDING BOTTOM-UP EMPOWERMENT
"The problem is that projects developed in favelas are in single isolated areas, there are also problems with corruption, so money isn't always spent correctly on projects. The projects are not sustainable or effective enough to solve the problems." [P5]	Lacking integration of projects. Accountability challenges with money, corruption common. Projects are often unstainable and do not address the issues correctly.	HOUSE-TO-HOUSE IS LOW-SCALE CORRUPTION MONEY ACCOUNTABILITY SUSTAINABILITY

6. Once a list of extended codes was generated (examples provided in column 3, table 4-3), a hierarchical weighting was applied to the codes that recurred most frequently. Themes were then sorted into categories and sub-categories linked to the conceptual framework and subsequent *a priori codes* (see figure 4-10, below) (King 2004).

I. SANITATION IN BRAZIL
  a. POTABLE WATER
    i. SUPPLY CHALLENGES
    ii. CONTAMINATION
  b. SEWAGE REMOVAL
    i. COMBINED SEWERS
  c. SEWAGE TREATMENT
    i. LACKING SEWAGE TREATMENT WORKS
    ii. RAW SEWAGE DISCARGED BY OCEAN OUTFLOW
  d. DRAINAGE
    i. GREYWATER
    ii. STORMWATER
    iii. FREQUENT FLOODING
      (1) BLOCKED DRAINS/GULLY POTS/PIPES OVERFLOW
    iv. LOWEST GOVERNMENT SANITATION PRIORITY
      (2) UNMAINTAINED INFRASTRUCTURE

II. SANITATION INFRASTRUCTURE AGENDA
  a. EVERYONE
    i. INADEQUATE CAPACITY
    ii. POOR QUALITY
    iii. LEGAL AREAS ONLY
  b. FAVELAS
    i. UPGRADING/IMPROVING
    ii. RELOCATION
    iii. REMOVAL

Figure 4-10: A sample selection of codes organised into categories and sub-categories

7. Similarly, to 'axial coding' in Grounded Theory (Glaser and Strauss 1976), each transcript was re-reviewed and re-examined following specifically chosen codes to gain greater depth from the data and to ensure that originally coded ideas re-emerged from this additional reviewing process – preventing bias or subjectivity related to themes (Cope 2010).

8. Subsequently, additional coding hierarchies were generated from inductive development - owing to extensive delving into the data (Boyatzis 1998; Braun, Clarke and Rance 2014), were then aligned to each original *a priori* code.

9. A final theme called 'outputs' was generated, and the remaining un-categorised codes assigned to this theme.

Having followed this primary analysis process (steps 1-9), a 'codebook' of key codes and their relationship to the conceptual framework of the project was created (see Appendix 4). This resulted in the generation of 5 broad thematic areas with 15 Categories (indicated by 'I.'), 58 sub-categories ('a.'), 117 primary sub-categories ('i.'), and 55 secondary sub-categories ('(1)').

Secondary Analysis: Aligning Codes to the Project Objectives

Following the completion of qualitative data analysis, it was necessary to re-address the conceptual framework themes: ZIKV, governance, favela, sanitation and the original aim and objectives of the project and align the output codes and resultant key quotations to each objective and thus the wider context of the research project. As there were two sets of interview schedules, aimed at either external stakeholders or favela community members, this process was conducted twice. A summary of both interview schedules and their alignment to the project objectives can be found in Appendix 5.

Having aligned each question and their respective themes together, this will aid the generation of the results and discussion chapter (Chapter 5). With each objective discussed and addressed in turn, to evaluate and contribute to the overall research aim and the generation of knowledge in the areas related to this project.

4.4.2 Quantitative Data Analysis: Using GIS

Reasons for GIS Integration in the Project.

As GIS is a common tool utilised by biologists and epidemiologists when mapping the spread of disease and to identify any potential underlying causes for disease distribution, the generation of maps as part of this project was deemed a suitable method for inclusion and particularly appropriate to the multidisciplinary research themes (Goodchild 2010). Furthermore, a discussion around the key challenges of using secondary data, along with specific challenges of the chosen data sources have been previously outlined in section 4.3.3 - *Quantitative Data* (pg. 95).

GIS Methodology

To address research objective 1: *To identify if there is a connection between ZIKV and favelas*, raw epidemiological data recording ZIKV and microcephaly cases was located; as well as shapefiles showing Rio de Janeiro state – broken into each census tract level (region, municipality, district etc) and the locations and area of each favela.

Data Sources and Formatting

Open access spatial data files are compiled by The Brazilian Institute of Geography and Statistics (IBGE – *Instituto Brasilierio de Geografia e Estatística*) and are available from their *Mapas* database (IBGE 2019a). The spatial data files used in this project are aligned to Brazil's 2010 census tracts with separate files identifying firstly, Rio de Janeiro's main municipalities (IBGE 2019b) and secondly the location of favelas (IBGE 2019c). Data on the number of cases of ZIKV and microcephaly in Rio de Janeiro state were extracted from the Brazilian Ministry of Health (Brasil 2016 cited in Vissoci *et al.* 2018). This is summarised in table 4-5:

Table 4-5: Quantitative data type, description and source utilised in the project.

Data Type	Description	Source
Spatial	Rio de Janeiro & associated districts census tracts	(IBGE 2019b)
	Locations of Favelas	(IBGE 2019c)
Numerical	ZIKV cases	(Brasil 2016 cited in Vissoci *et al.* 2018)
	Microcephaly cases	

Whilst ZIKV incidence data was available at a national level (Brasil 2016 cited in Vissoci *et al.* 2018), this was deemed unsuitable for identifying at a localised level whether a relationship exist between ZIKV and favelas. Therefore, prior to inputting case data into ArcGIS, data was aggregated by State, with any data outside of Rio de Janeiro State subsequently removed from the dataset prior to input in ArcGIS. Finally, confirmed cases of ZIKV and microcephaly were then attributed to each district census tract of Rio de Janeiro State on a weekly basis, with recorded data collated over an 11-month period, from January 2016 - December 2016.

Inputting and manipulating data in ArcGIS

Figure 4-11 outlines the main processes adopted by the researcher to: identify data, format the data prior to GIS importation, create the necessary files needed to import into ArcGIS and then the GIS processes utilised to display and visualise the data.

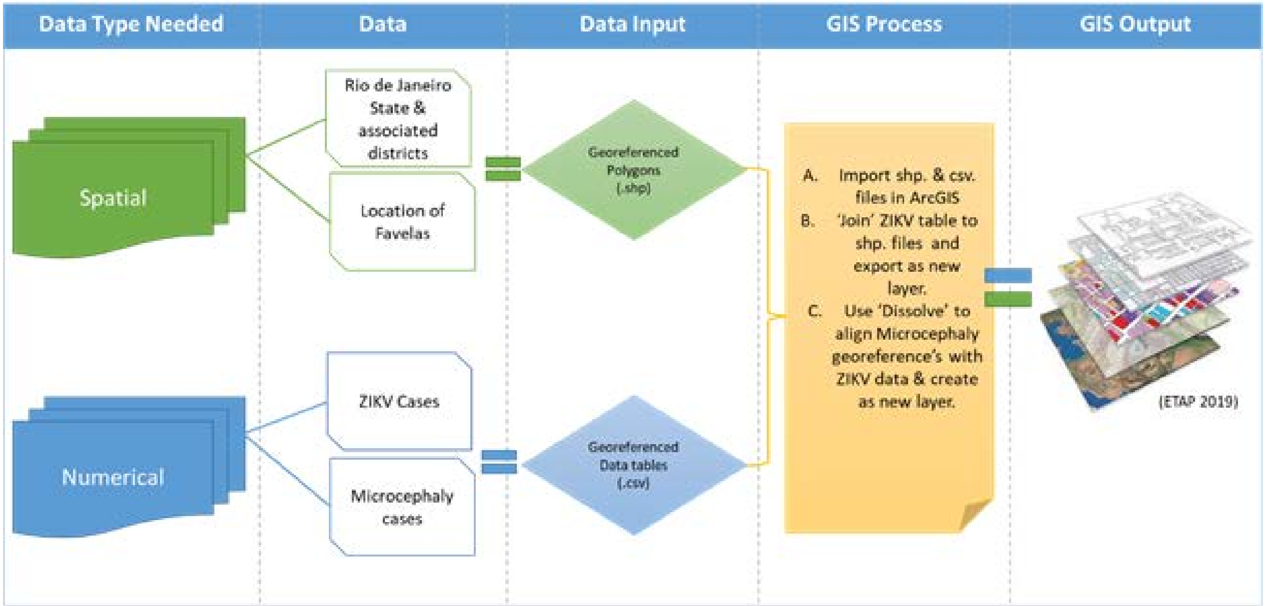

Figure 4-11: GIS process followed to produce original maps

Results & Analysis

Having adhered to the chosen process illustrated in figure 4-11, 7 maps have been generated that present the data outlined in Table 4-4. The final output maps of this project include: the distribution of both ZIKV and microcephaly throughout Rio de Janeiro State, ZIKV epidemiology specifically focused on Rio de Janeiro Metropolitan Region and the density of formally identified favelas inside each municipal area compared alongside the number of ZIKV/microcephaly cases. In turn these maps will support addressing research objective 1 – *To identify if there is a connection between ZIKV and favelas*, as such they will sit alongside qualitative findings related to objective 1 (see 5.2.2).

4.5 Conclusion

In conclusion, to adhere to the objectives for this project and a pragmatist research philosophy, a complementary mixed-methods approach was adopted to support the research aim: *To identify the potential for use of SuDS as a method to reduce ZIKV transmission in favelas*. Both primary and secondary data have been utilised, comprising face-to-face semi-structured interviews with 16 participants of varied backgrounds (4.3.2), as well as a review of both qualitative and quantitative secondary data (4.3.3) – addressing objectives 1, 2 and 3.

Qualitative secondary data sources underpin and are cited in the literature review (chapter 2), whereas quantitative secondary data has been utilised to address research objective 1, obtaining both spatial and numerical data relating to the geographical distribution and epidemiology of ZIKV and microcephaly throughout Rio de Janeiro. To generate results following analysis, a Template Analysis approach was followed the interview dataset, with each phase of the coding process underpinned by *a priori* codes - relating to the four main thematic areas of the project's conceptual framework (ZIKV, Sanitation, Governance, Favela/s) – enabling the generation of a codebook, containing key quotes and codes aligned to each research objective for further discussion in chapter 5. Additionally, having formatted the raw data pertaining the epidemiology of ZIKV and microcephaly along with the distribution of favelas throughout Rio de Janeiro state, metropolitan area and municipality, a series of maps have been produced using ArcGIS that triangulate qualitative data, and will inform and underpin the subsequent results and discussion chapter (Chapter 5).

5.0 Results and Discussion

5.1 Introduction

This chapter presents the results of the project, combining findings from both qualitative and quantitative data collection in response to the objectives stated in Chapter 1. Findings will be outlined and discussed in relation to the existing body of academic literature connected to the key themes (Chapter 2), as well as context-specific literature relating to public and environmental health issues that exist in Brazil's favelas (Chapter 3).

This chapter comprises three main sections, with findings discussed against each objective:

1. To identify if there is a connection between ZIKV and favelas (see 5.2)
2. To investigate current water management issues in favelas (see 5.3)
3. To evaluate the feasibility of SuDS approaches in favelas (see 5.4)

Section 5.4.2 presents two novel conceptual models which represent a synthesis of the main findings discussed throughout sections 5.2-5.4; to address the project's main aim: *To investigate the potential use of SuDS as a method to reduce ZIKV transmission in favelas*. The basis of each framework is discussed and linked to key findings, with supporting critique and opportunities for future work to enhance and improve the framework provided.

Having illustrated the area of study, 5.6 will highlight the main findings associated with the research as well as outline the extent in which the aim and objectives have been met. Novel contributions to knowledge are reviewed and recommendations for further research identified.

5.2 The connection between ZIKV and favelas

5.2.1 Qualitative results summary

When gathering responses during fieldwork, several different angles of questioning were presented to participants to address objective 1 (see Tables 5-1 and 5-2). This included government prevention approaches, favela conditions attributable to mosquito-vectors, and the impact of ZIKV/microcephaly on public attitudes and perceptions.

Table 5-1: External stakeholder interview questions relating to objective 1

Are you aware of any public initiatives/schemes initiated in the wake of the Zika outbreak in 2015 – to include the wider public and to favela communities?
How well does information about the prevention of Zika/dengue/chikungunya reach favela communities? Do favela communities respond to the information they are given?
Has the increase in microcephaly changed attitudes towards mosquito-transmitted disease?
What do you think is the reasoning behind consistently higher infection rates in favelas, in comparison to the wider urban environment?

Table 5-2: Favela community member interview questions relating to objective 1

Average number of people living in the household? What are the common relationships between household members? E.g. Grandmother, Mother, Father and Sisters etc.
What is the dwelling layout and condition/quality of construction? What building materials are used to build homes?
Where do they collect their water from? Where do they store Water? Do they use covered or uncovered water containers? Is water stored inside or outside of the house? Do they use any rainwater harvesting methods to collect water?
Do households/the community have access to insecticide to treat the water?
Where do they defecate? How do they flush it? How many people use the toilet?
How do they dispose of solid waste? Is there any formal garbage collection?
Has their community been involved in any Zika (chikungunya/dengue/yellow fever) campaigns or visited by outreach workers? Do you think Zika and Congenital Zika Syndrome (Microcephaly) is a perceived problem for the community?

Several themes emerged aligned to objective 1, with participants addressing key challenges in the implementation and dissemination of government campaigns to prevent mosquito-vectors. Participant responses reflected numerous communication methods, advice and community initiatives, including TV adverts, radio broadcasts, posters, and leaflets. Figure 5-1 is an example leaflet distributed by a community health worker based in favelas *'[Community Health Workers] have set routines [to monitor health parameters] … but if there's an epidemic like Zika… [they spread] information about standing water and mosquitoes' (Participant 7 (P7).*

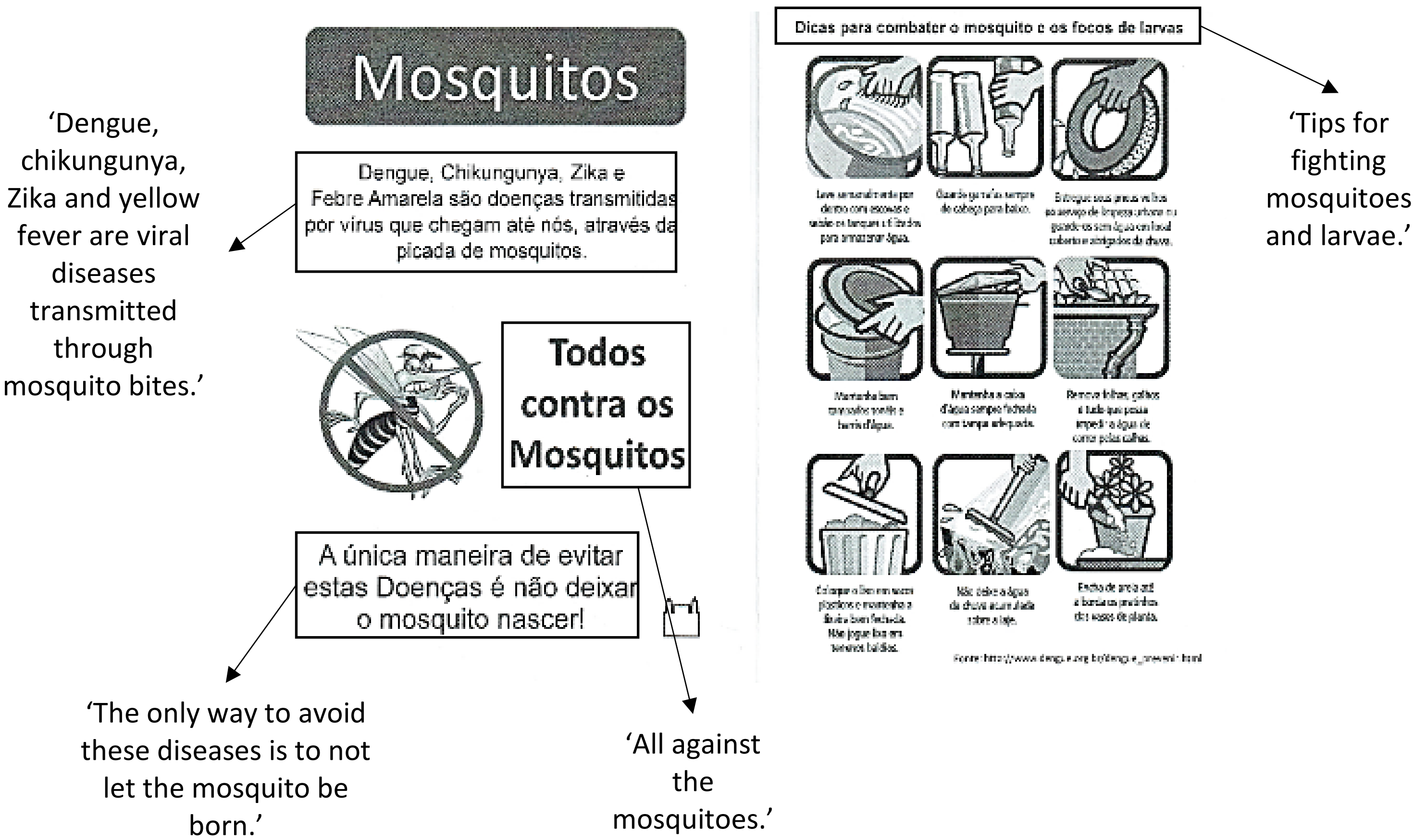

Figure 5-1: Brazilian Ministry of Health mosquito prevention advice leaflet distributed in 2015/2016

Figure 5-1 has a simple design and is clearly worded with supporting illustrations. Furthermore, whilst the left-hand page has been annotated for this thesis, the right-hand page is self-explanatory to both non-native speakers and those who may be illiterate (typical of individuals in favelas). As well as distributing leaflets and door-to-door advice, participant 7 also explained that free repellent was given out pregnant women, eligible through the *Bolsa Familia* programme: *'a cash-transfer scheme set up by the government (P10) … where* *financial support is given to families where each member earns R$200 (Brazilian Reals) or less a month' (P7)*; ensuring pregnant women could minimise the risk of contracting ZIKV and passing microcephaly to their unborn child. However, despite these effective engagement methods, participant 7 also expresses her frustration at minimal behavioural changes and attitudes in favela communities: *'some have taken precautions, but most have not. I will not give up; every time I go into the community, I continue to give out information' (P7).*

Despite an assortment of communication methods being used, it was apparent when discussing participant attitudes with both favela community members and academic experts, that there is prevailing misinformation and misunderstanding about the ZIKV and breeding habits of *Aedes aegypti*, including:

CODE = ZIKA:INITIATIVES (see Appendix 4)

'The vector of Zika … needs potable water to reproduce in.' (P4)

'The attention of the media and public was around sensitisation towards clean water management, not greywater or sewage.' (P5)

'They put out public broadcasts on TV telling people not to store water, not even in a vase.' (P12)

'There were TV advertisements about this, but they related to the mosquito in general.' (P14)

'There was not a focus on the consequence [of the virus, it was more] about how to avoid the problem.' (P1)

Therefore, it can be inferred that due to conflicting advice and lack of urgency in risk communication delivery, government approaches created an environment of mistrust in the public and individuals. This was suggested by two participants who perceived government actions to be a *'reactive measure implemented at the height of the outbreak' (P1)* in an effort to gain public trust and demonstrate action. Furthermore, owing to a gap of over a year between the declaration of the ZIKV epidemic and the association of microcephaly to ZIKV, *'many people [did] not trust the link between Zika and microcephaly' (P1)*, with the public expressing *'concerns that microcephaly is linked to poisoning from insecticides and not the mosquito at all' (P2).* For these reasons, lack of education and awareness relating to ZIKV is identified as a key challenge, emphasising the need for greater risk communication techniques that are linked to the impacts of the virus to motivate individuals at all levels of society.

Similarly, participants also reflected physical and societal characteristics of favela communities that are *'complementary to the mosquito' (P5).* The predominant linkages acknowledged by most participants reflected deficient sanitation conditions, owing to water providing breeding sites for *Aedes aegypti;* examples include:

CODE = FAVELA:CHALLENGES:ENVIRONMENTAL:NO SANITATION INFRASTRUCTURE

'Water collecting in the street … we also see lots of larvae in gully pots.' (P9)

'The population will store water, [in containers] without covers, which then turns them all into breeding locations for mosquitoes. … there are many factors: lack of rubbish collection, storing [potable] water, inadequate space and poor [soil] infiltration rates …all providing plenty of locations and opportunities for mosquito larvae to breed.' (P12)

'There are many opportunities for the creation of diseases like Zika and dengue … problems with water distribution means they must store gallons of water for drinking and for cleaning.' (P5)

Other physical attributes included *'incorrect sewage and garbage collection' (P14)* and *'inadequate space (P12)'* which results in high density *'housing' (P7)* and *'populations' (P4).* After sanitation issues, solid waste was the issue mentioned most frequently, cited by 14 of 16 participants; including both favela members and 12 external stakeholders. The predominant reason for this is that *'point-to-point … central dumpsters [are not provided in favelas] … so there is nowhere to deposit rubbish …and no [formal] collection system' (P12)* so it is customary for solid waste to be thrown outside:

CODE: FAVELA: CHALLENGES: ENVIRONMENTAL: UNCOLLECTED SOLID WASTE: NO SANITATION INFRASTRUCTURE

'At the first rains … drainage channels were blocked by a body, an oven and a sofa.' (P1)

'a large amount of garbage accumulates because men do not go there to collect it.' (P10)

'If you have rubbish in the house… or just throw it outside… when it rains this then becomes a breeding point for mosquitoes … I do not think they follow my instructions [as a community health worker] to put their solid waste in a nearby dumpster.' (P7)

In addition, several socio-economic and governance issues were raised as factors contributing to the distribution of ZIKV, participant 14 said: *'[people living in favelas] are more likely to get ill and have a lower life expectancy … they have less education, healthcare, and quality of life.'* Furthermore, due to the decentralised government system some municipalities have nationalist *'socio-political agendas' (P4)* that are against spending *'time and money to help' (P10)* improve the quality of life and livelihood conditions in favelas.

Another issue discussed with participants was the association between ZIKV/microcephaly and favelas, this was in fact disputed by 7 of the 16 participants, with many commenting that *'the territory of Zika is all over the city' (P4), 'not just in favelas' (P11).* However, they were willing to acknowledge *'higher levels of microcephaly in favelas' (P9),* as the clinical diagnosis of microcephaly has clear criteria, and ongoing *'monitoring [of] the child for one year to determine the condition' (P7).* However, in Rio de Janeiro a high proportion of ZIKV cases were recorded in formal communities that are considered wealthy – where adequate sanitation, water supply, and waste disposal habits exist. Several examples are given as to why this might be the case:

CODE: ZIKA: CHALLENGES: DISTRIBUTION OF CASES ACROSS URBAN ENVIRONMENT

'In Rio [de Janeiro] it is often hard to differentiate between favela communities and rich areas. This is because … there is less definition between rich and poor areas … they live side-by-side.' (P11)

'[Following a study] we found that …90% of the community has access to garbage collection … and to regular water supply … the areas we found the highest rate of cases were not … the poorest.' (P9)

As outlined above, scarce adherence to prevention advice also appears to be an issue in the formal environment as well as in favelas, with households *'[failing to] cover swimming pools … [and] remove empty plant pots' (P2), 'apartment roof slabs … allow[ing] water to pool inside … [that then go unchecked] for weeks' (P6), 'gutters not regularly cleaned' (P9)* and *'balconies left to store water on' (P11).* These issues were more widely replicated in wealthier locations owing to families having one or more homes *'where [they] visit at weekends and holidays' (P11).* Therefore, many apartments in these areas had to also be visited by specialist Community Surveillance Agents (like community health workers) to *'apply insecticide, empty swimming pools, and cover breeding sites' (P2).* For these reasons participant 9 (a specialist in arbovirus research) speculated that instead of inadequate sanitation and solid waste parameters, the underlying reason for ZIKV and microcephaly distribution is actually related to *'lacking prevention in homes … and neighbourhoods.'* In addition, it was also suggested that reliability and accuracy of ZIKV data should be challenged as they *'are not certain which cases have been confirmed by lab testing … and frequent misdiagnosis between Zika, chikungunya and dengue' (P9).* Finally, when discussing the underlying cause of why ZIKV is more likely to occur in favelas rather than in the wider urban environment, it was widely agreed amongst participants that a lack of understanding of the challenges and issues created by poor environmental health was the main contributor. Participant 1 believed that as communities do *'not [link] inadequate sanitation to disease and the breeding locations of the mosquito' (P1)* and for these reasons they are *'not interested in the causations and problems associated with Zika' (P2).* Therefore, should favela communities better understand the relationship between bad environmental health and public health, there may be a greater sense of urgency and interest in advocating for improvements in infrastructure and thus a reduction in the number of ZIKV and microcephaly cases that occurred throughout Rio de Janeiro.

5.2.2 Quantitative results summary

As outlined in Chapter 4 (4.4.2), 7 maps associated with objective 1 were generating using ArcGIS (ESRI 2019), with both spatial and quantitative data associated with Rio de Janeiro's different administrative boundaries (see Figure 5-2).

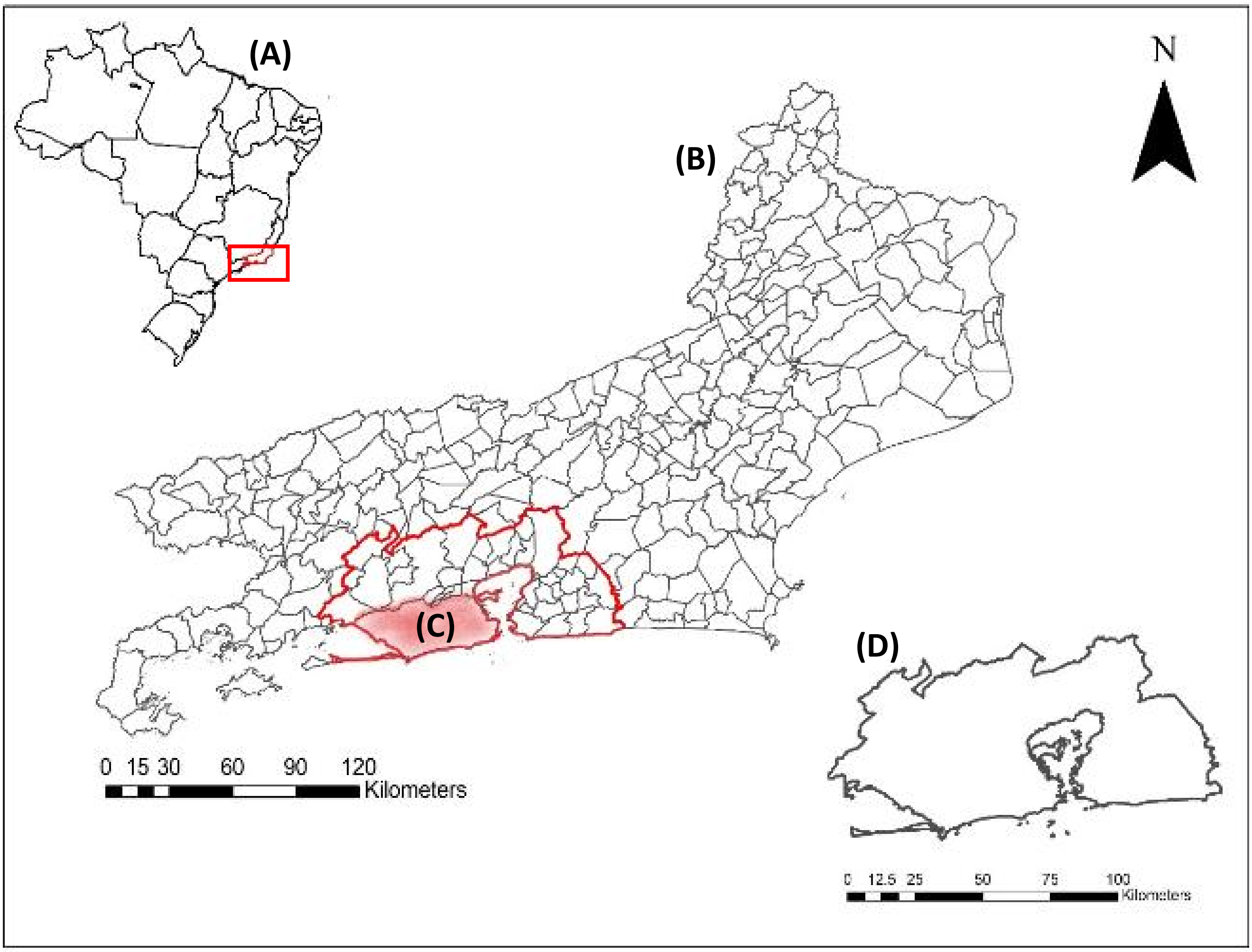

Figure 5-2: GIS Maps generated by the author outlining the administrative areas of Rio de Janeiro (IBGE 2019b). A) Brazil with Rio de Janeiro State outlined B) Rio de Janeiro State with Rio de Janeiro Metropolitan Area outlined C) Shaded area of Rio de Janeiro Municipality & D) Rio de Janeiro Metropolitan Area

Each map identified the location of favelas (IBGE 2019c), and the following variables: administrative boundary (aligned to census tracts) (IBGE2019b), topography (ESRI 2019a) and the epidemiology of ZIKV and microcephaly from January – December 2016 (Brasil 2016 cited in Vissoci *et al.* 2018). A short summary of each map will be provided combining both interpretative elements and basic analysis of the quantitative data obtained.

5.2.2a Topography of Rio de Janeiro State

Rio de Janeiro State has a variety of topographic conditions, hilly forested areas throughout, low-lying coastal areas in the south and rural areas on the northern state boundary. When comparing the location of favelas to topography, areas with the highest density of favelas coincide with dense urban areas (such as Rio de Janeiro); with favelas mostly located on steep forested areas (see figure 5-3). However, both Angra Dos Reis and Campos City are exceptions to this rule as both locations have low population densities of 71-163 people/Km² (IBGE c.2011). Angra dos Reis has a high number of favelas (106) compared with 66 in Campos city (IBGE 2019c), this is unusual as both are rural areas. However, Angra Dos Reis is a popular tourist location due to beaches on both coastlines, therefore the higher number of favelas could be attributed to informal sector job opportunities connected to tourism.

There are two areas of interest in Figure 5-3 related to ZIKV. Firstly, the two large waterbodies in east and south-eastern edges of the State could be potential breeding sites for *Aedes aegypti* as there is an increased potential for stagnant water. In addition, both sites have favela communities on their peripheries, which are likely to use the water bodies for drinking water, bathing and washing; and providing favourable breeding conditions in the peri-domestic environment. Secondly, as there is a clear distinction between rural and urban areas throughout the State and since *Aedes aegypti* is an urban dwelling mosquito (see 3.4.1), the deforested and sparser populated areas in the North are less likely environments for them to inhabit – thus ZIKV cases should be lower.

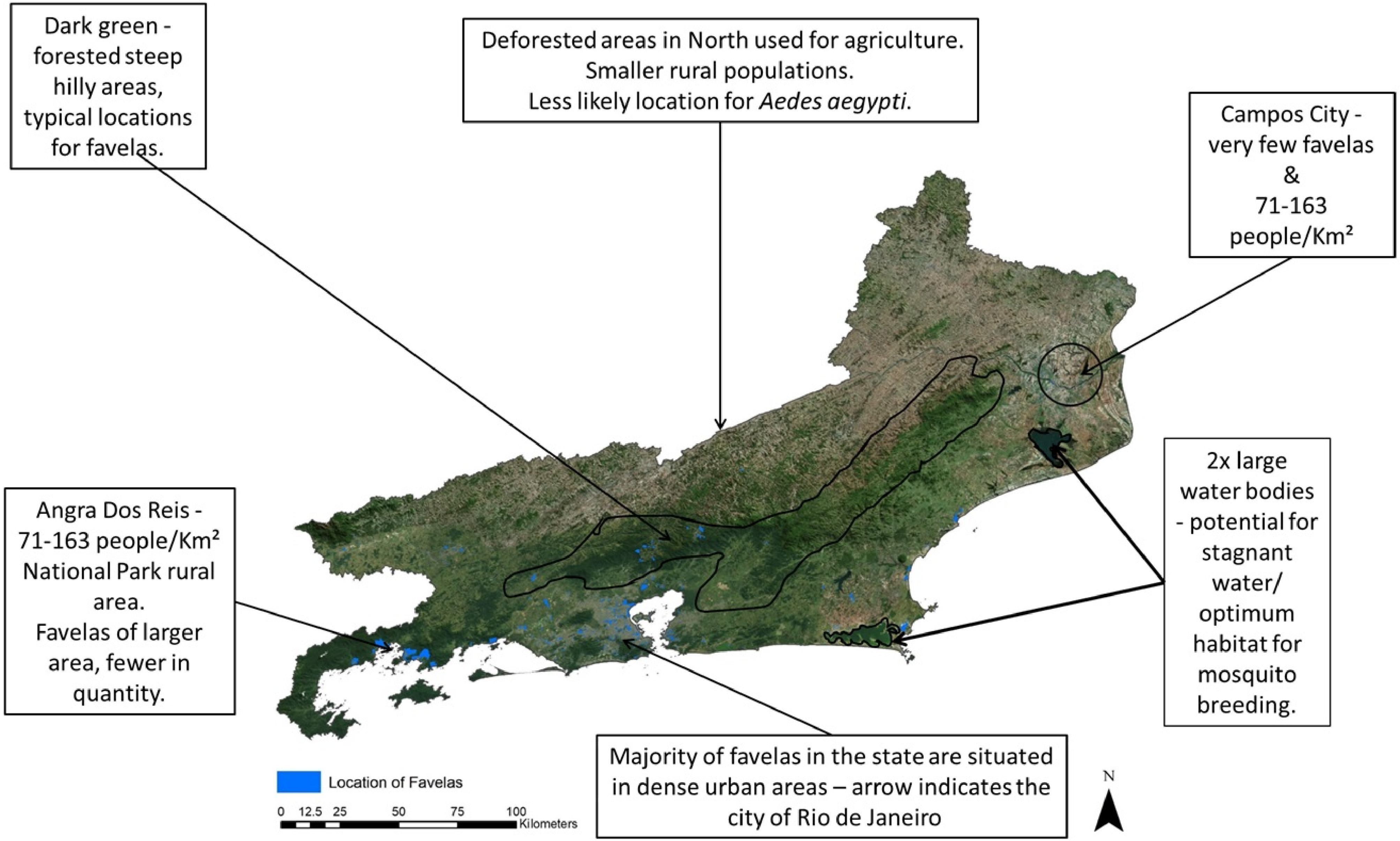

Figure 5-3: Annotated topographic map of Rio de Janeiro State

(ESRI 2019a; IBGE c.2011; IBGE 2019c).

5.2.2b Topography of Rio de Janeiro Metropolitan Region

Rio de Janeiro Metropolitan Region is the most populous region within Rio de Janeiro State and comprises five large cities (indicated in figure 5-4). Each of these cities has an average population density of 372-13,025 people/Km² (IBGE c.2011). Furthermore, it is apparent that these dense urban areas contain the highest number of favelas (see Rio de Janeiro, Nova Iguaçu and Duque de Caixas) – likely attributed to the high number of job opportunities in cities. In both Nova Iguaçu and Duque de Caxias, the favelas (in blue) are clustered amongst the city, typically, in low-lying floodplains or riverbanks. In contrast, in both Rio de Janeiro and Niteróí favelas are situated on hilly, forested areas.

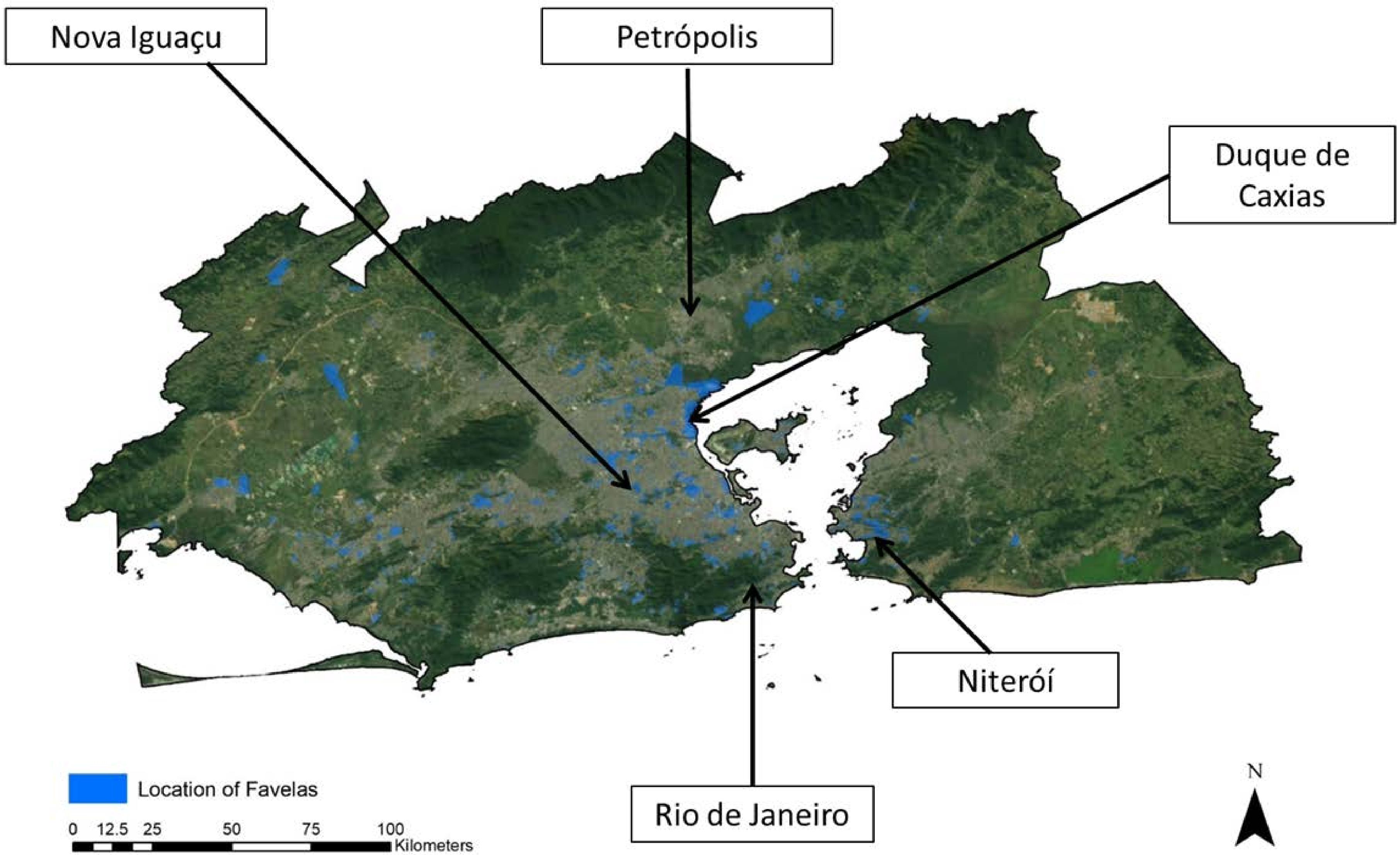

Figure 5-4: Annotated topographic map of Rio de Janeiro Metropolitan Area.

(ESRI 2019a; IBGE 2019b; IBGE 2019c).

5.2.2c Topography of Rio de Janeiro Municipality

With a total population of 6.3 million people (c. 2010) (DATARio n.d.), Rio de Janeiro Municipality, is the most populous municipality in the whole State. There is significant disparity between high and low income across the city with average annual incomes ranging from US$ 7,000-125,000/year. Communities with the lowest incomes are found in the industrial northeast of the city (inset map, figure 5-5), whereas wealthier areas run parallel with the city's popular beaches in Barra de Tijuca, Ipanema and Copacabana (Vetter, Beltrao and Messena 2014).

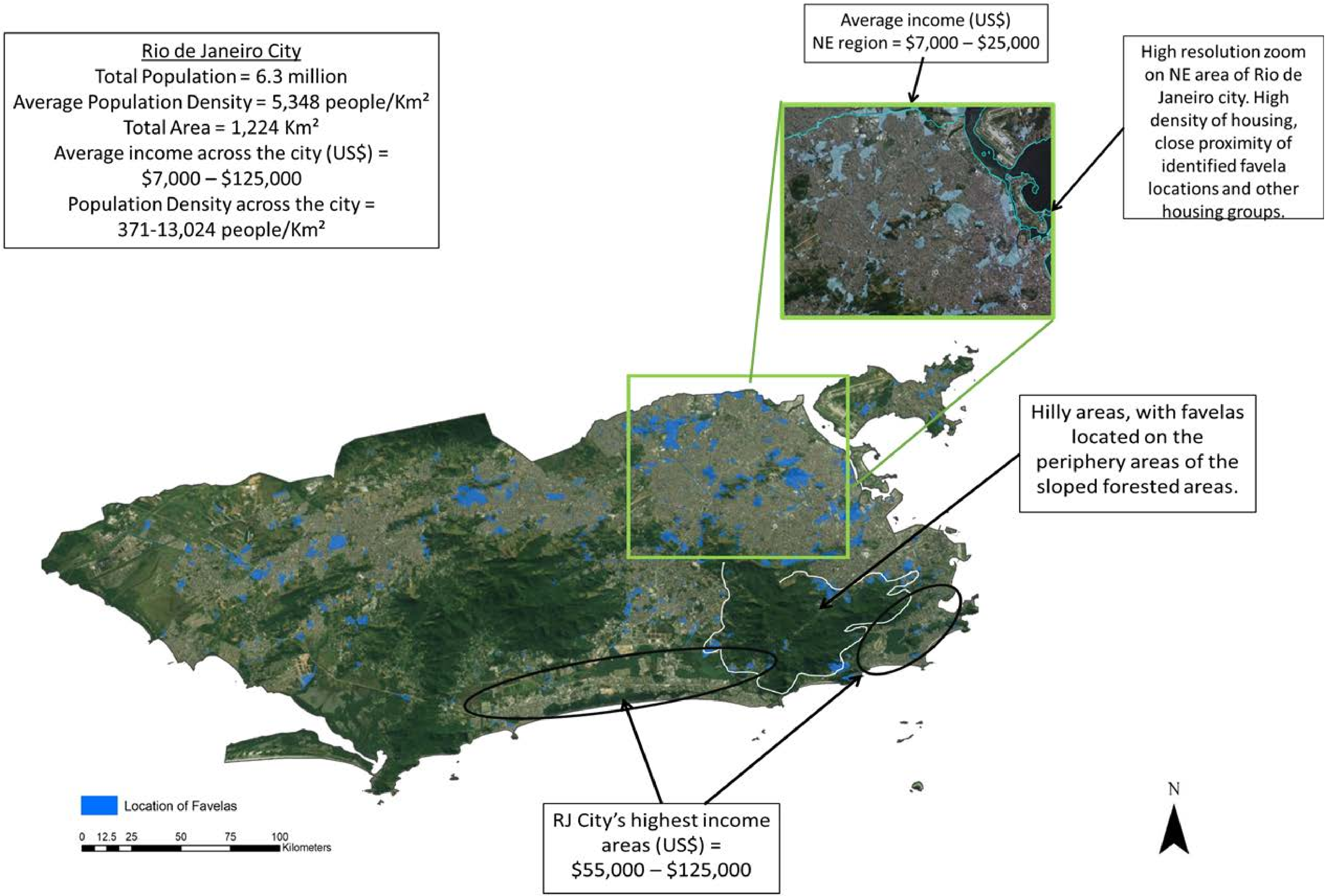

Figure 5-5: Annotated topographic map of Rio de Janeiro Municipality

(ESRI 2019a; DATARio n.d.; IBGE2019b; IBGE2019c; Vetter, Beltrao and Messena 2014).

5.2.2d Zika virus distribution in Rio de Janeiro State

In the following sections (5.2.2d-5.2.2g) both Rio de Janeiro State and Municipality will be discussed. For clarity, and to prevent repetition, State maps (5.2.2d-5.2.2e) have been annotated to only include locations excluded from the Metropolitan area; these elements will be specifically outlined in sections 5.2.2f and 5.2.2g.

In 2016, 51% (171,740 in total) of all nationally recorded ZIKV cases occurred in Rio de Janeiro State (Brasil 2016 – cited in Vicossi *et al.* 2018). The highest number of ZIKV cases occurred in and around the periphery of the Metropolitan Region, including Petrópolis, Cachoeiras de Macacu and Rio Bonito (see Table 5-3). Exceptions to this trend but still with high ZIKV cases include Campos dos Goytacazes, Volta Redonda, and Armação dos Búzios. These three locations, in spite of high cases, do not have dense clusters of favelas.

When identifying locations with no ZIKV cases and no microcephaly cases, two areas were identified, the Cantagalo-Cordeiro micro-region and the municipality of Silva Jardim (see Figure 5-6). Both these locations have few favelas also, with four recorded in the south of Silva Jardin and none in the micro-region (IBGE 2019c).

Table 5-3: Recorded ZIKV cases in Rio de Janeiro State
(Brasil 2016 – cited in Vicossi *et al.* 2018

Municipality	Number of Cases
Campos dos Goytacazes	7,507
Armação dos Búzios	2,261
Rio Bonito	1,875
Rio das Ostras	1,653
Petrópolis	1,310
Cachoeiras de Macacu	1,278
Volta Redonda	1,049
Cabo Frio	241
Macaé	196
Teresópolis	28
Santo Antônio de Pádua	20
Saquerema	20
Miguel Pereira	12
Aperibé	8

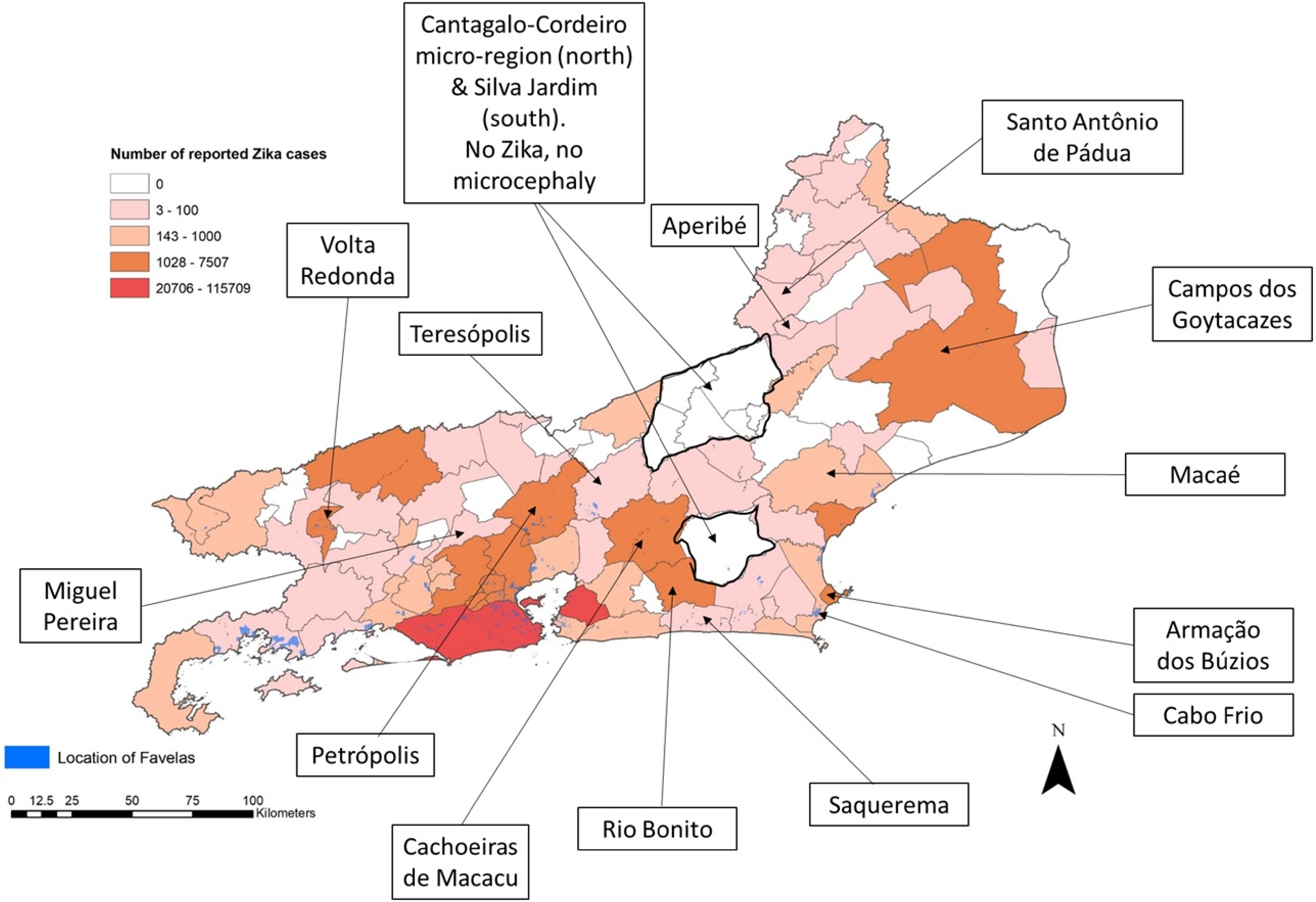

Figure 5-6: Annotated Zika map of Rio de Janeiro State

(IBGE 2019b; IBGE 2019c; Brasil 2016 cited in Vissoci *et al.* 2014).

5.2.2e Microcephaly distribution in Rio de Janeiro State

Although 171,740 cases of ZIKV were recorded throughout the State, only 0.09% (171 individual cases) of these cases led to a child being born with microcephaly in Rio de Janeiro State (Brasil 2016 – cited in Vicossi *et al.* 2018). The highest number of microcephaly cases were reported in Rio de Janeiro Municipality (see section 5.2.2g). When relating figure 5-7 (below) to Figure 5-6 no significant trends emerge when comparing high ZIKV and high microcephaly directly (see figure 5-7 - Valença, Angra Dos Reis and Cabo Frio).

Aside from Rio de Janeiro Metropolitan Region, a few cases of microcephaly were identified in Rio de Janeiro State:

- 3 microcephaly cases in Campos dos Goytacazes;
- 2 microcephaly cases in Macaé;
- 1 case of microcephaly in: Santo Antônio de Pádua, Teresópolis, Volta Redonda, Aperibé, Saquerema and Miguel Pereira.

From these results, there appears to be no obvious relationship between the number of favelas, population density and cases of microcephaly (see Table 5-4).

Table 5-4: Comparison between the number of favelas (IBGE 2019c) and population density (IBGE c.2011) in municipalities with >1 microcephaly cases (Brasil 2016 – cited in Vicossi *et al.* 2018)

Municipality	Number of Favelas	Population Density (people/Km²)
Volta Redonda	134	371-13,023
Macaé	72	169-351
Teresópolis	68	169-351
Campos dos Goytacazes	66	71-163
Santo Antônio de Pádua	0	40-70
Miguel Pereira	0	71-163
Aperibé	0	71-163
Saquerema	0	169-351

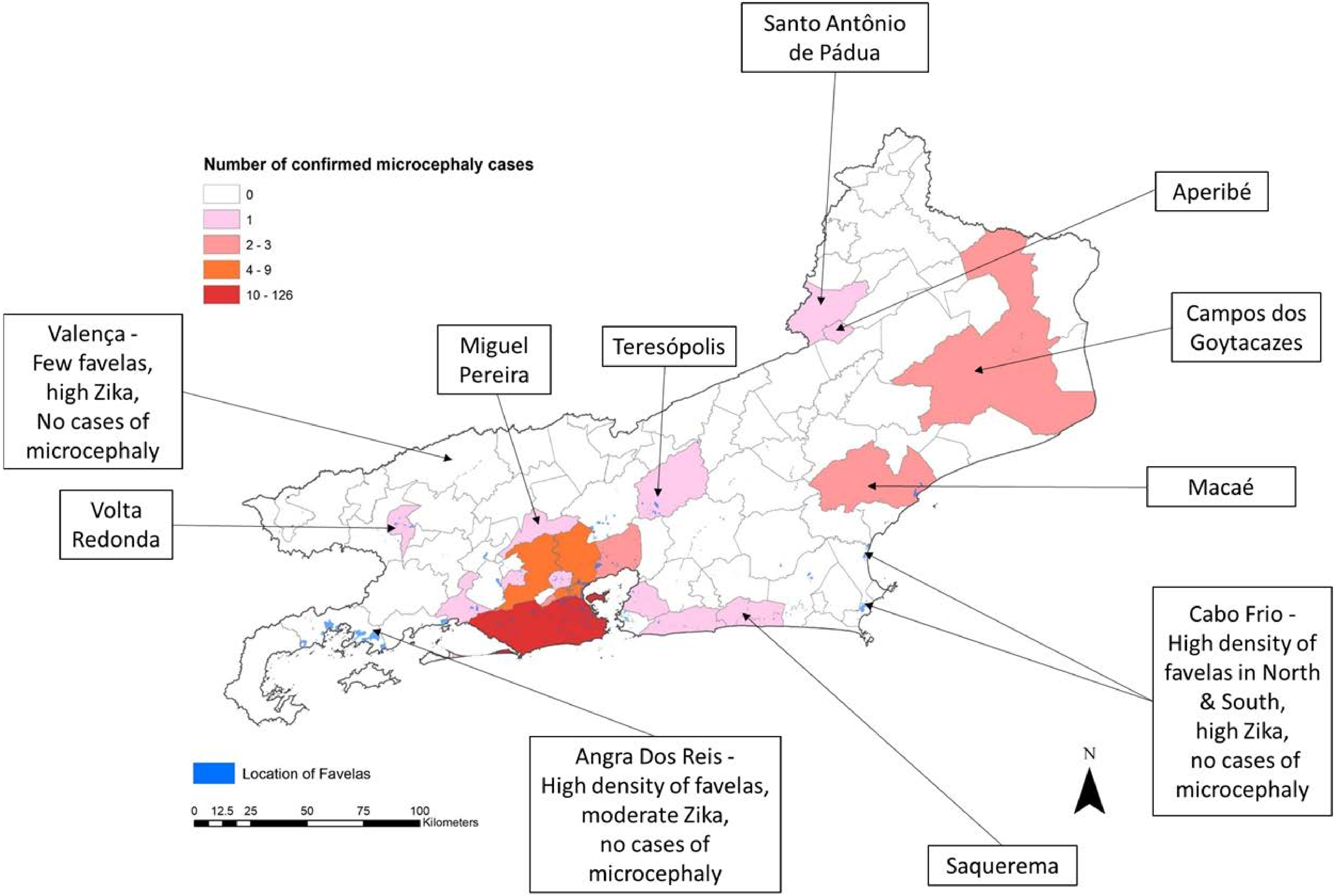

Figure 5-7: Annotated microcephaly map of Rio de Janeiro State

(IBGE 2019b; IBGE 2019c; Brasil 2016 cited in Vissoci *et al.* 2014)

5.2.2f Zika virus distribution in Rio de Janeiro Metropolitan Region

Across the region, 148,077 ZIKV cases were recorded (86% of the State total) between January 2016 – December 2016 (Brasil 2016 – cited in Vicossi *et al.* 2018). There is a clear trend between municipalities with high population densities and ZIKV cases exceeding 1,000 – see Table 5-5. When compared with the number of favelas, except for Rio de Janeiro there does not appear to be a relationship in figure 5-8 between the number of favelas and high ZIKV cases. For example, Mesquita and Nilópolis have >1,000 ZIKV cases but few favelas, whereas Niterói had less than 1,000 ZIKV cases (717) but a high number of favelas (221).

Table 5-5: Comparison between municipalities with ZIKV cases >1000 (Brasil 2016 – cited in Vicossi *et al.* 2018), the number of favelas (IBGE 2019c) and population density (IBGE c.2011)

Municipality	Number of Cases >1000	Number of Favelas	Population Density (people/Km²)
Rio de Janeiro	115,709	2,990	371-13,024
São Gonçalo	20,706	51	371-13,024
Nova Iguaçu	1,861	28	371-13,024
Duque de Caxias	1,695	424	371-13,024
Mesquita	1,193	4	371-13,024
São João de Meriti	1,112	117	371-13,024
Belford Roxo	1,042	68	371-13,024
Nilópolis	1,037	9	371-13,024

The only municipalities in the region without any recorded favelas are Guapimrim and Tanguá (see figure 5-8). Guapimirim only had 16 ZIKV cases and Tanguá none. Tanguá is the only exception to these speculated trends with no recorded cases of either ZIKV or microcephaly.

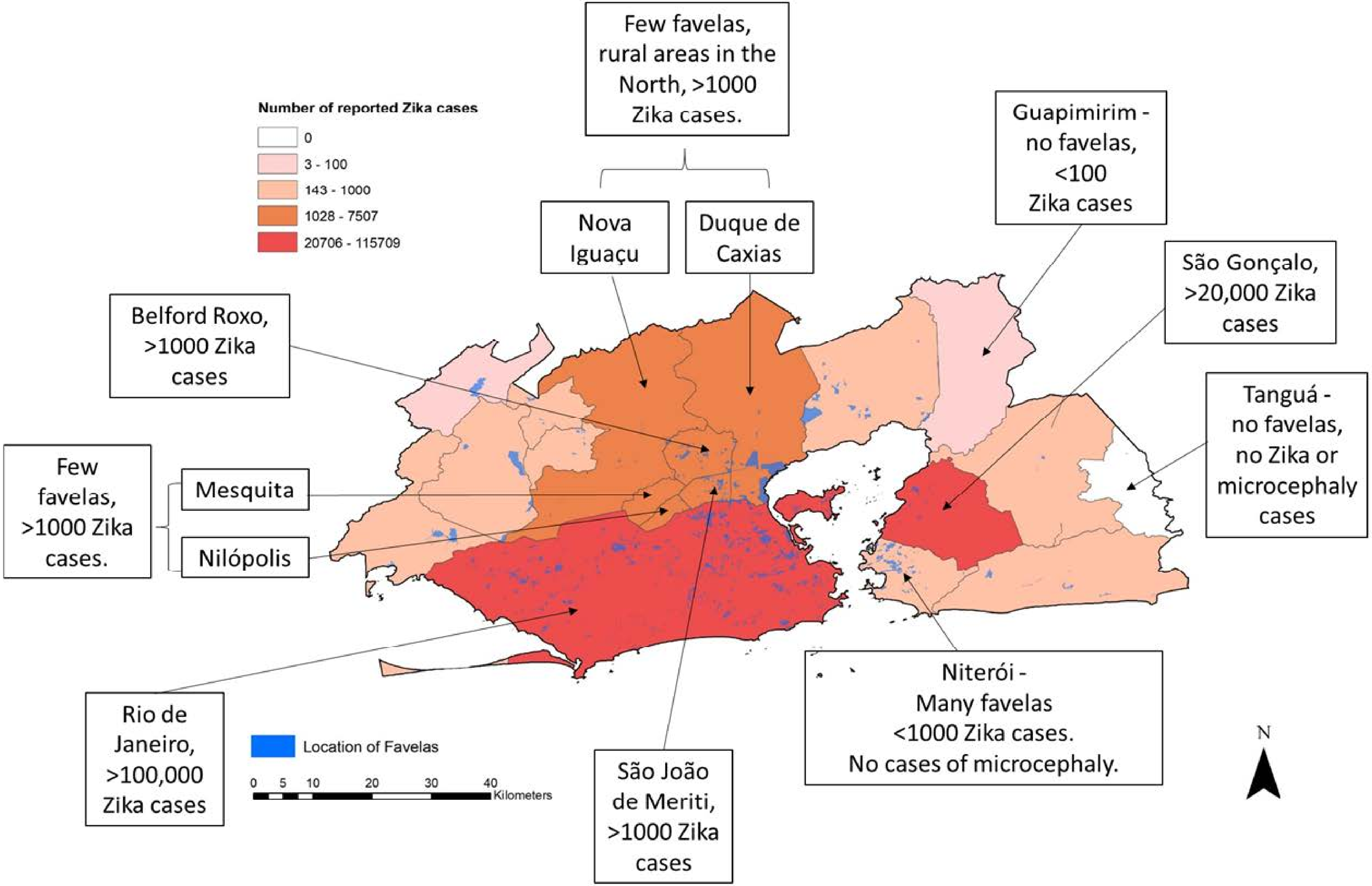

Figure 5-8: Annotated Zika map of Rio de Janeiro Metropolitan Region

(IBGE 2019b; IBGE 2019c; Brasil 2016 cited in Vissoci *et al.* 2014)

5.2.2g Microcephaly distribution in Rio de Janeiro Metropolitan Region

160 of the 171 microcephaly cases in Rio de Janeiro State were recorded in the Metropolitan Region. The highest number of cases were reported in Rio de Janeiro and Duque de Caxias, with both areas having high population densities and the highest number of favelas (see Table 5-6).

Table 5-6: Comparison between municipalities with microcephaly cases >1 (Brasil 2016 – cited in Vicossi *et al.* 2018), the number of favelas (IBGE 2019c) and population density (IBGE c.2011).

Municipality	**Number of Cases >0**	**Number of Favelas**	**Population Density (people/Km²)**
Rio de Janeiro	126	2,990	371-13,024
Duque de Caxias	9	424	371-13,024
São João de Meriti	7	117	371-13,024
Nova Iguaçu	7	28	371-13,024
Nilópolis	3	9	371-13,024
Magé	3	47	371-13,024
Belford Roxo	1	68	371-13,024
Itaguaaí	1	27	371-13,024
Maricá	1	36	169-351
Queimados	1	12	371-13,024
São Gonçalo	1	51	371-13,024

Compared with figure 5-8 (previous) there is no obvious trend between municipalities with high ZIKV and high microcephaly in figure 5-9 (below). For example, Mesquita had 1,193 ZIKV cases yet recorded no microcephaly. Niterói had moderate ZIKV cases (717), but no recorded cases of microcephaly – despite having the 3rd highest number of favelas (221). This finding was also identified in the municipalities in the northwest of the region (Paracambi, Japeri and Seropêdica) where no cases of microcephaly were recorded, despite there being up to 1,000 ZIKV cases and several large-sized favelas (see figure 5-9).

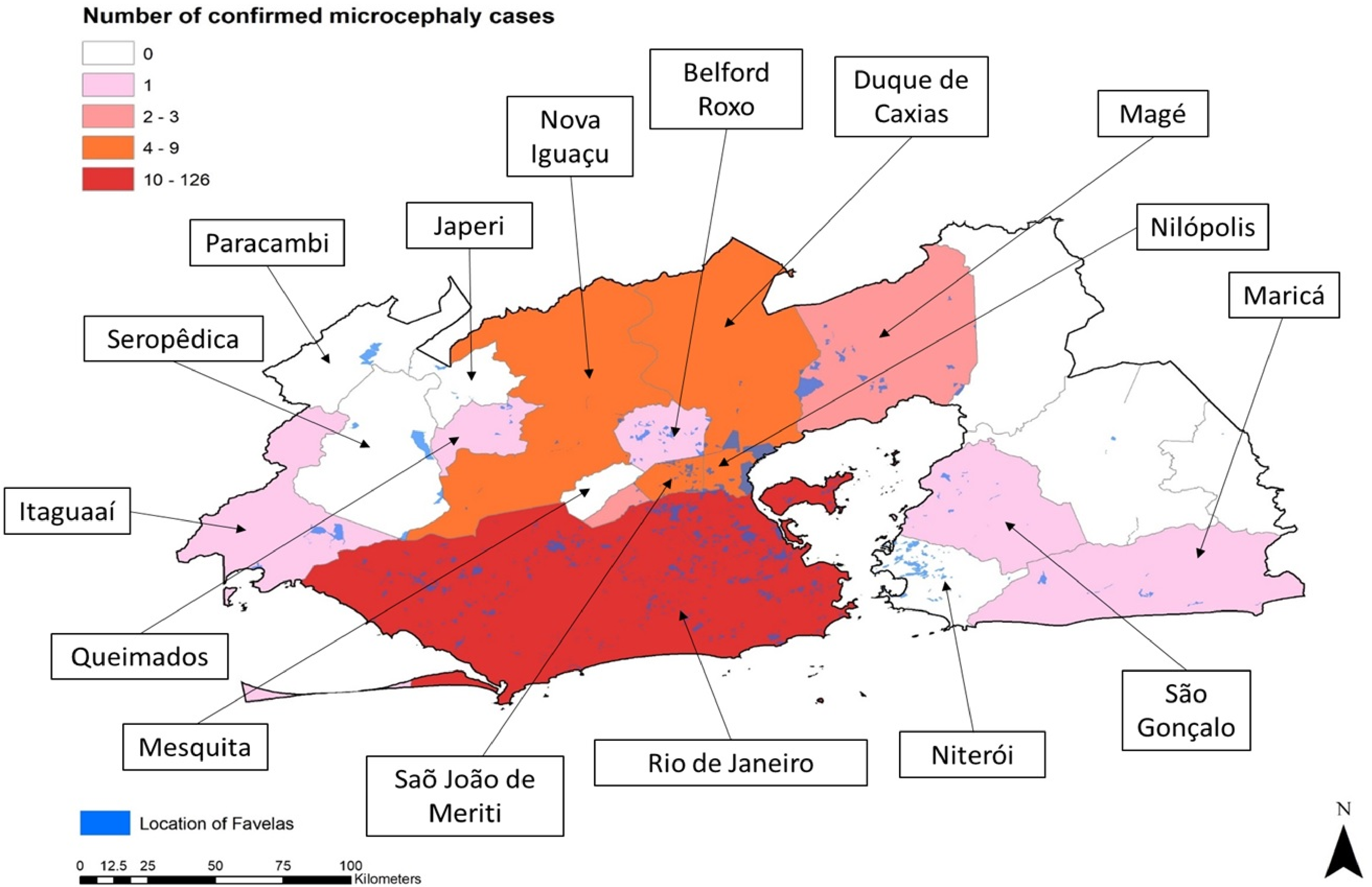

Figure 5-9: Annotated microcephaly map of Rio de Janeiro Metropolitan Region

(IBGE 2019b; IBGE 2019c; Brasil 2016 cited in Vissoci *et al.* 2014)

5.2.3 Discussion of key findings

Having reviewed the key findings in 5.2.1 and 5.2.2*,* two areas emerged requiring further discussion. Firstly, the dissemination and implementation of risk prevention advice and activities, and secondly uncertainty regarding a correlation between ZIKV and favelas. Whilst these are both separate aspects, the latter part of this discussion will illustrate their relationship and the resultant implications on the ZIKV epidemic in Brazil.

Dissemination and implementation of risk prevention advice

Several different communication methods were utilised by public health officials and government campaigns during the ZIKV epidemic, including door-to-door health worker visits, TV adverts, radio broadcasts and distribution of posters and leaflets. Furthermore, each of these approaches ensures many of the target population received and were made aware of the situation and risks in order to respond appropriately (Gubler and Clark 1996). However, owing to lack of emphasis surrounding the impacts of microcephaly, Zika campaign messages were subsequently diluted, with minimal public uptake of prevention advice.

Implementation challenges were also acknowledged, with reluctance in both formal and informal settlements. This finding is unusual when compared with other international development discourse, as it widely inferred that lack of education and engagement with low-income communities caused community withdrawal from campaigns (Gubler 2011). However, several participants did state that regular visits and application of larvicide by health and surveillance workers occurred across the whole city. Additionally, health workers encouraged the community to continue adhering to advice, by removing water-storing objects/containers around dwellings, or on balconies/rooftops. For this reason, it can be argued that additional factors must have influenced lack of engagement throughout the city as both education and engagement were considered and designed into public health approaches.

Owing to failings of past *Aedes aegypti* prevention campaigns between the 1940s and 1990s (see 3.4.4) (Araújo *et al.* 2015), and the current distribution of dengue, chikungunya and yellow fever throughout Brazil, there is public distrust and frustration at the government for failing to control mosquito-vectors (Proenca-Modena *et al.* 2018). Despite clear messaging being used in leaflets (see figure 5-1), participants stated that conflicting messages portrayed by media TV campaigns led to confusion about which actions to implement. Furthermore, many did not believe the government's insistence that there was a relationship between ZIKV and microcephaly, so distrust prevailed (Lowe *et al.* 2018). Furthermore, the time lag between the declaration of a national ZIKV emergency (November 2015) and then confirmation of microcephaly in May 2016 further hindered government communication efforts (de Souza *et al.* 2018).

Distrust of government health campaigns is a common feature during large scale epidemics (Gubler 1989), therefore it is vital that public health officials tailor their intended messages to the target audience. Approaches advocated by Knudsen and Slooff (1992) suggest policy-makers and communities must work together when designing vector prevention approaches, proposing that communities adopt and implement their own prevention activities based on unified awareness and collective understanding of the issue (see 3.4.4). It could be suggested that whilst community engagement efforts occurred, they were mostly using top-down methods and as such there was a disconnect between the communities and their environment (Knudsen and Slooff 1992), with individuals *'not adequately linking inadequate sanitation to disease and the breeding locations of the mosquito' (P1).* Therefore, the findings of this project align with those of Gubler (1989), Gubler and Clark (1996) and Knudsen and Slooff (1992) who examined vector prevention approaches aligned with community engagement efforts, highlighting that successful methods foster a change in mind-set via intensive sustainable engagement approaches, this is unlike the methods adopted in Brazil.

Uncertainty regarding a correlation between ZIKV and favelas.

As shown in 3.4.3, there are several Brazilian studies which have investigated the potential correlation between socio-economic, environmental and infrastructure factors and the epidemiology of *Aedes aegypti* viruses and other health issues. Therefore, although it is agreed that water supply and the quality of sanitation infrastructure are factors associated with mosquito-vectors, there is still a conflict of opinion when attempting to correlate water and sanitation characteristics with the distribution of mosquito-borne disease (Teixeira and Cruz 2011). Whilst this conflict has been discussed extensively regarding dengue in Brazil

(Flauzino *et al.* 2009; Kikuti *et al.* 2015; Teixeira and Cruz 2011), very little research has been compiled when associating ZIKV to sanitation factors.

Having amalgamated qualitative and quantitative findings, several points have been identified that contribute to current knowledge associated with *Aedes aegypti* and the distribution of ZIKV and microcephaly in urban areas. Each point will be discussed further below, but in summary, these findings are:

1. Favelas have the greatest opportunities for mosquito breeding owing to poor sanitation and socio-economic conditions.
2. There is uncertainty about connections between ZIKV and favelas. ZIKV and microcephaly cases occurred both inside and outside of favela areas in Rio de Janeiro. However, microcephaly case numbers are higher in favela communities compared to elsewhere.

Many *Aedes aegypti* breeding locations in favelas were identified including, outside stormwater and greywater ponding, stormwater collecting in gully pots, improvised drainage channels, and solid waste in the street. Additionally, domestic and peri-domestic issues were raised with uncovered water containers and drinking water reservoirs. Each of these findings agrees with previous *Aedes aegypti* habitat studies (Getachew *et al.* 2015) along with wider research investigating disease vectors in informal settlements in Nigeria, and India where mosquitoes are also present (Parkinson, Tayler and Mark 2007; Reed 2004).

Several issues were also identified in formal settlements, where it was assumed prevention advice was followed due to increased knowledge and awareness of public health issues (Arbex *et al.* 2016; Vissoci *et al.* 2018). The largest number of prevention issues were associated with families having one or more homes. These homes were used at weekends and seasonally for holidays, therefore prevention advice was not regularly being followed. As such, community vigilance teams routinely identified swimming pools, and apartment balconies/rooftops where insecticide had to be applied and plant pots/containers removed.

Cabo Frio, (a coastal area in southeast Rio de Janeiro State, see figure 5-6) was specifically mentioned by participant 2 as a popular holiday destination which had a high number of ZIKV cases. When compared with other municipalities Cabo Frio had 241 cases of ZIKV, whereas the neighbouring municipality Armação dos Búzios had 2,261 ZIKV cases (4th highest in the State) (Brasil 2016 cited in Vissoci *et al.* 2018). As Armação dos Búzios and Cabo Frio are on both on the coastline, it could be suggested participant 2 was referring to both these areas. Furthermore, when compared with the density of favelas, Cabo Frio had a higher number of favelas at 114 (6th highest in the State) compared with 2 in Armação dos Búzios (IBGE 2019c).

These findings, therefore, contradict earlier suggestions that there may be an association between favelas and ZIKV. Furthermore, despite moderate to high levels of ZIKV, neither location had any recorded cases of microcephaly. Holiday homes in Cabo Frio and probably Armação dos Búzios also were inspected and treated by community vigilance agents, this could have contributed to lower ZIKV cases; despite the high density of favelas. Furthermore, as a wealthy area, individuals are more likely to have access to contraceptive health services and pregnant mothers being regularly monitored for microcephaly (Arbex *et al.* 2016; Brasil *et al.* 2016). Therefore, as hypothesised by participant 9 *'lacking prevention in homes … and neighbourhoods'* could be an underlying reason for the distribution of ZIKV in these two locations, rather than an association with water and sanitation parameters. This finding is also comparable to that of Rodrigues *et al.* (2018:9) whose study in Manguinhos, (northeast Rio de Janeiro city, see figure 5-5), found that risk exposure levels to dengue, chikungunya, and ZIKV were not explained by water and sanitation indicators alone.

Therefore, although the findings of the project contribute additional knowledge and support the results of Rodrigues *et al.'s* (2018) study, there are several areas that could be further developed both in the wider discourse and in this project specifically. To date, studies focussing on identifying correlating factors with the distribution of ZIKV in Brazil have adopted cross-sectional study approaches, limited to a specific area or location (de Souza *et al.* 2018; Rodrigues *et al.* 2018; Souza *et al.* 2018). Therefore, whilst the findings of other studies and of this project can be generalised, there is a lack of transferability at a national or regional level due to the heterogeneity of cities and of the settlement type (formal or informal) chosen for investigation. For this reason, further studies and retrospective analysis of epidemic data are needed in order to further evaluate the potential associations between ZIKV epidemiology and water and sanitation conditions.

5.3 Water management issues in favelas

5.3.1 Qualitative results summary

Similarly to the design of the interview questions addressing objective 1, when addressing objective 2 (*To investigate current water management challenges in favelas)* an equally wide array of questions was asked of each participant (see Tables 5-7 and 5-8). Questions related to the themes of government policy and initiatives, sanitation infrastructure provision, surface water management issues in favelas and favela-driven innovations to address drainage issues - with the intention to acquire both an insider and outsider perspective on the realities of favela drainage provisions.

For this reason, several questions addressed to favela community members were duplicated and suitable for analysis against both objectives 1 and 2; with the intention of objective 2 identifying current practices, rather than to analyse the implications of outlined practices on the epidemiology of ZIKV (objective 1).

Table 5-7: External stakeholder interview questions relating to objective 2

Are you aware of any government policies or initiatives that support the provision of better infrastructure in favelas?
Are you aware of any favela communities where formal drainage exists? Is it effective in operation?
When you have been interacting with favela communities have you noticed any efforts initiated by community members to improve sanitation?
Do you believe that problems exist in favelas with the drainage of surface & grey water? Do you think these problems are sufficient enough to be addressed?

Table 5-8: Favela community member Interview questions relating to objective 2

Average number of people living in the household? What are the common relationships between household members? E.g. Grandmother, Mother, Father and Sisters etc.
What is the dwelling layout and condition/quality of construction? What building materials are used to build homes?
Where do they collect their water from? Where do they store Water? Do they use covered or uncovered water containers? Is water stored inside or outside of the house? Do they use any rainwater harvesting methods to collect water?
Do households/the community have access to insecticide to treat the water?
Where do they defecate? How do they flush it? How many people use the toilet?
How do they dispose of solid waste? Is there any formal garbage collection?
Past or present – Does flooding occur in the community? What is the origin of the flood? River or Rain? Are there any isolated problem areas for flooding within the community? When are the heaviest periods of rainfall during the year?
Where do they dispose of household greywater (created by cooking, cleaning, bathing)?
Do the community use any improvised methods to create drainage or sanitation infrastructure? Have the community ever been involved in any, municipal/NGO/research project where improved built infrastructure has been implemented?
What are the concerns/problems/issues in the community that you have experienced? What do you think would be the most important issue for action if chosen by a favela member?

All participants identified that prejudice and a lack of willingness from the government was the most significant impediment preventing the installation of sanitation infrastructure in favelas, despite interventions being implemented in the past. Several participants (6 out of 16) reflected that high levels of *'drug trafficking and insecurity' (P3),* alongside *'corruption and crime hierarchy within the favelas' (P1)* were the major factors preventing *'the government and communities… [from] working together' (P12)*; as a result, favela communities were prevented from accessing public-funded support and services. Furthermore, several external stakeholder participants considered that many families who live in favelas *'do not want to live without services or in violent areas, they simply have no choice' (P12)*, as it is the *'drug traffickers who [hold] power … and often do not permit [government and livelihood] activities' (P4).* Additionally, ongoing contentions over *'land legality' (P1)* and capitalist desires of utility companies meant sanitation investment happened in *'wealthier areas [where companies] can make good profits' (P11).*

Despite recent government agendas working against upgrading initiatives in favelas, participants reflected positive impacts of previous initiatives like *'the Profaće programme … [which bought] infrastructure to the favelas in the form of drinking water and sewage' (P11).* Results of this can be seen in the Rocinha favela (southwest Rio de Janeiro). Furthermore, participant 11, a researcher in sanitary engineering and microbiology, expressed positive opinions regarding ongoing Community Health Worker initiatives: *'they are the closest government solution [in the favelas, as they live there themselves and are provided with training] that educates on the links between health and the environment.'* Finally, despite the government promoting favela relocation projects as a successful upgrading and integration initiative, participant 15 says: *'the government see improved apartments [social housing provided by favela-removal projects] as a formal area. … [But] social initiatives are only to help families … living in informal areas [so we miss out].'* Therefore, although they have been provided with improved housing and infrastructure, they remain on low-incomes and continue to be excluded from wider social initiatives. Despite this initiative claiming to reverse poverty it actually contributed to continued low socioeconomic status, as relocated families lived in better conditions and *'aspire to work, [but] they still return to [livelihood] conditions of poor development' (P2).*

Challenges of water supply were also discussed, with implications for both formal and informal areas during summer months. This was expressed as a particular problem in 2015 prior to the Olympics: *'there were many problems with scarcity of water. The government had to turn off the water to many homes and apartments [in Rio de Janeiro]' (P11)*; meaning households were forced to store water and increased the potential for contamination and poor water quality. Similarly, past infrastructure projects have attempted *'to connect [favela] communities to water … but the supply was never consistent… often slums are the last point on the water network. … This sometimes reduces the water pressure and so the water does* *not reach the communities' (P16).* Furthermore, as favelas in Rio de Janeiro are usually situated on hillslopes, there needs to be a high-pressure gradient to pump the water uphill. As well as external factors concerning water supply and governance hindering favela communities, several internal considerations and examples were provided. In many cases, the location of the favela had its own hydrological considerations that impacted surface water management – with both flooding and landslides outlined as the biggest issues. Both pluvial (stormwater) and fluvial (rivers, lakes) flooding were mentioned with pluvial flooding associated with inadequate drainage systems *'causing a build-up of water and sewage … so when there is a lot of rain it floods' (P10).* Fluvial flooding is also a challenge, impacting *'favela communities located on flat areas [river-banks and flood plains]' (P14), 'as they are below the maximum level of the river' (P1).* Landslides are also a *'severe issue [in hilly areas], caused by greywater and stormwater' (P5)* as *'there is a thin layer of soil' (P1),* which becomes unstable following *'heavy rains' (P16).*

Owing to deficient formal infrastructure for sewage disposal and sanitation, some communities *'buy the materials … and do it themselves' (P10)*, however this has implications on environmental health and the wider environment owing to *'discharge of sewage into the rivers' (P11)* and *'illegal connections into [formal] drainage systems' (P1)* which subsequently *'contaminates the potable water supply' (P11).* However, in comparison, participant 16 who grew up in Bahia State, said that *'greywater disposal [relied] on the slope of the favela but sewage was kept in a septic tank under the toilet' (P16).* This example provides evidence of appropriate infrastructure in favelas, but also of community-built and maintained systems. Another positive example was given by a participant in Nova Iguaçu (a municipality north of Rio de Janeiro), who stated *'the government builds [a] central [sewer] system and then each family is responsible for their connection … [as a result only] 30-40% of the people in Nova Iguaçu are on the poverty line' (P10).*

Finally, although a small number of participants gave examples of improved sanitation being implemented in favelas, 9 of the 16 participants evidenced insufficient understanding in favelas of *'how sanitation and health are linked' (P3)*. Hence despite the awareness and advice given by community health workers, *'communities [continue to] perceive the river … as a sewage channel' (P11).* While this is disappointing, in relocated housing the resident's association *'ensures people dispose of their waste properly' (P15) as well as attempting to 'construct flood barriers around their homes' (P15).* Similarly, *'many [favela] areas have people who are bricklayers … and build their own septic tanks. … the challenge is how to spread this knowledge, … many people feel the government should be providing … and paying to build their drainage systems' (P11).* Many of the reasons why prevention or improvement activities are not being achieved in favelas is due to lack of external investment and the prevalence of socio-economic vulnerability of the favela communities themselves. For many households sanitation problems are not an issue *'because it is outside of their reality' (P6) and 'how they will eat and how their children survive … is a bigger worry for them' (P16).* Therefore it is necessary to consider these issues and establish which improvements are in the interests of the community; both for health and wellbeing, and the environment.

5.3.2 Discussion of key findings

As highlighted in 5.3.1, water management issues were identified by participants associated with stormwater, greywater or sewage disposal. Furthermore, each example provided aligns with the existing discourse on informal settlements (Armitage 2011; Parkinson 2003; Parkinson, Tayler and Mark 2007; Reed 2004). For the purpose of this discussion (5.3.2), attention will be given to the most pressing issues that are currently researched less, these are infrequent water supply, solid waste and the socio-economic factors discouraging sanitation investment.

Infrequent water supply

Although the Brazilian government data claims that 95% of Rio de Janeiro city is connected to the water supply system (Kelmen 2015), this figure does not reflect infrequency of supply and thus cannot make sense. This issue is illustrated by participants and academics (Britto *et al.* 2018; Dias *et al.* 2018) who detail regular issues with piped water supplies that traverse hillsides to reach favela communities, as well as seasonal supply issues related to widespread drought or high demand (ie. the 2016 Olympic Games). In Rio de Janeiro's favelas, water supply created several health concerns associated with incorrect storage, water quality deterioration, disease pathogens, cross-contamination and the presence of disease vectors; such as mosquitoes (see 3.3.3). Each of these issues is typical of informal settlements internationally as well as in other Brazilian cities (Christova-Boal *et al.* 1996; Katukiza *et al.* 2012; Mara *et al.* 2007; Jiusto and Kenney 2016). Furthermore, in relation to the ZIKV epidemic, uncovered water reservoirs on rooftops and containers in homes have provided favourable breeding locations for *Aedes aegypti* (Lowe *et al.* 2018).

Solid waste

In addition to evidence of water supply issues, solid waste was also discussed by participants, with issues connected to disease vectors and drainage (see 5.3.1 and 5.4.1). Furthermore, whilst these issues are discussed extensively in the fields of informal settlements (Jiusto and Kenney 2016; Parkinson 2003; Parkinson, Tayler and Mark 2007) and mosquito-transmitted disease (Lines 2002; Schofield and White 1983), the issue of solid waste is yet to be fully integrated into multi-disciplinary studies investigating mosquito-vectors in informal settlements (Armitage 2011; Batterman *et al.* 2009; Wilson, Davis and Lindsay 2019).

In Rio de Janeiro, despite provisions for solid waste being explicitly stated in the Basic Sanitation Law 11,445 (Sampaio, Kligerman and Junior 2009), favelas communities are excluded from municipal waste collection services. Therefore, solid waste is thrown outside into the streets, down hillsides, and into rivers; polluting the environment, accumulating stormwater and encouraging disease vectors. Many of these issues are frequently cited in cities worldwide (see 2.4.1, Dar es Salam and Kampala) with issues being attributed to drain blockages and the spread of waterborne and water-based diseases (see 2.5.2) (Annenberg Foundation 2017; Christova-Boal *et al.* 1996). Similarly, a recent PhD project by Mezue (2018:207) investigating the potential for SuDS implementation in Lagos, Nigeria identified solid waste hindering drainage infrastructure. Therefore, as the findings in this study agree with the findings of other scholars, it can be argued that greater emphasis is needed in future research regarding solid waste, alongside other typical factors associated with sanitation in favelas and informal settlements.

Governance barriers

Unlike informal settlements in Africa and Asia, high levels of crime and persistence of drug trafficking in Brazil has resulted in lack of government investment in improved infrastructure and quality of life for communities (O’Hare and Barke 2002). Furthermore, hierarchical structures in the favela itself (i.e. drug lords and their associates) mean continual distrust exists between both internal and external actors. Furthermore, inflammatory police raids, and the presence of UPP since 2008 to facilitate pacification attempts, have meant that both internal and external stakeholders hold negative perceptions of each other, thus preventing activities encouraging them to work together (Adler *et al.* 2017). These issues have been identified in the context of past 'slum-upgrading' and household infrastructure improvements (Denaldi *et al.* 2016; Ren 2018 and Samora 2016). More recently, highcourt corruption investigations and major sporting events have disrupted government budgets and agendas. Therefore, few programmes have attempted to re-establish large-scale infrastructure projects such as the *PAC-UAP* (see 3.3.2). Instead, smaller public health initiatives remain by training community health workers who live in favelas, circumventing the need for government representatives and other individuals from entering and engaging with communities. Whilst many of these issues are discussed by the authors referred to in this section, minimal literature exists that specifically addresses these barriers directly in the context of water management in favelas. Therefore, this project addresses this direct issue and advocates a need for further research in these areas, to identify a suitable way forward.

5.4 Could SuDS approaches be feasible in favelas?

5.4.1 Qualitative results summary

As the underlying focus of the project, objective three is arguably the most important owing to its direct implication on the project's aim. Therefore, questions were asked from several different perspectives, to identify the potential for different stakeholders to implement SuDS and the challenges SuDS devices may have to address (Tables 5-9 and 5-10).

Table 5-9: External stakeholder interview questions relating to objective 3

Are you aware of any government policies or initiatives that support the provision of better infrastructure in favelas?
Are you aware of any NGOs or University research projects working on upgrading activities in favelas?
Are you aware of any favela communities where formal drainage exists? Is it effective in operation?
When you have been interacting with favela communities have you noticed any efforts initiated by community members to improve sanitation?

Table 5-10: Favela community member Interview questions relating to objective 3

Past or present – Does flooding occur in the community? What is the origin of the flood? River or Rain? Are there any isolated problem areas for flooding within the community? When are the heaviest periods of rainfall during the year?
Where do they dispose of household greywater (created by cooking, cleaning, bathing)?
Do the community use any improvised methods to create drainage or sanitation infrastructure? Have the community ever been involved in any, municipal/NGO/research project where improved built infrastructure has been implemented?
What are the concerns/problems/issues in the community that you have experienced? What do you think would be the most important issue for action if chosen by a favela member?

Participant responses have been separated into two main areas, firstly the feasibility of SuDS in general and then secondly, the ability for SuDS to address ZIKV. In both cases participants identified that *'government support, capital and resources' (P10)* are pivotal to the success of any implemented activity, and would require additional support through other stakeholders to *'work together and exchange ideas' (P12)* with favela communities; *'to give [them the]* *knowledge and ability to identify and understand their own problems, so they can work towards solving the issues themselves' (P11) -* both to address sanitation issues and also ZIKV.

When participants considered SuDS separately from the external influences of government and finance, there were several mixed opinions as to how successful improved sanitation and drainage infrastructure (either through SuDS or conventional drainage methods) would be in countering epidemiology of mosquito-borne diseases such as Zika. Many felt that *'low-scale [sanitation interventions] will not work, sanitation on a large scale is needed because mosquitoes can fly' (P6).* Other participants felt that a more holistic approach was needed as *'drainage [and sanitation] on its own will not be able to do this' (P13), 'you need education on health, environment … and the connections between … drainage and the mosquito' (P4).* Many of the participants who were apprehensive about a reduction in ZIKV expressed concerns over *Aedes aegypti*'s ability to *'go everywhere' (P2)* in the city. Isolating interventions specifically to favelas (as the original research aim suggests) may not resolve the issue, owing to infections occurring in formal areas also.

Compared with conventional drainage approaches, participants felt more optimistic about the benefits of SuDS-like methods in favelas *'drainage does not need pipelines to be innovative… nature-based solutions like infiltration … may be more appropriate after studying how ecosystem and drainage problems interact' (P3).* Similarly, participant 6 suggested greater work on *'installing green roofs in favelas' (P6)* should be carried out. In addition, the benefits to sustainability and ecosystem biodiversity were also raised by three participants who gave equal priority to solutions supporting improvements in both environmental and public health. However as stated by participant 14: *'there is no straightforward solution, and the policies we currently have are likely not going to help.'*

When presenting the final interview question to external stakeholders (see Table 5-11), several solutions and areas for development in Brazil were raised, with many similar parallels being drawn from participants despite their contrasting backgrounds and disciplines.

Table 5-11: Interview question asked of external stakeholders to address the research aim.

In areas where there is inadequate drainage and water infrastructure, if methods were applied to reduce the presence of surface water, do you believe that there would be a reduction in mosquito populations and the transmission of vector-borne disease?

Fourteen of the sixteen participants were asked this question owing to their expertise in the fields related to the project, and their understanding of wider policy and governmental agendas in these areas. Although participants were interviewed separately without awareness of other participants, responses fell into four main categories:

1. Appropriate project management and adequate community engagement (GOVERNANCE NEEDS, see figure 5-10);
2. Increased public awareness of water-related issues (EDUCATION/AWARENESS BUILDING);
3. The necessity for integrated and holistic approaches addressing water, sanitation and drainage challenges alongside vector-borne disease and other health issues simultaneously (ENVIRONMENTAL HEALTH);
4. Increased investment in both new and improved sanitation and solid waste infrastructure, across the whole urban environment instead of small-scale isolated interventions (LARGE-SCALE APPROACH, GOVERNMENTAL WILLINGNESS, ADAPTABLE TO CLIMATE CHANGE).

Figure 5-10 summarises the views that represent both the current challenges, and the necessary solutions envisaged by participants to resolve the problem of ZIKV in favelas. The diagram is based on the analytical codebook (Appendix 4) and uses the themes chosen from the initial conceptual framework of the project (governance, favelas, ZIKV and sanitation, see figure 3-16); each theme is indicated by the colour coding adopted in figure 5-10. The diagram reflects the coded comments addressed and highlighted by interviewees and does not illustrate all the possible challenges and solutions.

The challenges outlined on the left-hand branches of figure 5-10 were drawn from section 5.2. Each branch and their associated strands are sorted by theme with subsequent coloration choices indicating any relationships with other themes. For example, although uncollected solid waste is acknowledged to be an environmental challenge specific to favelas, the text is written in blue to signify that the origin of the challenge is grounded in poor sanitation infrastructure. To expand on this concept further, on the sanitation branch both the infrastructure agenda and its subcategories are underlined in red to highlight the need for governance involvement in enabling effective sanitation.

On the right-hand side of figure 5-10, a series of potential solutions are highlighted, and taken from participant responses to the interview question presented in Table 5-11. Whilst the same method of colour-coding has been adopted for both challenges and solutions, the variety of colours related to the potential solutions highlights both the complexity and level of dependency associated with each suggested solution. Like the approach to this research project, a multidisciplinary holistic approach has been advocated by participants as the most appropriate means of addressing ZIKV and sanitation problems in favelas. For instance, for empowerment to be achieved, there must be adaptation of alternative governance styles by all stakeholder levels, as well as changes to sanitation conditions, regulations and procedures. In addition, the favela communities themselves must also adopt responsibility and ownership for dealing with the issues raised.

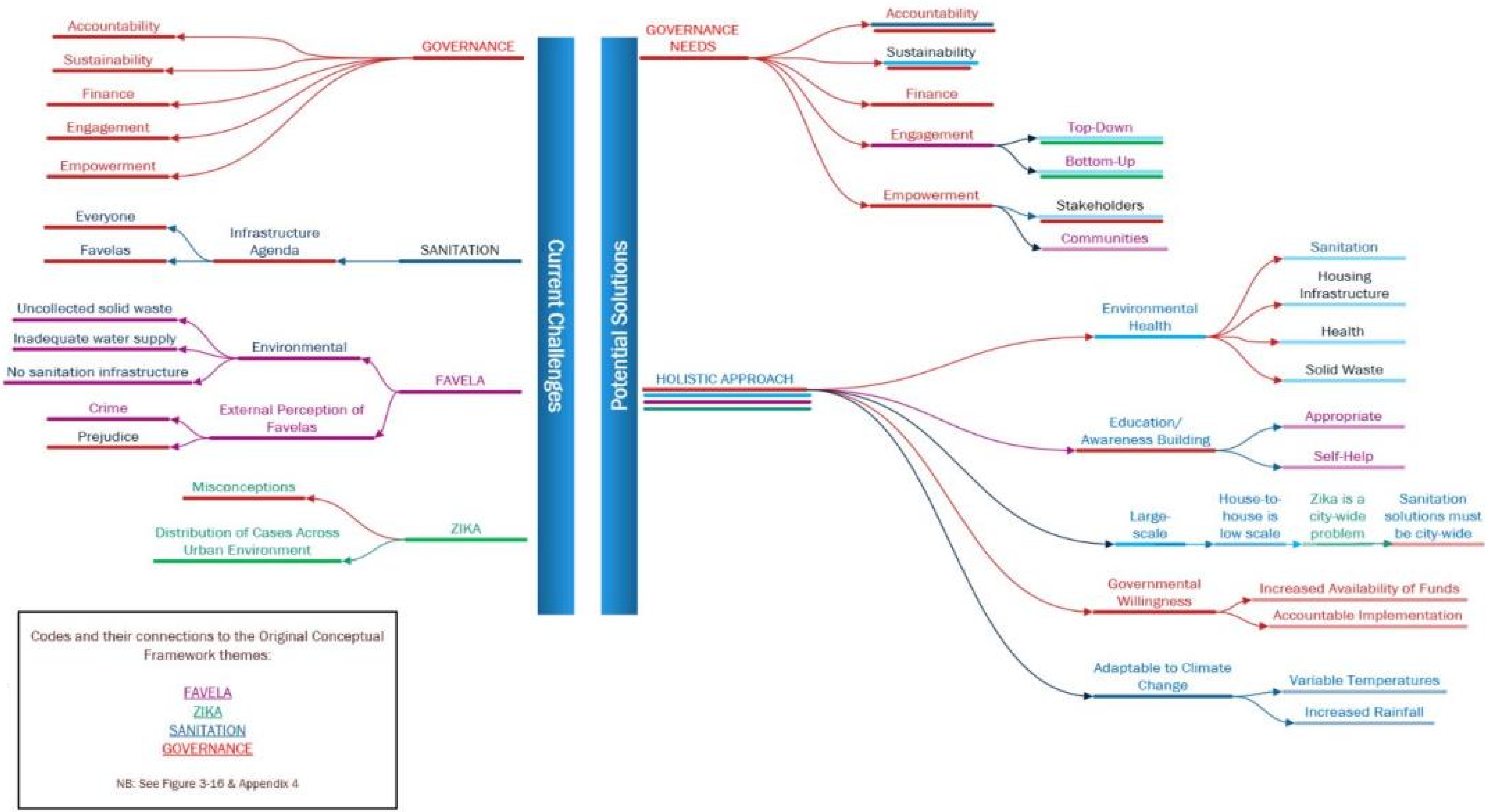

Figure 5-10: A coded diagram to illustrate the current challenges and potential solutions identified by participants

Findings related to these four areas are discussed in detail below:

1) Appropriate project management and community engagement

Owing to corruption throughout Brazil, many participants stated that the most pressing issues with government projects were *'financial accountability'* and lacking *'sustainability' (P5).* Funds are often not used appropriately, and projects are not designed with *'sustainability at the heart' (P4).* For these reasons, participants believe there is a need for *'collaboration' (P1)* and *'community-led' (P2)* approaches; advocating projects that reduce *'vertical approaches' (P1)* and design *'appropriate projects … that work with [existing] skills and knowledge [of the community]' (P4).* Participant 1 suggested *'you have to have conversations … and ask them [the community] their opinions and discuss methods of collaboration'*. By following this approach, the community is encouraged to *'improve and sustain themselves' (P4)* enabling *'sufficient jobs … and develop[ment of] skills to ensure dignity for the community … [and for] future community-led improvements' (P2).*

2) Increased public awareness of water-related issues

Due to the absence of public integration with sanitation improvements, it was suggested that projects needed to implement educational activities in the initial stages, to prevent ongoing reduced awareness of *'the risks and consequences of a polluted environment' (P3).* Participant 1 identified*: 'without sanitation education, we cannot try to bring people together' as* it is only once *'behaviour changes' (P2)* that people *'will see the issues' (P6)* and engage with *'solving sanitation problems' (P1).*

3) Integrated and holistic approaches

As discussed in 5.3.1, whilst many sanitation issues exist in favelas, there are several underpinning aspects, such as: *'living conditions, income, [and solid] waste collection' (P13).* It can be argued that it is then beneficial to address these issues using a holistic approach, owing to the connections between public and environmental health. However, Brazilian government policy-makers *'don't always link everything together' (P12)* and so the positive actions of one department are often disrupted by other departmental agendas. For this reason, integrated, collaborative approaches are necessary to *'effectively deal with these issues' (P12).*

4) Increased investment in sanitation and waste infrastructure

Although participants' opinions were mostly positive, two participants articulated scepticism about the level of government investment that would be required – with investment referring to the scale of projects and the finance needed:

> *'I think these problems can be solved … some solutions have been made … I'm not saying there's no solution, but it would take a very large intervention from the government'(P6).*

Furthermore, participant 14 was particularly concerned about extreme weather: *'we are struggling to deal … with existing systems in the current climate … those with no systems are just going to get worse'.* Hence it was vital that systems were designed with climate in mind; with considerations regarding the scale of interventions, participant two said: *'sanitation must be everywhere, by only improving one neighbourhood you're not improving everywhere.'* This suggestion also aligns with earlier concerns raised about *Aedes aegypti*'s ability to fly, as well as the reciprocal relationship between drainage and hydrology in cities.

Having taken into consideration the results presented throughout this section the following sub-section (5.4.2) contextualised and applies findings to two conceptual frameworks aligned to the aims and objectives of the project.

5.4.2 Discussion of Conceptual Frameworks

Conceptual Framework (A)

Figure 5-11 - Conceptual Framework (A) presents the findings of this project, combining participant interviews and data obtained from a comprehensive thematic review (Chapter 3) when applied to the current situation in Rio de Janeiro.

Before discussing the contextual basis of Conceptual Framework (A), it is necessary to outline the visual elements of the framework and implications. A series of arrows are used to illustrate the relationships or association between elements. The focus of the framework is the spectrum of existing conditions in *formal* and *informal settlements*, measured against the level of *governance* (y-axis) and *financial investment* (x-axis). The red arrows point to each settlement type's position on the spectrum, with the self-governed informal settlement at minimal investment, versus the formal settlement with high government regulation and investment. Due to different levels of governance and investment, the blue boxes illustrate the social, environmental and public health conditions that currently exist in each settlement. Finally, these conditions feed into the incidence rates of ZIKV and microcephaly in each area (purple boxes).

For clarity, the separation of *Informal* and *Formal Settlements* is shown along the bottom of the framework. A common theme addressed by participants was segregation between political and societal agendas regarding those living in formal or informal areas (see 5.2.1 and 5.3.1). As such, although in geographical proximity they are interlinked and have a reciprocal relationship (through surface water runoff or for employment means), there is an absence of acknowledged integration between the two settlement types – represented by the arrows between the settlement types in Figure 5-11.

This level of segregation extends further and is demonstrated by the visibility of existing governance interventions in each contrasting settlement type, with governance approaches designed and implemented by the *government*, or associated stakeholders on their behalf. For this reason, a series of socio-economic and environmental conditions prevail, originating from governance input in infrastructure and wellbeing improvements and the extent of *financial investment*. It is typically *informal settlements* who are at the lowest end of the spectrum, despite a small number of NGOs and civil society organisations working to support them. Examples of interventions are Monwabisi Park and Langrug settlements in South Africa (see 2.5.3) (Button *et al.* 2010; Harris *et al.* 2011). This finding is also supported by David *et al.* (2007), Pastor (2015) and Mittlin and Sattherthwait (2004) who agree that socio-economic prejudice prohibits informal settlements from the same rights and access to resources as their formal settlement counterparts. Furthermore, in direct relation to the aim of this project Larsen *et al.* (2015) summarise that because of informal status governments are disinterested in water management projects.

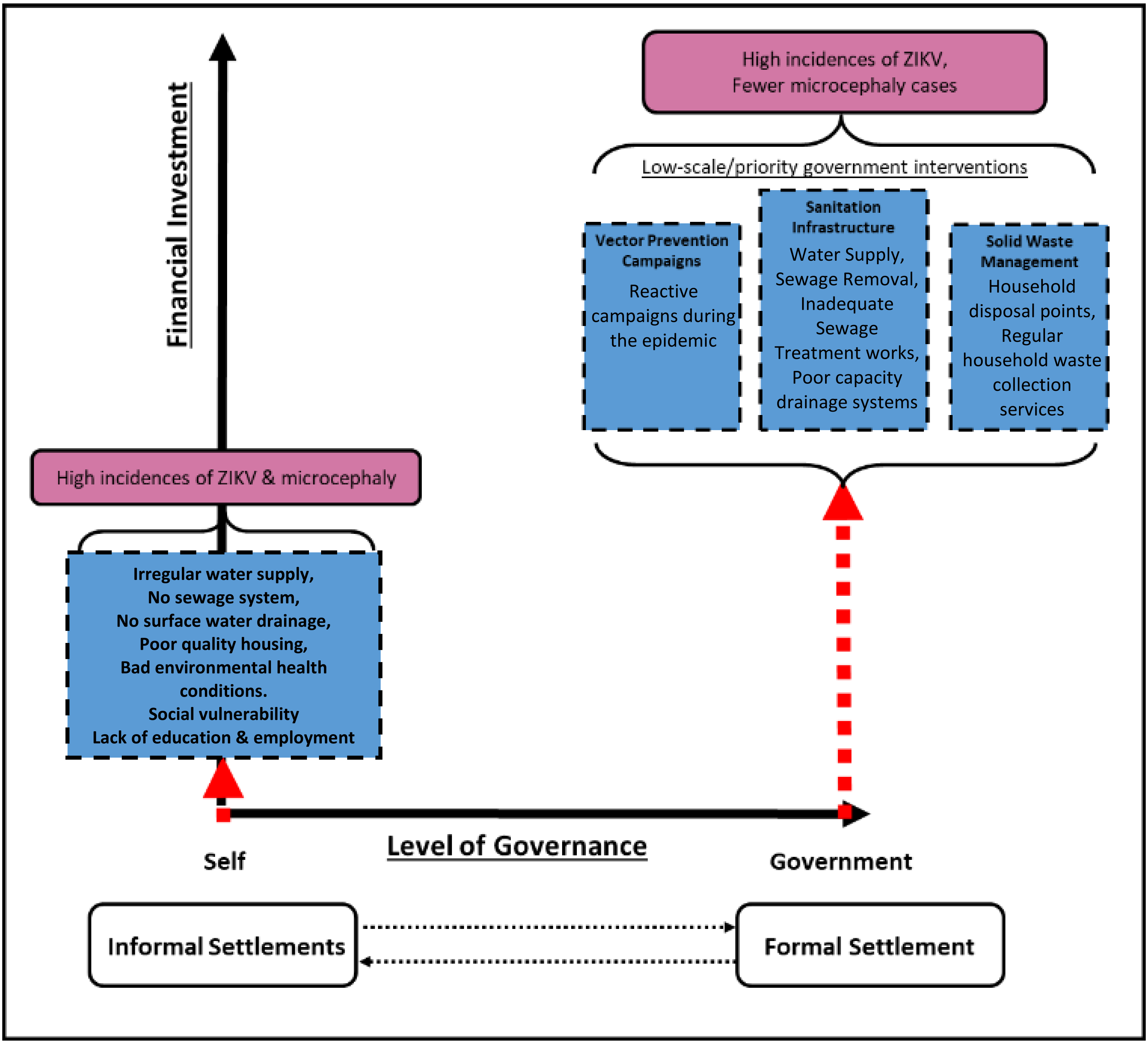

Figure 5-11: Conceptual Framework (A): The spectrum between informal and formal settlements in relation to current research findings in the context of Rio de Janeiro.

As presented on the *Informal Settlement* side of the framework (left), a lack of formal governance initiatives, and access to suitable funding, creates numerous challenges related to the themes and objectives of this project, such as sanitation, ZIKV and health. Whilst it has not been empirically proven, there is an academic consensus that a positive correlation exists between the water supply, sanitation and waste issues in favelas, and the preferred breeding locations of *Aedes aegypti* (de Souza *et al.* 2018; Lowe *et al.* 2018; Texeira and Cruz 2011). Nevertheless, further research is needed to examine if a correlation exists between cases of ZIKV and favela communities. Similarly, despite one-off interventions being implemented at the time of the Olympics (Brum 2016), many favela communities and individuals lacked the finance to purchase such chemicals to continue these initiatives (discussed by participant 7). Therefore, owing to segregation and lack of initiatives, it can be concluded that a higher number of ZIKV and microcephaly cases can be attributed to *informal settlements* (see 5.2.1*)*.

In formal areas accountable to municipal or federal governments, whilst there was still a prevalence of ZIKV, there were fewer incidences of microcephaly when compared directly to those living in informal areas (Rodrigues *et al.* 2018). When related to participant responses, it was identified that interventions conducted during the epidemic in the areas of: vector prevention (e.g. fogging, application of insecticide, covering/emptying containers), solid waste management (regular waste collection and correct disposal) and sanitation (regular water supply, emptying of drains, unblocking drain covers) were likely to have an impact on the proliferation of *Aedes aegypti* breeding sites and thus reduced mosquito populations. Furthermore, whilst government integration between different interventions and programmes was not forthcoming, each intervention complemented wider efforts to reduce mosquito-vectors, as well as public and environmental health. As such, by triangulating findings from the literature (Rodrigues *et al.* 2018) and the views of participants it can be argued that implementation of day-to-day low-scale interventions could be one of the main contributors to reducing in ZIKV.

Conceptual Framework (B)

Having presented the current situation in Rio de Janeiro in Conceptual Framework (A), Figure 5-12 - Conceptual Framework (B), amalgamates the main issues and challenges discussed throughout Chapter 5. The framework addresses both the project's aim: *To investigate the potential use of SuDS as a method to reduce ZIKV transmission in favelas* and the current gaps in academic discourse (see Chapters 2 and 3)

Firstly, the foundation of this framework demonstrates that whilst the focus of this research project has been favela communities, owing to the density of cities, the proximity of formal and informal areas, and the free movement of *Aedes aegypti*, a city-scale approach is needed to address the issue of ZIKV. Therefore, rather than viewing *informal* and *formal settlement* areas as opposing components of the city, governance approaches must regard them as equal, and view these contrasting settlement types as integrated features of the whole *urban environment*. In addition, for the activities outlined in the three blue boxes (*increased awareness and education, improved sanitation infrastructure, adequate solid waste management)* to be sustainable and demonstrate positive results, an increase in collaboration is required that utilises both top-down and bottom-up approaches and stakeholders. This is illustrated by the double-ended arrows pointing from *official governance* to *informal* and *formal settlement.*

Whilst vector prevention campaigns feature during *Aedes aegypti*-transmitted epidemics, there is no follow-up or collaborative approach that ensures advice is understood and correctly applied outside of epidemic periods – increasing the risk of the virus returning. Similarly, in informal settlements, very little is attempted in an '*official governance'* capacity to engage and improve livelihoods - with the high levels of crime and violence being cited as the justification; despite there being examples of NGOs and academic institutions who have successfully implemented projects and designed them around these challenges (see 3.5.3). Therefore, whilst the framework implies through the terminology of *official governance* that this directly applies to the government, there are many ways in which the government could engage with other stakeholders and organisations (either collaboratively or through grants) to implement the activities associated with *increased awareness and education, improved sanitation infrastructure and adequate solid waste management,* as well as to encourage a joined-up approach that integrates and collaborates with small-scale interventions already being conducted in these areas by lesser-known stakeholders.

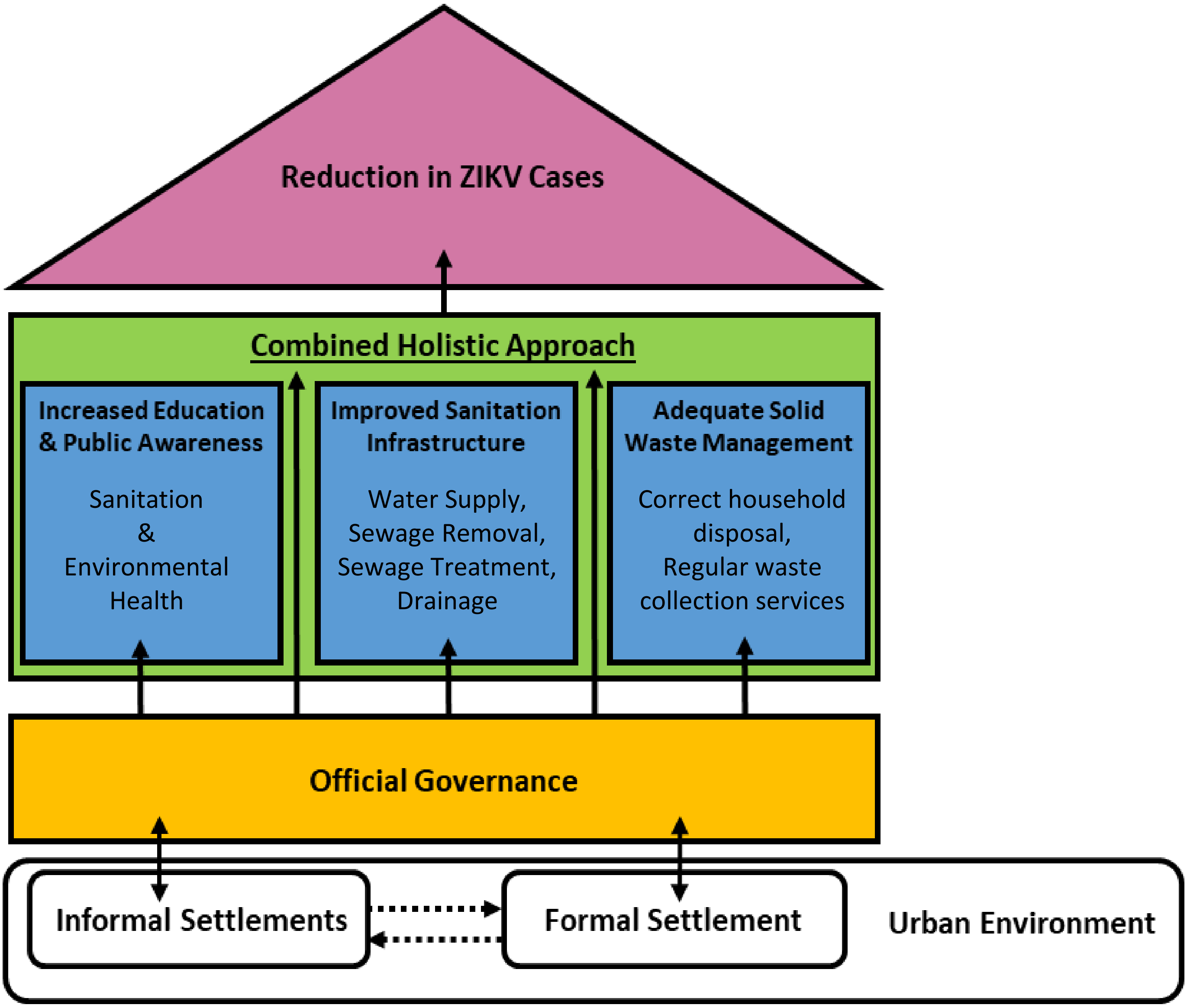

Figure 5-12: Conceptual Framework (B): An integrated holistic approach to address distribution of ZIKV in Brazil

Although the framework presents an idealised approach, the three activity boxes (in blue) are an exception. Typically, these aspects (*Increased awareness, improved sanitation infrastructure and adequate solid waste management*) are treated in silos, despite their resulting outcomes having a wider impact on each other. Additionally, in the case of Rio de Janeiro, each of these actions are currently responsibilities of different government departments and sanitation agencies, therefore it would be unrealistic to expect organisations and governments to re-structure to ensure the framework can be implemented. However, the framework highlights the intersections of each action and encourages a holistic approach (visualised by the surrounding green box) in the design and implementation of any subsequent programmes attributed to these three action areas.

Having discussed the areas featured in Conceptual Framework (B) throughout this Chapter, this is a consensus amongst participants that an approach combining the elements in Figure 5-12 could reduce transmission rates of ZIKV. However, to validate this further, empirical study is needed. Nevertheless, by adopting an integrated and holistic approach across the whole urban environment, not only should there be a reduction in *Aedes aegypti* populations and microcephaly, there will be positive implications on environmental health and wellbeing across the whole urban environment.

Limitations with Conceptual Models (A) and (B)

Although both models present the findings of this project in a concise and replicable manner, there are several issues that further field-based research and greater development of the project could address. These include:

- Both frameworks imply linear, step-by-step progress is needed to address the problems, but a more cyclical and iterative approach using many stakeholders is more realistic.
- Conceptual Framework (B) does not integrate the concerns raised by participants in section 5.4.1, point 1 (appropriate project management…) regarding project management, project delivery approaches, and distribution of funds.
- In both frameworks the Informal Settlement/Formal Settlement boxes are the same size, this implies they have the same 'advocacy' rights as each other and therefore have equal priority in the government agenda. This is not the case in reality as an ingrained social class hierarchy exists in Brazil.
- The inclusion of 'official' alongside governance (yellow box, model (B)) implies that suggested actions can be achieved through formal means, however, it does not reflect or address the barriers informal communities will face to achieve this.
- No explicit mention of key stakeholders – the government is implied but not directly stated. The roles of NGOs, international funding bodies, agencies, community stakeholders, etc. need to be more explicit

5.5 Chapter Conclusion

Chapter 5 presented and discussed both qualitative and quantitative results. Findings have been evaluated against the existing body of literature, with each area and its contribution to knowledge detailed. Having amalgamated findings in relation to existing discourse, two conceptual frameworks have been created that apply findings and suggest an appropriate conceptual approach in order to address the aim and objectives of the project with appropriate limitations discussed.

5.6 Thesis Summary and Contributions to Knowledge

This thesis has explored the concepts and context associated with the feasibility of SuDS implementation in Brazil, corresponding to the challenges associated with the ZIKV and inadequate water and sanitation in favelas. Using an inductive approach, framed around the observation that a higher number of ZIKV and microcephaly cases occurred in favelas when compared with the rest of urban areas, the themes and context associated with this were reviewed and a project aim was generated: *to identify the potential use of SuDS as a method to reduce ZIKV transmission in favelas.*

A thorough review of conceptual and contextual knowledge in the areas of study were conducted, and an initial conceptual framework designed (figure 3-15, pg.72), that corresponded to the gaps in the literature and acknowledged current understanding associated with the themes of the project (governance, sanitation, ZIKV and favelas). Subsequently, this initial framework was used as the basis for the methodological approach and supported the design of data collection tools, with the intention of exploring and testing the components of the framework.

When considering the unique challenges associated with research in the context of Brazil's favelas, a mixed-methods approach was adopted using familiar data collection techniques and methods in the areas of study to produce novel results. A series of maps illustrating the epidemiology of ZIKV and microcephaly, as well as the spatial distribution of favelas were produced, along with a comprehensive dataset of participant quotations gathered from interviews held with key external stakeholders, and favela community members.

When reviewing and analysing the results of the project, contrary to the initial hypothesis, findings outlined other issues associated with both the ZIKV and conditions in Rio de Janeiro's favelas – relating to housing density, inaccuracy of data and lack of adherence to *Aedes aegypti* prevention advice throughout formal and informal (favela) communities Therefore, a conclusive relationship between ZIKV and favelas cannot be drawn without further additional research. When investigating conditions in favelas related to water and sanitation conditions, many issues associated with stormwater, greywater and sewage removal were identified. Therefore, whilst these findings are consistent with current scholarly literature, as detailed in this chapter additional emphasis regarding provision for water supply and solid waste management are needed alongside other typical challenges such as sewage disposal in river courses, surface water flooding and inadequate open drainage channels encouraging disease vectors. Furthermore, potable supplies and solid waste management featured highly in the priorities of project participants, yet are under-researched in the wider discourse, surprising when they have negative impacts on both sanitation conditions and *Aedes aegypti* prevalence in favelas.

In order to apply findings, two novel frameworks were created that addressed objective 3 and the wider aim of the whole project. The first framework was created based around existing literature as well as the explicit findings discussed with participants. The second framework was built using existing literature and the opinions solicited from participants to generate a novel contribution to knowledge directly related to discourse in the areas of study.

The first framework, (A) (figure 5-11), identified the key barriers and challenges existing in both formal and informal settlements that are associated with differences in distribution of ZIKV and microcephaly. Framework (A) demonstrated that lack of governance and low levels of financial investment in informal settlements are the predominant contributors to existing socioeconomic, environmental and health inequalities. Framework (B) (figure 5-11), proposed an integrated holistic approach to address ZIKV distribution in Brazil. The framework suggests that whilst poor drainage (as per the project aim), provides favourable locations for mosquito vectors to breed, isolated drainage interventions will not achieve a reduction in ZIKV transmission. Therefore, it is suggested that an approach to manage the whole urban environment is required, to address the widespread issues associated with lack of public awareness of sanitation and environmental health, poor sanitation infrastructure and inadequate solid waste management. However, this approach can only be achieved when financial and political governance agendas align (as per Framework (A)). Therefore, further multidisciplinary research is required across the areas of medicine, environment, policy, engineering and social studies, so that the benefits of an approach such as that in Framework (B) are widely explored to assess suitability and replicability in different contexts throughout Brazil.

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Appendix 1

Interview Schedule for External Stakeholders - Linked to the Conceptual Framework

Question	Question themes relevant to the conceptual framework
- What aspect of your role/work involves working with or in favelas?	N/A – Soliciting general background of the participant
- How long have you been working with favela communities? What are the outcomes of your interaction/project?	
- What is your positionality on favelas and their existence?	
1. Are you aware of any government policies or initiatives that support the provision of better infrastructure in favelas?	GOVERNANCE
2. Are you aware of any NGOs or University research projects working on upgrading activities in favelas?	GOVERNANCE
3. Are you aware of any favela communities where formal drainage exists? Is it effective in operation?	SANITATION/GOVERNANCE
4. When you have been interacting with favela communities have you noticed any efforts initiated by community members to improve sanitation?	SANITATION/FAVELA
5. Do you believe that problems exist in favelas with the drainage of surface and grey water? Do you think these problems are sufficient enough to be addressed?	FAVELA
6. Are you aware of any public initiatives/schemes initiated in the wake of the Zika outbreak in 2015 – to include the wider public and to favela communities?	ZIKA/GOVERNANCE
7. 2. How well does information about the prevention of Zika/dengue/chikungunya reach favela communities? Do favela communities respond to the information they are given?	FAVELA/ZIKA
8. Has the increase in microcephaly changed attitudes towards mosquito-transmitted disease?	ZIKA/FAVELA
9. What do you think is the reasoning behind consistently higher infection rates in favelas, in comparison to the wider urban environment?	FAVELA/ZIKA
10. In areas where there is inadequate drainage and water infrastructure if methods were applied to reduce the presence of surface water, do you believe that there would be a reduction in mosquito populations and the transmission of vector-borne disease?	FAVELA ZIKA SANITATION GOVERNANCE

Appendix 2

Interview Schedule for Favela Community Members – Linked to the Conceptual Framework

Question	Question themes relevant to the conceptual framework
• Can you give me some background on the community where you live? [Name, Location, How long have you lived there? How long has the community been located there?	N/A – Soliciting general background of the participant
Household Attributes • Average number of people living in the household? • What are the common relationships between household members? E.g. Grandmother, Mother, Father and Sisters etc. • What is the dwelling layout and condition/quality of construction? • What building materials are used to build homes?	FAVELA
Water and Sanitation • Where do they collect their water from? • Where do they store Water? • Do they use covered or uncovered water containers? • Is water stored inside or outside of the house? • Do households/the community have access to insecticide to treat the water? • Do they use any rainwater harvesting methods to collect water? • Where do they defecate? • How do they flush it? • How many people use the toilet? • How do they dispose of solid waste? • Is there any formal garbage collection?	FAVELA SANITATION GOVERNANCE
Surface Water Issues • Past or present – Does flooding occur in the community? • What is the origin of the flood? River or Rain? • Are there any isolated problem areas for flooding within the community?	FAVELA SANITATION

• When are the heaviest periods of rainfall during the year? • Where do they dispose of household greywater (created by cooking, cleaning, bathing)? • Do the community use any improvised methods to create drainage or sanitation infrastructure? • Have the community ever been involved in any, municipal/NGO/research project where improved built infrastructure has been implemented?	GOVERNANCE
<u>Zika</u> • Has their community been involved in any Zika (chikungunya/dengue/yellow fever) campaigns or visited by outreach workers? • Do you think Zika and Congenital Zika Syndrome (Microcephaly) is a perceived problem for the community?	ZIKA FAVELA GOVERNANCE
<u>Vulnerability Prioritisation</u> • What are the concerns/problems/issues in the community that you have experienced? • What do you think would be the most important issue for action if chosen by a favela member?	FAVELA GOVERNANCE

Appendix 3

Security report generated prior to data collection in Rio de Janeiro

Security Brief WorldAware®

Brazil: Presidential Election Result Likely to Lead to Further Polarization - *November 2, 2018*

The historic victory of Jair Bolsonaro in the 2018 presidential election is likely to result in an increase in civil unrest and violence during the president-elect's term in office. Bolsonaro has proposed and will likely implement a heavy-handed security strategy, particularly in low-income neighbourhoods. As a result, extrajudicial killings and disproportionate use of force by security forces may increase, particularly in Brazil's *favelas* (shanty towns). Organized crime groups will likely respond to heightened security efforts with increased violence, and homicide rates are expected to rise consequently. Civil unrest, fuelled by anti- and pro-Bolsonaro sentiment, will likely escalate in reaction to Bolsonaro's security policies. Nonetheless, markets have reacted positively to a Bolsonaro presidency, but the president-elect will need to sustain Brazil's economic recovery beyond the near term to curb escalating public dissatisfaction.

Key Judgments

- Bolsonaro's election victory will likely lead to heightened security in major cities, particularly in low-income neighbourhoods.
- The threat of civil unrest may rise as anti- and pro-Bolsonaro groups increase their activity in response to the president-elect's heavy-handed security policies.
- Markets will likely continue to react positively in the short term, but the country's ongoing economic recovery may falter if Bolsonaro fails to fix a ballooning public debt burden.
- Operation *Lava Jato* (Car Wash), a far-reaching corruption probe, will remain a fixture in Brazilian politics and will likely incite further civil disobedience.

Background

The election results are the culmination of a multi-round fight for the presidency that ultimately came down to a contest between Jair Bolsonaro of the Social Liberal Party (Partido Social Liberal, PSL) and Fernando Haddad of the Workers' Party (Partido dos Trabalhadores, PT). Bolsonaro campaigned on a far-right platform that criticized many progressive sectors of society: women's rights groups and the Lesbian, Gay, Bisexual, Transgender, and Queer (LGBTQ) community were common targets. While Bolsonaro's initial support base was largely white, educated, and of a higher socioeconomic class, he was successful at attracting younger and less-affluent voters in the final months of the election.

Bolsonaro successfully made the purported pro-Venezuelan and anti-democratic views of the PT a core issue of the election, while also emphasizing the PSL's popular proposals to tackle violent crime and improve the economy. In the build-up to the Oct. 28 runoff election, Bolsonaro repudiated some of his more controversial claims and policy pledges. For example, he revoked his promise to withdraw Brazil from the Paris Agreement on climate change. Ultimately, diminishing violent crime was the campaign pledge that most resonated with voters.

Crime and Violence

Bolsonaro's anti-crime rhetoric was central to his campaign for president. After Bolsonaro assumes the presidential mantle in January 2019, it remains very likely that the president-elect will hold firm to his pledge to wage war on violent crime. This will likely entail more troops on the streets, as well as greater impunity for security forces who shoot and kill suspected criminals. Congress is likely to approve any major anti-crime bill the PSL coalition proposes; according to the Brazilian Forum of Public Safety, the murder rate in 2017 in Brazil was the highest in the country's history at approximately 30 per 100,000 people. Military operations will likely become more common in low-income neighbourhoods in major cities such as Sao Paulo and Rio de Janeiro.

A public schism surrounding the success of Bolsonaro's war on crime will likely develop in response to security efforts in favelas. The backlash by favela dwellers to previous military-like operations in their neighbourhoods is emblematic of the type of resistance that many people in low-income communities will continue to display under Bolsonaro's presidency, even as a significant number of people in those same communities champion Bolsonaro's new security strategies. As the military effort increases in scope in large cities, a greater number of bystanders may be caught in the crossfire between security forces and organized crime groups. If notable activists, such as the recently murdered politician Marielle Franco, whose death sparked widescale protests, continue to be killed, civil unrest will likely reach new heights. Similar to Brazil's experience following former president Dilma Rousseff's impeachment, anti- and pro-Bolsonaro protests will likely become a common feature even before Bolsonaro takes office.

Conclusion

Anti- and pro-Bolsonaro sentiment will continue to be a dominant feature in the dialogue between politicians and the public. An increase in violence, protests, and civil unrest is likely. Despite this, a possible short-term reduction in violent crime rates may also occur following the implementation of the president-elect's heavy-handed security strategy. Ultimately, Bolsonaro's ability to enact economic and social reform will also determine the levels of crime and public dissatisfaction during his presidency, as the success or failure of such reforms will likely determine the country's long-term economic health. Either way, Bolsonaro's victory is likely to further polarize public discourse in Brazil.

Appendix 4

Analytical Codebook sorted by Conceptual Framework themes.

GOVERNANCE

I. GOVERNMENT
   a) BOLSONARO
      i) UNCERTAINTY
   b) POLICY
      i) FREQUENT CHANGE OF AGENDA
      ii) REACTIVE NOT PROACTIVE
   c) FEDERAL
   d) STATE
   e) MUNICIPALITY
   f) SANITATION COMPANIES
      i) PROFIT

II. GOVERNMENT INITIATIVES
   a) INFRASTRUCTURE
      i) FAVELA BARRIO
      ii) PAC
      iii) PROFACE
   b) SOCIAL SECURITY
      i) BOLSA FAMILIA
      ii) MI CASA, MI VIDA
   c) PUBLIC HEALTH
      i) COMMUNITY HEALTH WORKERS
         (1) SURVEILLANCE AGENTS
            (a) FUTURE UNCERTAIN
         (2) HEALTH AGENTS
            (a) FUTURE UNCERTAIN

III. UNIVERSITY INITIATIVES
   a) ZIKA ALLIANCE
      i) PREGNANT WOMEN
      ii) BABIES WITH MICROCEPHALY
   b) OPEN UNIVERSITY
      i) COMMUNITY ENGAGEMENT
      ii) SOCIAL AND PRACTICAL PILOT PROJECTS
   c) TIAS PROJECT
      i) SOCIAL ENTERPRISE/JOB CREATION
      ii) EDUCATION, SKILLS & KNOWLEDGE SHARING

IV. NGO INITIATIVES
   a) NATIONAL NGOS
      i) ADHERE GOVERNMENT AGENDA
      ii) GOVERNMENT FUNDS INCONSISTENT
      iii) POORLY FUNDED
      iv) LACK OF PROPER PLANNING
   b) INTERNATIONAL NGOS
      i) BETTER FUNDED
      ii) MORE CONTINUITY OF PROJECTS

V. GOVERNANCE NEEDS
   a) ACCOUNTABILTY
   b) SUSTAINABILITY
   c) FINANCE
      i) CORRUPTION
   d) ENAGEMENT
      i) TOP-DOWN
      ii) BOTTOM-UP
   e) EMPOWERMENT
      i) COMMUNITIES
      ii) STAKEHOLDERS

SANITATION

I. SANITATION IN BRAZIL
   a) POTABLE WATER
      i) SUPPLY CHALLENGES
      ii) CONTAMINATION
   b) SEWAGE REMOVAL
      i) COMBINED SEWERS
   c) SEWAGE TREATMENT
      i) LACKING SEWAGE TREATMENT WORKS
      ii) RAW SEWAGE DISCARGED BY OCEAN OUTFLOW
   d) DRAINAGE
      i) GREYWATER
      ii) STORMWATER
      iii) FREQUENT FLOODING
         (1) BLOCKED DRAINS/GULLY POTS/PIPES OVERFLOW
      iv) LOWEST GOVERNMENT SANITATION PRIORITY
         (1) UNMAINTAINED INFRASTRUCTURE

II. SANITATION INFRASTRUCTURE AGENDA
   a) EVERYONE
      i) INADEQUATE CAPACITY
      ii) POOR QUALITY
      iii) LEGAL AREAS ONLY
   b) FAVELAS
      i) UPGRADING/IMPROVING
      ii) RELOCATION
      iii) REMOVAL

III. FORMAL DRAINAGE IN FAVELAS
   a) CEILANDIA (BRASILIA)
   b) ROCHINA (PAC PROGRAMME)
      i) SUPPORTING NATURAL DRAINAGE
      ii) CHALLLENGE OF SEWAGE DISPOSAL
   c) NOVA IGUACU
      i) CENTRAL NETWORK PROVIDED
      ii) HOUSEHOLD RESPONSIBLE FOR OWN CONNECTION

IV. COMMUNITY INITIATED SANITATION
   a) PRAIA DO SONO
      i) EVAPOTRANSPIRATION TANK
      ii) FOR HH GREY & BLACK WATER
      iii) CONDENSED VAPOUR COLLECTED AND USED FOR AGRICULTURE

FAVELA

I. CHALLENGES
  a) HOUSEHOLD ENVIRONMENT
    i) OVERCROWDING
    ii) POOR QUALITY MATERIALS
  b) ENVIRONMENTAL
    i) UNCOLLECTED SOLID WASTE
      (1) ACCUMULATED WASTE IN THE STREET
    ii) NUISANCE ANIMALS
      (1) VECTORS - RATS, FLIES, MOSQUITOS
      (2) DOMESTIC ANIMALS – HORSES, COWS, CHICKENS, SHEEP
    iii) INADEQUATE WATER SUPPLY
      (1) STORAGE OF POTABLE & STORMWATER IN HOMES
        (a) IMPROPER/UNCOVERED CONTAINERS
    iv) NO SANITATION INFRASTRUCTURE
      (1) ILLEGAL CONNECTIONS TO EXTERNAL SYSTEMS
      (2) INABILITY TO CONNECT TO FORMAL SYSTEMS (PROXIMITY)
      (3) DISCHARGE WASTEWATER INTO RIVER/THROW OUTSIDE
        (a) POOLS OF CONTAMINATED WATER
        (b) RIVER COURSE POLLUTION
    v) TOPOGRAPHY/SOIL/ROCK TYPE
      (1) HILLSLOPE/FLOOD PLAIN
      (2) PERMEABILITY
    vi) FLOODING
    vii) LACK OF SPACE BETWEEN HOMES
  c) HEALTH
    i) DISEASE
      (1) LEPTOSPIROSIS/HEPATITIS A/TUBERCULOSIS
      (2) ZIKA/CHIKUNGUNYA/DENGUE
    ii) MALNUTRITION
  d) EMPLOYMENT
    i) LOW INCOME
      (1) INABILITY TO PAY UTILITY BILLS
    ii) LACKING OPPORTUNITIES
    iii) LACKING SKILLS
  e) EXTERNAL PERCEPTION OF FAVELAS
    i) SAFETY
    ii) CRIME
    iii) RACISM/PREJUDICE
  f) ACCESS
    i) TRADITIONAL EDUCATION
      (1) LACKING AWARENESS OF ENVIRONMENTAL ISSUES
        (a) UNABLE TO LINK PROBLEMS TO CONNECTED ROOT CAUSES
    ii) VOCATIONAL SKILLS/KNOWLEDGE
    iii) TO FUNDS
    iv) TO RESOURCES
  g) FAVELA INTERNAL HIERARCHY
    i) POWER STRUCTURE
      (1) DRUGS/GANGS
        (a) FRICTION BETWEEN GOVERNMENT & COMMUNITY
  h) DEPENDENCY VS EXPECTATION
    i) ON OTHERS TO PROVIDE SOLUTIONS

II. MOSQUITO PREVENTION
  a) AGENT VISITS
    i) FREE REPELLANT FOR PREGNANT WOMEN
      (1) LOW-COST HOMEMADE RECIPE GIVEN TO THOSE WHO DON'T QUALIFY
    ii) IMPLEMENT/MONITOR PREVENTION MEASURES
  b) BARRIERS
    i) HABITS
    ii) LACK OF AWARENESS/UNDERSTANDING
      (1) MISCONCEPTIONS ABOUT VIRUS'
      (2) NO AWARENESS OF VIRUS/PREVENTION METHODS
    iii) VULNERABLE INDIVIDUALS REQUIRE ADDITIONAL SUPPORT
    iv) MONEY
    v) SAFETY FOR AGENTS
    vi) ACCESS TO TREATMENT
      (1) PROXIMITY OF HC FACILITIES/SPECIALIST CENTRES
    vii) PERCEPTION OF RISK OF Z/C/D
    viii) NARROW STREETS
      (1) FOGGING VEHICLES CANNOT PASS

ZIKA

INITIATIVES

- a) PROGRAMMES
  - i) TRIPLICE EPIDEMIC
  - ii) ZIKA/CHIKUNGUNYA 2015
  - iii) DENGUE
- b) RADIO/TV/POSTERS
  - i) PREVENTION ADVICE
    - (1) EMPTY POTTED PLANTS
    - (2) CLEAN WATER TANKS
    - (3) EMPTY/TREAT SWIMMING POOLS
    - (4) APPLY INSECTICIDE
    - (5) REMOVE POOLS OF WATER
    - (6) REDUCE SOLID WASTE ACCUMULATION
    - (7) CLEAR GUTTERS
    - (8) COVER CONTAINERS
- c) HEALTH AGENTS
  - i) ADVICE
  - ii) DISTRIBUTE REPELLENTS
    - (1) EPIDEMIC ONLY
- d) SURVEILLANCE AGENTS
  - i) PREVENTION MONITORING
    - (1) EPIDEMIC ONLY
  - ii) IMPLEMENT CONTROL MEASURES
    - (1) EPIDEMIC ONLY
      - (a) HOUSE-TO-HOUSE
        - (i) FOGGING
        - (ii) APPLYING INSECTICIDE
- e) MUNICIPAL GOVERNMENT-LED PROJECTS
  - i) GOOD EXAMPLES IN RECIFE, SALVADOR

II. CHALLENGES

- a) FINANCE
  - i) UNAVAILABILITY OF FUNDS
- b) POLITICAL AGENDA
  - i) NOT ALWAYS SEEN AS A PRIORITY
- c) ACCURACY OF DATA
  - i) LATE TO BECOME NOTIFIABLE DISEASE
  - ii) MICROCEPHALY DATA MORE ACCURATE
- d) MISCONCEPTIONS
  - i) ZIKA
    - (1) BREED IN CLEAN WATER
  - ii) MICROCEPHALY
    - (1) CAUSED BY
      - (a) PESTICIDE USE IN FARMING
      - (b) INSECTICIDE APPLIED TO WATER
      - (c) LACK OF NUTRITION
- e) WEALTHY NEIGHBORHOODS
  - i) ROOFTOP ACCUMULATION IN APARTMENT BLOCKS
  - ii) HOLIDAY/RENTED APARTMENTS
    - (1) UNEMPTIED/TREATED SWIMMING POOLS
    - (2) UNEMPTIED PLANTPOTS/WATER RESERVOIRS
- f) AEDES AEGYPTI
  - i) URBAN DWELLING
  - ii) TRAVEL SHORT DISTANCE
    - (1) DENSITY OF HOMES AND POPULATION
  - iii) FAVOUR BRAZIL'S CLIMATE
- g) ACCESS TO HEALTHCARE
  - i) INCONSISTENT FACILITIES/SERVICES NATIONALLY
- h) DISTRIBUTION OF CASES ACROSS URBAN ENVIRONMENT
  - i) ZIKA
    - (1) EVERYWHERE
  - ii) MICROCEPHALY
    - (1) HIGHER PROBABILITY IN FAVELAS
    - (2) BUT… ALSO IN WEALTHY AREAS TOO.
  - iii) RIO DE JANEIRO
    - (1) FAVELAS AND WEALTHY AREAS ARE SIDE-BY-SIDE.

OUTPUTS

I. GOVERNANCE NEEDS
  a) ACCOUNTABILITY
  b) SUSTAINABILITY
  c) FINANCE
    i) CORRUPTION
  d) ENGAGEMENT
    i) TOP-DOWN
    ii) BOTTOM-UP
  e) EMPOWERMENT
    i) COMMUNITIES
    ii) STAKEHOLDERS

II. POSSIBLE SOLUTION
  a) HOLISTIC APPROACH
    i) ENVIRONMENTAL HEALTH
      (1) SANITATION
      (2) HOUSING INFRASTRUCTURE
      (3) HEALTH
      (4) SOLID WASTE
    ii) EDUCATION/AWARENESS BUILDING
      (1) APPROPRIATE
      (2) SELF-HELP
    iii) LARGE-SCALE APPROACH
      (1) HOUSE TO HOUSE IS LOW-SCALE
      (2) ZIKA IS A CITY-WIDE PROBLEM
      (3) SANITATION SOLUTIONS MUST BE CITY-WIDE
    iv) GOVERNMENTAL WILLINGNESS
      (1) ACCOUNTABLE IMPLEMENTATION
      (2) INCREASED AVAILABILITY OF FUNDS
    v) ADAPTABLE TO CLIMATE CHANGE
      (1) INCREASED RAINFALL
      (2) VARIABLE TEMPERATURES

Appendix 5

A summary of both interview schedules and their alignment to the themes and research aims & objectives

Questions for *External Stakeholders*	**Question themes relevant to conceptual framework**	**Research Objectives**
1. Are you aware of any government policies or initiatives that support the provision of better infrastructure in favelas?	GOVERNANCE	Obj 3/2
2. Are you aware of any NGOs or University research projects working on upgrading activities in favelas?	GOVERNANCE	Obj 3
3. Are you aware of any favela communities where formal drainage exists? Is it effective in operation?	SANITATION/GOVERNANCE	Obj 3/2
4. When you have been interacting with favela communities have you noticed any efforts initiated by community members to improve sanitation?	SANITATION/FAVELA	Obj 2/3
5. Do you believe that problems exist in favelas with the drainage of surface & grey water? Do you think these problems are sufficient enough to be addressed?	FAVELA	Obj 2
6. Are you aware of any public initiatives/schemes initiated in the wake of the Zika outbreak in 2015 – to include the wider public and to favela communities?	ZIKA/GOVERNANCE	Obj 1
7. 2. How well does information about the prevention of Zika/dengue/chikungunya reach favela communities? Do favela communities respond to the information they are given?	FAVELA/ZIKA	Obj 1
8. Has the increase in microcephaly changed attitudes towards mosquito-transmitted disease?	ZIKA/FAVELA	Obj 1
9. What do you think is the reasoning behind consistently higher infection rates in favelas, in comparison to the wider urban environment?	FAVELA/ZIKA	Obj 1
10. In areas where there is inadequate drainage and water infrastructure, if methods were applied to reduce the presence of surface water, do you believe that there would be a reduction in mosquito populations and the transmission of vector-borne disease?	FAVELA/ZIKA /SANITATION GOVERNANCE	Research Aim.

Questions for *Favela Community Members*	Question themes relevant to the conceptual framework	Research Objectives
Average number of people living in the household? What are the common relationships between household members? E.g. Grandmother, Mother, Father and Sisters etc. What is the dwelling layout and condition/quality of construction? What building materials are used to build homes?	FAVELA	Obj 1/2
Where do they collect their water from? Where do they store Water? Do they use covered or uncovered water containers? Is water stored inside or outside of the house? Do households/the community have access to insecticide to treat the water? Do they use any rainwater harvesting methods to collect water? Where do they defecate? How do they flush it? How many people use the toilet? How do they dispose of solid waste? Is there any formal garbage collection?	FAVELA SANITATION GOVERNANCE	Obj 1/2
Past or present – Does flooding occur in the community? What is the origin of the flood? River or Rain? Are there any isolated problem areas for flooding within the community? When are the heaviest periods of rainfall during the year? Where do they dispose of household greywater (created by cooking, cleaning, bathing)? Do the community use any improvised methods to create drainage or sanitation infrastructure? Have the community ever been involved in any, municipal/NGO/research project where improved built infrastructure has been implemented?	FAVELA SANITATION GOVERNANCE	Obj 2/3
Has their community been involved in any Zika (chikungunya/dengue/yellow fever) campaigns or visited by outreach workers? Do you think Zika and Congenital Zika Syndrome (Microcephaly) is a perceived problem for the community?	ZIKA FAVELA GOVERNANCE	Obj 1
What are the concerns/problems/issues in the community that you have experienced? What do you think would be the most important issue for action if chosen by a favela member?	FAVELA GOVERNANCE	Obj 2/3

Appendix 6

Three ethics applications were submitted and approved:
1) Desk-based study: P72203, 2) Fieldwork and Data Collection in Brazil: P72851
3) Online Questionnaires: P79400.

Certificate of Ethical Approval

Applicant:

Rebecca Lewis

Project Title:

Can sustainable drainage lead to a reduction in Zika Virus transmission in Brazil?

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Low Risk

Date of approval:

25 July 2018

Project Reference Number:

P72203

Certificate of Ethical Approval

Applicant:

Rebecca Lewis

Project Title:

Addressing disease vectors with Sustainable Drainage: the Zika virus in favelas in Brazil

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

22 October 2018

Project Reference Number:

P72851

Coventry University

Certificate of Ethical Approval

Applicant:

Rebecca Lewis

Project Title:

Can sustainable drainage lead to reduction in Zika Virus transmission in Brazil's favelas?

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

01 January 2019

Project Reference Number:

P79400