DEPARTMENT OF HEALTH & HUMAN SERVICES **Public Health Service**

Centers for Disease Control
and Prevention (CDC)
Atlanta GA 30341-3724

May 14, 2015

Impact Evaluation Design Report

Lusaka Water Supply, Sanitation, and Drainage (LWSSD) Project

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ACRONYMS AND ABBREVIATIONS

ABA	Ampicillin Blood Agar
APW	Alkaline Peptone Water
ARI	Acute Respiratory Infection
CBD	Central Business District
CDC	Centers for Disease Control and Prevention
CDC-A	U.S. Centers for Disease Control and Prevention – Atlanta
CDC-Z	Centers for Disease Control and Prevention – Zambia
COD	Chemical oxygen demand
CSO	Zambian Central Statistics Office
DD	Difference in Differences
DMA	District Metering Area
EIA	Enzyme Immunoassay
ERB	Ethical Review Board
ERR	Economic Rate or Return
FCR	Free chlorine residual
FGD	Focus Group Discussion
GEE	Generalized Estimating Equations
GEMS	The Global Enteric Multicenter Study
GET	GPS Enabled Tracker
GIS	Global Information Systems
GPS	Global Positioning System
GRZ	Government of Zambia
HF	Health Facility
HH	Household
HPC	Heterotrophic plate count
IDI	In Depth Interview
IDSR	Integrated Disease Surveillance and Response
IEC	Information, Education and Communication
IRB	Institutional Review Board
KAP	Knowledge, Attitudes, and Practices
KII	Key Informant Interview
LCC	Lusaka City Council
LCMS	Zambia Living Conditions Monitoring Survey
LSMD	Laser Speed Measuring Device
LWSC	Lusaka Water and Sewerage Company
LWSSD	Lusaka Water Supply, Sanitation, and Drainage Project
M&E	Monitoring and Evaluation
MAC	MacConkey Agar
MCA Zambia	Millennium Challenge Account Zambia
MCC	Millennium Challenge Corporation
MDG	Millennium Development Goals
MOH	Zambian Ministry of Health
MOU	Memorandum of Understanding
MSA	Mannitol Salt Agar
NGO	Non-Governmental Organization

PCR	Polymerase Chain Reaction
ppm	Parts per million (equivalent to mg/L)
PSU	Primary Sampling Unit
PUA	Peri-Urban Area
QA/QC	Quality assurance/quality control
QR	Quality Review
SEA	Standard Enumeration Area
SFB	Selenite-F Broth
SOP	Standard operating procedures
SRS	Simple Random Sample
SSU	Secondary Sampling Unit
TCBS	Thiosulfate Citrate Bile Salts Sucrose Agar
TOR	Terms of Reference
TOR	Terms of Reference
TSS	Total suspended solids
TTGA	Taurocholate Tellurite Gelatin Agar
USG	United States Government
UTH	University Teaching Hospital
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WTP	Water Treatment Plant
XDL	Xylose Lysine Agar
ZABS	Zambia Bureau of Standards

BACKGROUND

Basic water infrastructure is lacking or inadequate to meet the needs of urban populations in most cities in sub-Saharan Africa, contributing to a significant burden of diarrheal disease and under 5 child mortality. In Lusaka, the capital city of Zambia, the water and sanitation infrastructure was built in the 1960s and 1970s when the population was less than 300,000. Water system maintenance and construction of new water infrastructure have not kept pace with population growth – Lusaka currently has 1.8 million residents (Central Statistics Office, 2011), and by 2035, the population is projected to exceed 5 million (Millennium Challenge Corporation, 2012).

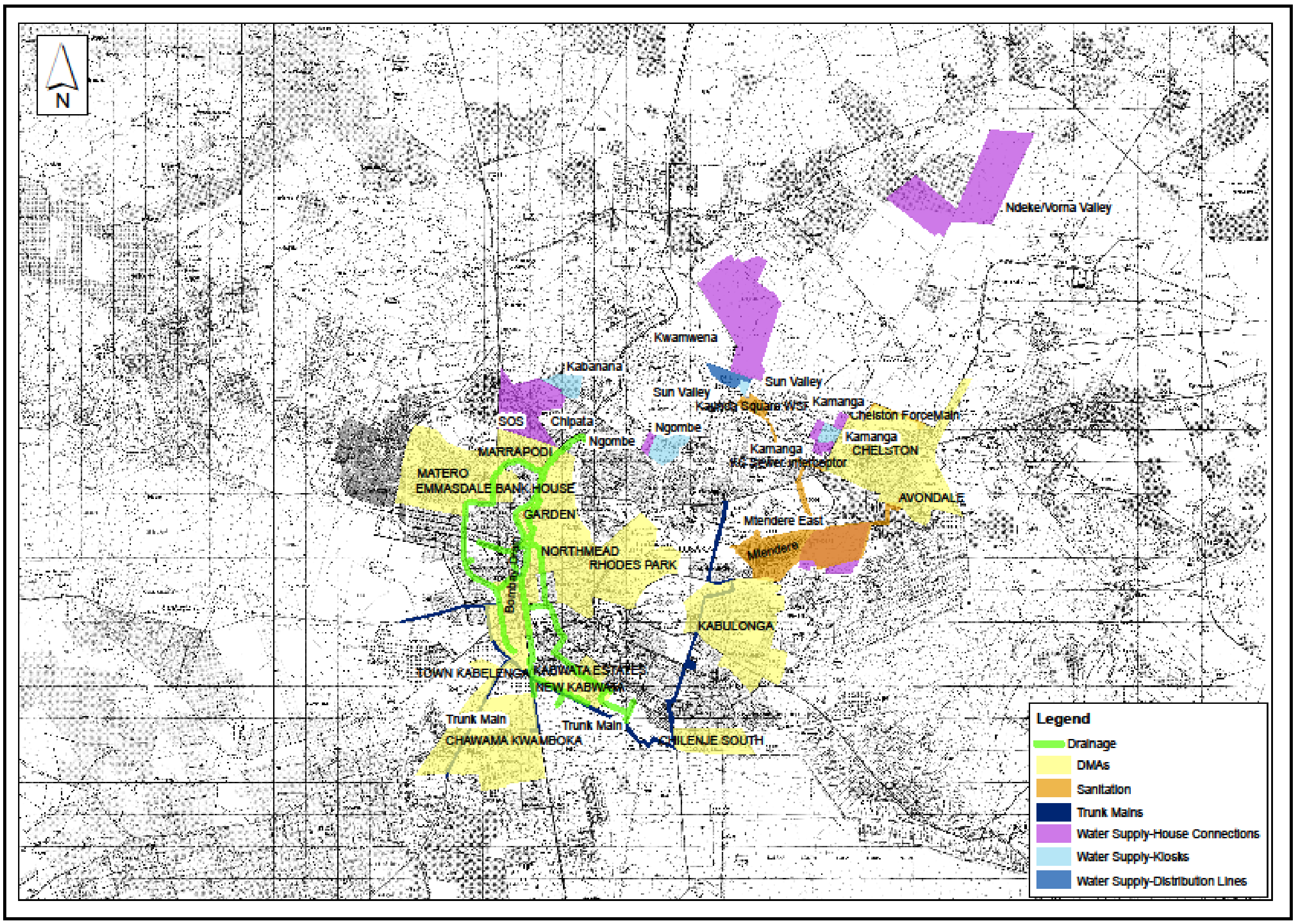
The Millennium Challenge Corporation (MCC), established in 2004 as a foreign assistance program under the U.S. Department of State, funds development projects – Compacts – in approximately 30 countries, primarily in Africa, Asia and Latin America. Compacts are funded and implemented over five years and focus on development projects in specific sectors including agriculture, transportation, energy, water or WASH (water, sanitation and hygiene), education, and healthcare. Each Compact is managed by the host country government under a Millennium Challenge Account (MCA). MCC requires independent evaluations for each Compact.

ZAMBIA COMPACT

MCC in partnership with the Government of Zambia (Millennium Challenge Account Zambia [MCA Zambia]) is implementing a large-scale, $350 million upgrade and extension of the water, sanitation, and drainage infrastructure in Lusaka to increase population access to potable water, sanitation, and flood protection. The Lusaka Water Supply, Sanitation and Drainage (LWSSD) project (the Compact) will strengthen and upgrade the main surface water treatment plant for Lusaka, extend water supply and sanitation networks into areas with limited household water connections and toilets, rehabilitate existing water kiosks, and improve the drainage network for the primary business district and surrounding residential communities in Lusaka (Figure 1). The location, type, and scope of the Compact interventions was determined by MCC, the Government of Zambia (GRZ), MCA Zambia, and key stakeholders such as the Lusaka Water and Sewerage Company and the Lusaka City Council.

MCC and the U.S. Centers for Disease Control and Prevention (CDC) signed an Inter-agency Agreement in April 2013 for CDC to serve as the Independent Evaluator for the Zambia Compact. CDC will conduct monitoring and evaluation activities to assess the project's impact on health outcomes; economic indicators; water availability, access, cost, and time spent collecting water; WASH knowledge and behavior; and flood-related impacts.

Figure 1: Map of Proposed Compact Activities in Lusaka, Zambia



Note: District Metering Areas (DMAs) are water service areas and are designated by LWSC. Further explanation of DMAs is included in the Water Supply and Sanitation Interventions, Study Population section.

Source: MCA Zambia

Compact Goal, Objectives, Activities, and Beneficiaries

Goal and Objectives

The goal of the LWSSD Compact is to reduce poverty through economic growth in Zambia. The Compact objectives are to expand access to and improve the reliability of the municipal water supply, to extend the sewerage network and provide access to household sanitation, and to improve drainage systems in select urban and peri-urban areas in Lusaka to decrease the incidence of water-borne and water-related diseases, generate time and cost savings for households and businesses, and reduce non-revenue water in the water supply network.

Activities and Beneficiaries

Not all activities in the Compact will be covered by this evaluation. As outlined in the Compact logic (Appendix 1), the Compact consists of institutional strengthening and innovation grant activities that will be monitored and evaluated separately from the impact evaluation outlined in this report. Water supply interventions in areas of higher socioeconomic status (Ndeke/Vorna Valley, Kwamwena) will also be monitored and evaluated separately. Specific infrastructure activities and the number of beneficiaries of the LWSSD Compact are described below and in Table 1. A more detailed summary of Compact activities and beneficiaries can be found in Appendix 2, and details on the Economic Rate of Return (ERR) of the Compact can be found in Appendix 3.

1. *Core Water Network Rehabilitation (Water Supply)*: Rehabilitation of the Iolanda treatment plant to restore production to 110,000 m^3/day from 98,000 m^3/day, rehabilitation of transmission mains and distribution centers, and strengthening of the primary distribution system. This component is expected to benefit approximately 860,000 people by providing more reliable water service and increased water supply and coverage. MCA Zambia refers to these sub-projects as LP-1, LP-6, LS-1. These sub-projects are part of Contract Packages (CP) (e.g., construction projects) 1 and 2.

2. *Chelston Distribution Line Rehabilitation and Expansion (Water Supply)*: Extension and rehabilitation of secondary and tertiary networks into the Central and Chelston Branch district metering areas, including the extension of distribution pipes into residential areas to facilitate new household connections, construction of new water kiosks, and rehabilitation of existing kiosks. Over 568,000 beneficiaries are expected from these activities: 416,000 from rehabilitation and 152,000 from network expansion. Beneficiaries are located in Chipata/SOS East, Ng'ombe, Kamanga, Mtendere, Kwamwena, and Ndeke/Vorna Valley (see Table 1). MCA Zambia refers to these sub-projects as LS-2 and LS-3. These sub-projects are part of CPs 3 and 5.

3. *Chelston and Kaunda Square Sewersheds Rehabilitation and Expansion (Sanitation)*: Expand sewer network to facilitate new household and business connections in Mtendere, upgrade Chelston sewage pumping station and Kaunda Square interceptor, and upgrade and expand the Kaunda Square stabilization ponds. 98,000 beneficiaries are projected from the expanded sewer network in Mtendere; nearly 57,000 beneficiaries are expected from rehabilitative sanitation interventions. MCA Zambia refers to these sub-projects as CSE-44, CSU-4, CSU-15, TU-5, TE-3. These sub-projects are part of CPs 3 and 4.

4. *Bombay and Mazyopa Drain Improvements (Drainage)*: Extension and rehabilitation of the Bombay drainage system in central Lusaka, and rehabilitation of the Mazyopa Drain in Northern Lusaka to accommodate the expected increased flow from the Bombay Drain. An estimated 188,000 people are expected to benefit from these drainage improvements. These sub-projects are part of CPs 7 and 8.

Table 1: Compact Beneficiaries by Intervention and Sub-project

Intervention	Water Supply			Sanitation	Drainage
Sub-project	LP-1, LP-6, LS-1	LS-2	LS-3*	CSE-44, CSU-4, CSU-15, TU-5, TE-3	Bombay Drain
Contract Package (CP)	1, 2	5	3, 5	3, 4	7, 8
Intervention Location**	System-wide	Chipata/SOS East, Ng'ombe	Mtendere, Kamanga, Ndeke/Vorna Valley, Kwamwena	Mtendere, Kaunda Square, Chelston	City-wide
Total beneficiaries by subproject	860,000	318,566	250,102	155,280	188,005
No. Rehabilitation Beneficiaries	-	282,662	133,750	56,931	-
No. of Network Expansion Beneficiaries	-	35,904	116,352	98,349	-

*These figures include Ndeke/Vorna Valley and Kwamwena. However, the numbers are subject to change if the Compact is re-scoped.
**For a map with the location of water and sanitation interventions: see Figures 1 and 6; Drainage interventions: see Figures 1 and 9

Source: MCC: ERR (adapted), 2014.

LITERATURE REVIEW

The U.N. Millennium Development Goals (MDGs) for water and sanitation are to halve the proportion of people without access to improved drinking water and sanitation facilities between 1990 and 2015 (WHO and UNICEF, 2013). Despite meeting the water goal and progressing towards the sanitation goal, at the end of 2011 there remained 768 million people without access to an improved water source and another 2.5 billion without access to improved sanitation facilities (WHO and UNICEF, 2013). Lack of access to improved water and sanitation facilities can result in diarrheal illness, which causes 760,000 deaths among children under 5 each year (WHO, 2013). This lack of access can also lead to respiratory illness (Dinh et al., 2006; Hennessy et al., 2008; Luby and Hadler, 2008). Worldwide, acute lower respiratory infections caused over 900,000 deaths among children under 5 in 2013 (WHO, 2014). As 2015 draws to a close a new set of goals, the Sustainable Development Goals (SDGs), will replace the MDGs. By 2030 the water and sanitation SDGs aim to achieve universal, equitable access to drinking water and sanitation (United Nations, 2014). In order to achieve this ambitious goal, significant expansion of water and sanitation infrastructure will be required. Common strategies to provide better access to water and sanitation facilities have included introducing community wells, point of use water disinfection, and latrines to rural communities (Fewtrell et al., 2005; Waddington et al., 2009; Clasen et al., 2010; Wolf et al., 2014).

More than 50% of the world's population lived in cities in 2011 and additional urbanization is expected; in Africa, the urban population is projected to triple by 2050 (United Nations, 2012). Many cities are not equipped with the necessary water and sanitation infrastructure to support such substantial urban population growth. In 2011, an estimated 132 million and 728 million urban dwellers did not have access to improved water and sanitation, respectively (WHO and UNICEF, 2013). Zambia, where approximately 40% of the population lives in urban areas, is not on track to reach the MDGs (WHO and UNICEF, 2013). From 1990 – 2011 the proportion of the urban population with access to improved water sources decreased from 89% to 86%, and the proportion with access to improved sanitation also decreased, from 61% to 56% (WHO and UNICEF, 2013).

Limited access to adequate water and sanitation is one of the key developmental challenges faced by Zambia. Zambia has a high poverty rate, at 74% in 2010 (using a Purchasing Power Parity at US$1.25 per day), compared to 49% in the World Bank's low income countries aggregate grouping (World Bank, 2015). In addition, Zambia has high income inequality, with a GINI Index of 58 in 2010 (World Bank, 2015). Key indicators of health are similarly low. Life expectancy at birth in 2013 was 58 in Zambia, compared to 62 in the World Bank's low income countries aggregate grouping (World Bank, 2015). The mortality rate for children under 5 (per 1,000 live births) was 87 in 2013; in the World Banks's low income countries aggregate grouping the mortality rate was 76 (World Bank, 2015). Malnutrition (stunting) is also prevalent in Zambia, at 46% in 2007 (World Bank, 2015). These indicators are directly or indirectly related to the status of water supply and sanitation infrastructure, and underscore the universal necessity of equitable access to WASH facilities.

The lack of adequate water and sanitation infrastructure is apparent in Lusaka, where the current infrastructure - built in the 1960s and 1970s for a population of 300,000 - is not sufficient to meet the needs of the current population of 1.8 million (Central Statistics Office, 2011). The situation is especially acute in low-income, peri-urban areas (PUA) in Lusaka, which constitute approximately 70% of the Lusaka population (Central Statistics Office, 2010). In 2010, only 24% of peri-urban households had piped water to the home or plot, and nearly 60% collected their water from community sources such as kiosks (Central Statistics Office, 2010). Lusaka Water and Sewerage Company (LWSC) estimates that water is available an average of 17 hours per day in the network, however, some peri-urban areas have access to water for an average of only 4 hours per day (CDC, unpublished data).

Access to sanitation infrastructure in PUAs is similarly low, where nearly 88% of households use pit latrines (Central Statistics Office, 2010). However, a majority of these pit latrines do not meet the definition of "improved" (e.g., pit latrines without a slab or shared pit latrines) (Central Statistics Office, 2012) and many are not properly constructed (Millennium Challenge Corporation, 2012). Coupled with the karst geology in much of Lusaka (Gauff Ingenieure, 2013b) - which is highly permeable and characterized by caves and cracks - these latrines can contaminate the shallow wells that some peri-urban residents use as a water source (Millennium Challenge Corporation, 2012), and can lead to diarrheal illness and outbreaks.

The drainage infrastructure in Lusaka is also challenged and has degraded from a lack of maintenance (Millennium Challenge Corporation, 2012). In addition, informal residential areas have been built in areas that are close to drains, and these areas are particularly prone to flooding (Gauff Ingenieure, 2013b). Topographically, Lusaka is fairly flat, and consequently, parts of the city are inundated each rainy season (November to April), leading to additional risk of waterborne illness (Gauff Ingenieure, 2013b). Furthermore, because Lusaka has a high water table (Gauff Ingenieure, 2013c), flooding can be severe and longer in duration in areas with karst geology when the water table reaches the ground surface (Gauff Ingenieure, 2013b).

Given the current state of WASH infrastructure in Lusaka, its expansion and revitalization will become increasingly more important to health and well-being as urbanization trends continue. The infrastructure interventions planned as part of the Compact aim to, among other things, decrease waterborne disease and promote economic growth by building new and rehabilitating existing community kiosk connections, expanding residential water supply and sanitation networks to underserved areas, and rehabilitating the drainage system.

A review of the literature offers strong evidence for the benefits of better WASH infrastructure. The importance of water supply has been shown in meta-analyses that found water supply interventions - such as installing standpipes or household connections - reduce diarrheal illness by 25-37% (Fewtrell et al., 2005; Wolf et al., 2014; Esrey et al., 1991). A meta-regression conducted by Wolf et al. to identify the health effects of different types of water supply interventions found a relative risk for diarrheal disease of 0.86 (95% CI: 0.72, 1.03) from interventions that provided piped water connections (with non-continuous flow) to households that previously relied on improved community sources (e.g., stand pipes), and a relative risk of 0.21 (95% CI: 0.08, 0.56) in interventions that provided continuous, high quality piped water connections to households that previously relied on improved community sources (Wolf et al., 2014). While the illness reduction from a continuous connection is based on limited evidence from a single study, the meta-regression identifies the health benefits that can be achieved from household connections that provide continuous water supply, which are envisioned in the intervention in Lusaka.

The health benefits of closer and more reliable access to water sources has been shown in several other studies. For example, one multi-country study in sub-Saharan Africa found that even a 5-minute decrease in one-way travel time was associated with decreased diarrheal disease incidence and improved weight-for-age measures (Pickering & Davis, 2012). Closer access to piped water has also been found to be protective against diarrheal morbidity (Thompson, 2001), and to reduce diarrheal illness duration (Jalan & Ravallion, 2003). Further, close access to piped water, either in the home or compound, has been linked to an increase in the quantity of water consumed (Devoto et al., 2011; Thompson, 2001), and increased water consumption has been shown to be protective against diarrheal disease (Shrestha et al., 2013).

Lacking water access and infrastructure has also been linked to respiratory diseases. A 2004 study in Vietnam found the lack of an indoor water source to be associated with the development of influenza A H5N1 infection (Dinh et al., 2006). Another study in rural Alaska found higher hospitalization rates for pneumonia, influenza, and respiratory syncytial virus (for children under 5) in regions with lower proportions of in-home water service (Hennessy et al., 2008). And a study in Bangladesh found having a place inside the house with water to wash hands to be protective against children under 5 reporting a cough or difficulty breathing in the last 7 days (Luby and Hadler, 2008).

There is also significant evidence to support the importance of improved sanitation on health (Fewtrell et al., 2005; Waddington et al., 2009; Wolf et al., 2014). However, as nearly 88% of peri-urban households in Lusaka already have access to a pit latrine (CSO 2010), and the LWSSD Compact aims to facilitate household connection to the sewer system via a flush toilet, this review of the literature will be limited in scope to the health benefits associated with sewer-connected toilets. Sewer connections have been widely shown to decrease diarrhea; one meta-analysis found a 31% reduction in diarrheal morbidity among households with access to a toilet (Waddington et al., 2009). In addition, a meta-regression, though based on findings from only two studies, found a relative risk for diarrheal disease of 0.37 (95% CI: 0.31, 0.44) for sanitation interventions that provided a sewer-connected toilet where before there was an improved sanitation facility (e.g., a latrine) (Wolf et al., 2014). Installations of sewer connections in large urban cities in Brazil and Iran also demonstrated a decrease in diarrheal prevalence; Barreto and colleagues found a decrease of 22% in Salvador, Brazil, while Kolahi et al. found diarrheal incidence to decrease by 9% in Tehran, Iran (Barreto et al., 2007; Kolahi et al., 2009). Furthermore, a study in peri-urban Lima, Peru, found the lack of a sewer connection to be associated with decreased child growth (Checkley et al., 2004). While considering these findings, it is important to note the studies are non-experimental in design (i.e., the site of interventions was not determined by the authors), and therefore there is a risk for confounding. Randomized, experimental interventions that provide sewer connections are few given the inherent cost of sanitation infrastructure and equity considerations. However, the studies presented, though limited in their study design, demonstrate the substantial health gains that can result from sewerage connections in urban areas.

The benefits of adequate drainage infrastructure can also be found in the literature. In another observational study in Brazil, the combined benefits of drainage and sewerage were demonstrated by Moraes et al., who found a 40% and nearly 70% lower incidence of diarrhea in neighborhoods that had drainage systems or both drainage and sewerage systems, respectively, compared to neighborhoods that had neither (Moraes et al., 2003). In Lusaka, higher incidence of cholera has been linked to areas that have smaller, insufficient drainage networks, and thus less flood control (Sasaki et al., 2009).

Diarrheal illness can also create a financial burden for households as a result of medical and transportation costs. Furthermore, illness can prevent a person from working or require that they stay home to care for ill family members, resulting in potential income lost. This financial burden is measured in a study in three African countries that found the total average cost per episode of diarrheal illness to range from $2.63 to $6.24 (Rheingans et al., 2012). The potential gain in productive days due to averted diarrheal illness is also substantial. One cost-benefit analysis reported a worldwide gain of 310 and 550 million working days for adults 15 to 59 years old by meeting the Millennium Development Goals for water and sanitation and achieving universal access to improved water supply and sanitation facilities, respectively (Hutton et al., 2007). In sub-Saharan African countries, the economic loss associated with inadequate access to water supply and sanitation is estimated to be 4.3% of annual GDP (Hutton, 2013). In Zambia, the economic loss associated with inadequate sanitation alone is estimated to be 1.3% of the national GDP, an equivalent of approximately $194 million dollars. Nearly $180 million of that loss is attributed to premature death from WASH-related diarrhea, diarrheal disease-related healthcare costs, and productivity loss while sick with or accessing healthcare for diarrheal illness (Water and Sanitation Program, 2012).

Beneficiaries of new or improved water supply infrastructure may also save time by spending less time collecting water. Water collection can take considerable time in homes that do not have private piped water connections (Hutton et al., 2007; Sorenson et al., 2011). Hutton et al. compiled findings of the time spent per day in other studies, which ranged from 0.5 hours to 4-7 hours per day (Hutton et al., 2007). Women, predominantly, and children, are mostly responsible for water collection in these households (Sorenson et al., 2011). As a result of the time burden of water collection – due to the lacking infrastructure – as well as a woman's other household responsibilities, it is postulated that women are less able to enter the work force (Agénor et al., 2010; Koolwal & van de Walle, 2010). Indeed, a cost-benefit analysis of water supply and sanitation interventions found that more than 210 billion hours per year would be saved by universally providing piped water and sewer connected toilets to most countries of sub-Saharan Africa (Hutton et al., 2007). Furthermore, it is estimated that universal access to an improved water supply alone would lead to a benefit of over 8 billion US dollars per year, with nearly 50% attributed to time savings in water collection (Hutton, 2013). However, some studies have found that time saved in water collection does not necessarily result in women spending additional time in "productive activities" (Devoto et al., 2011; Koolwal & van de Walle, 2010).

The extent to which the expected benefits to health, water supply, sanitation, drainage, time savings, and economic growth are realized through this Compact will be assessed through the proposed impact evaluation. These results will also help inform the estimated benefit-cost ratios for different scenarios of worldwide water supply and sanitation coverage, as defined in the MDGs and future SDGs. For example, Hutton estimates that meeting the MDG for water and sanitation in sub-Saharan Africa between 2010 and 2015 yields a benefit-cost ratio of 2.7 (Hutton, 2013). In addition, the results will contribute to the relatively small amount of literature regarding the health and economic effects of large-scale water supply, sanitation, and drainage interventions in populous urban centers. To date evaluations of most infrastructure interventions have been conducted in rural environments or on a smaller scale. These findings will also help inform decisions made by international organizations and governments that have considered introducing similar interventions in their urban centers.

EVALUATION

Evaluation Questions

The Zambia Compact is comprised of interventions to the water, sanitation, and drainage infrastructure in the city of Lusaka. The goals of these interventions include reducing poverty through economic development, decreasing the incidence of waterborne and water-related diseases, and generating time savings for businesses and households. To evaluate the impact of the Compact interventions the following evaluation questions were developed by MCC, MCA Zambia, and CDC as part of the terms of reference (TOR) between MCC and CDC, finalized in April 2013.

Health

- What are the health benefits attributable to each type of Compact activity?

Safe Water Supply/Consumption

- What are the current consumption rates of safe versus un-safe water consumption and usage?
- Do Compact activities lead to an increase in safe water consumption?

Economic and Social

- Do households experience an increase in income due to Compact activities?
- Are households able to afford household connections, toilets, and water bills?
- Were subsidy provisions adequate for sanitation connections?
- What is the probability of finding work for beneficiaries?
- What are the time and cost savings/use attributable to each Compact activity?

Flooding

- Is there a decrease in the frequency, intensity and duration of flooding
- Is there a decrease in property damage and loss of business caused by flooding?
- Is there a decrease in travel time due to reduced flooding?

Process Questions

- How were activities planned and implemented? What were the differences between what was planned and what was implemented and why?
- What are the implications for future MCC policy and practice?

Evaluation type

Given the cause-and-effect nature of the Compact as described in the logic model, CDC recommends an impact evaluation, where possible, as the most appropriate method to evaluate the effect of the interventions. The impact of interventions to extend water supply and sanitation networks to residential areas will be evaluated by comparing pre and post outcome measures in both intervention and control (counterfactual) areas. Control areas are peri-urban areas that are similar to intervention areas with respect to water and sanitation characteristics, but that are not receiving any interventions.

A suitable control group for the households and businesses that will be affected by the drainage intervention in central Lusaka does not exist. Characteristics that make the Bombay Drain system unique include its mix of commercial and residential development and their propensity to flood due to their co-location along a primary drainage system (the Bombay Drain). The Bombay Drain flows through the major business and commercial districts of Lusaka (e.g., the central business district and Kamwala Market). This commercial density is not present to the same degree in other drainage systems. The Bombay Drain is also distinguished by its length, approximately 25km (Gauff Ingenieure, 2013a); other major drainage systems in Lusaka – with the exception of the Kanyama/John Laing/Makeni Drain – are not as extensive. The Bombay Drain is further distinguished by the nature of its flooding, which is characterized as the result of surface runoff and inadequate drainage infrastructure, rather than primarily the result of a high underlying water table (CH2MHILL, 2011). The Kanyama/John Laing/Makeni Drain, for example, was excluded as a potential control because its flooding is predominantly caused by high groundwater levels (CH2MHILL, 2011). As a result of the unique characteristics of the Bombay Drain, we are unable to identify a drainage system in Lusaka with characteristics similar enough to the Bombay Drain to serve as an adequate control area. Therefore, the impact of the drainage intervention on households and businesses will be estimated using pre-post comparisons with no control group.

Indicators

Data on a number of indicators will be collected through household and business surveys and analyzed as part of this evaluation. The primary health outcomes that will be investigated in this evaluation are diarrhea and acute respiratory illness. For the economic evaluation, we will measure indicators related to household income and expenditures, time savings, health care expenditures, days of work or school missed due to illness, flooding impacts to businesses, and other economic indicators. WASH indicators include access to water, availability of water, water consumption, time spent collecting water, access to sanitation, sanitation type, hygiene behavior, and water quality. The indicators will be measured at the individual, household, and business level, and where applicable, will be disaggregated by sex, age, location, and income (as measured by household expenditures) to assess the differential impact on specific beneficiary groups (e.g., women and children). The indicators, their expected direction of impact, and level of disaggregation are provided in Table 2.

Table 2: Indicators and Expected Impact

Indicator	Indicator Definition	Level of Measurement	Expected Impact	Disaggregation
Average household income	Average household income per year based on expenditure patterns	Household	Increase	Location and income (household); sex of Head of Household (HoH) and age (individual)
Incidence of waterborne disease*	Percentage of household/individuals with diarrhea, acute respiratory infection (ARI), in last 2 weeks	Household and individual	Decrease	Location and income (household), sex and age (individual)
Time spent gathering water*	Amount of time households spend gathering water per round trip	Household and individual	Decrease	Income (household); sex and age (individual)
Access to improved water supply	Percentage of households whose main drinking water source is a private household tap,	Household	Increase	Income, location, sex of HoH

	public tap, borehole, or protected well			
Residential water consumption	Average water consumption per household per day	Household	Increase	Income, location, sex of HoH
Continuity of service	Average hours of service per day for water supply	Household	Increase	Income, location, sex of HoH
Access to improved sanitation	Percentage of households who get access to and use a flush toilet to a piped sewer system	Household	Increase	Income, location, sex of HoH
Household garbage disposal	Percentage of households with a garbage disposal system	Household	Increase	Income, location, sex of HoH
Percent of people practicing safe hygiene	Refers to hand washing and treatment of water	Household	Increase	Income, location, sex of HoH
Travel time during flooding	Amount of time spent travelling from one place to another in Lusaka during flooding	Individual	Decrease	Sex (individual), income, sex and location (household)
Frequency of flooding	Percentage of time there is flooding per month in surveyed houses and businesses	Household and business	Decrease	Location, sex of HoH
Property damage due to flooding	Amount of property damage to households and businesses caused by flooding per month	Household and business	Decrease	Location, sex of HoH
Percentage of business closures due to flooding	Percentage of time businesses were closed as a result of flooding	Business	Decrease	Location, sex of HoH

*The head of the household will answer these questions as a proxy for individual household members

EVALUATION DESIGN

Through the improvement and extension of water supply, sanitation, and drainage infrastructure in Lusaka, this Compact aims to decrease the incidence of water-borne disease (e.g., diarrhea) and generate household and business time and cost savings. Several quantitative approaches will be utilized to assess whether the expected outcomes have been realized. Indicators (Table 2) for most of the health, WASH, economic and flooding questions will be measured and analyzed using quantitative methods and inferential statistics by a variety of factors including sex, age, and household level expenditures. The evaluation methodologies employed differ according to intervention type (water supply, sanitation, and drainage) and beneficiary type (household or businesses). An explanation of the different evaluations is summarized in Table 3. Additional assessments may be conducted using qualitative methods among sub-groups of beneficiaries. The process-oriented questions related to lessons learned will be assessed after completion of the evaluation and submitted as part of the final reports and deliverables.

Table 3: Type of Impact Analysis and Evaluation Design for Primary Outcome Measures

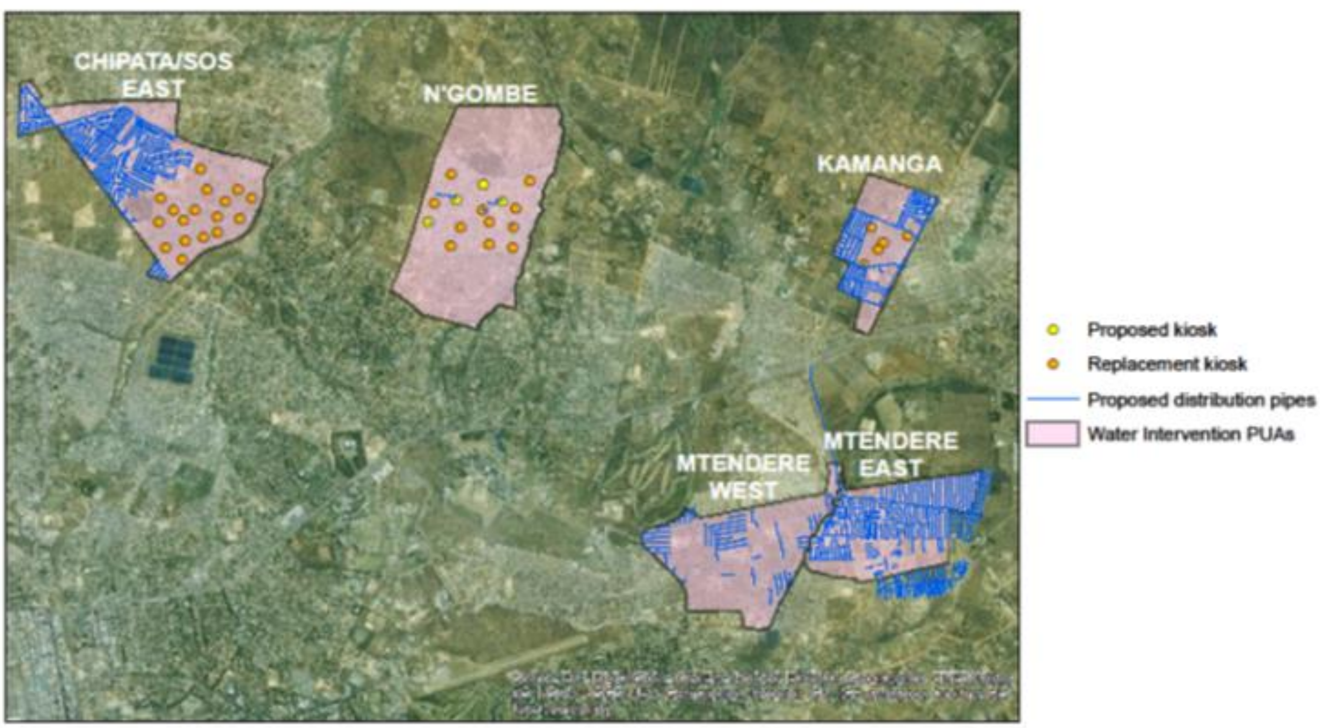
Outcome	Data Source	Unit of Analysis	Evaluation Design and Control Area (Counterfactual)	Evaluation methodology or approach	Measures	Potential limitations	Analysis	Survey Module
Health/waterborne disease prevalence in children under 5years of age	HH survey (All intervention HHs); Sentinel surveillance	Individ.; HH	Cross-sectional surveys in intervention and control areas pre-post. Control areas: PUAs not receiving water and sanitation interventions	Difference in proportions and means; and difference in differences (DD)	Binary response: diarrhea, acute respiratory illness (ARI)	Prevalence may be lower than expected with decreased power to detect changes; rotavirus vaccine could introduce additional noise to analysis*	Quantitative	B
Water, sanitation, and hygiene access, use, availability, cost; garbage disposal practices	HH survey (All intervention HHs)	HH			These measures are both interval, continuous and categorical			D-G, H
Time savings and household expenditure		Individ.; HH		Difference in means and DD				HH not in flood areas: C, I HH in flood areas: C, J
Flooding frequency and duration, business revenue, travel time	HH survey (only drainage intervention HHs); Business survey; Traffic study; Focus Group Discussions (FGD); Key Informant Interviews (KII)	Business; HH; Individ.	Cross sectional surveys (pre and post intervention) in businesses and households (no control areas available); Repeat studies to assess traffic flow at flood-affected intersections; FGD; KII	Pre-Post			Quantitative; Qualitative	Business: All; HH in flood areas: I

*A rotavirus vaccination campaign has been implemented in Lusaka and may have impacted the prevalence of diarrheal disease in the city. Our analysis will take this into account so that reductions in diarrheal illness due to vaccination are not incorrectly attributed to Compact interventions.

Water Supply and Sanitation Interventions

To evaluate water supply and sanitation interventions two quantitative evaluations are planned. The first evaluation will be of areas that will only receive water supply interventions (network extensions into peri-urban areas, new and rehabilitated water kiosks): Chipata/SOS East, Ng'ombe, and Kamanga. The second evaluation will be of the combined sanitation and water supply intervention in Mtendere. Both areas of Mtendere (West and East) will receive an extension of the sewerage network, however differing levels of water supply are proposed due to differences in baseline water supply coverage. In Mtendere East, there is a lower level of existing water supply infrastructure while in Mtendere West approximately 70% of households already have water connections (LWSC personal communication, 2014). Our baseline data collection will further substantiate this number. See Figures 2-4 for detailed maps of each intervention.

Figure 2: Water Supply Interventions

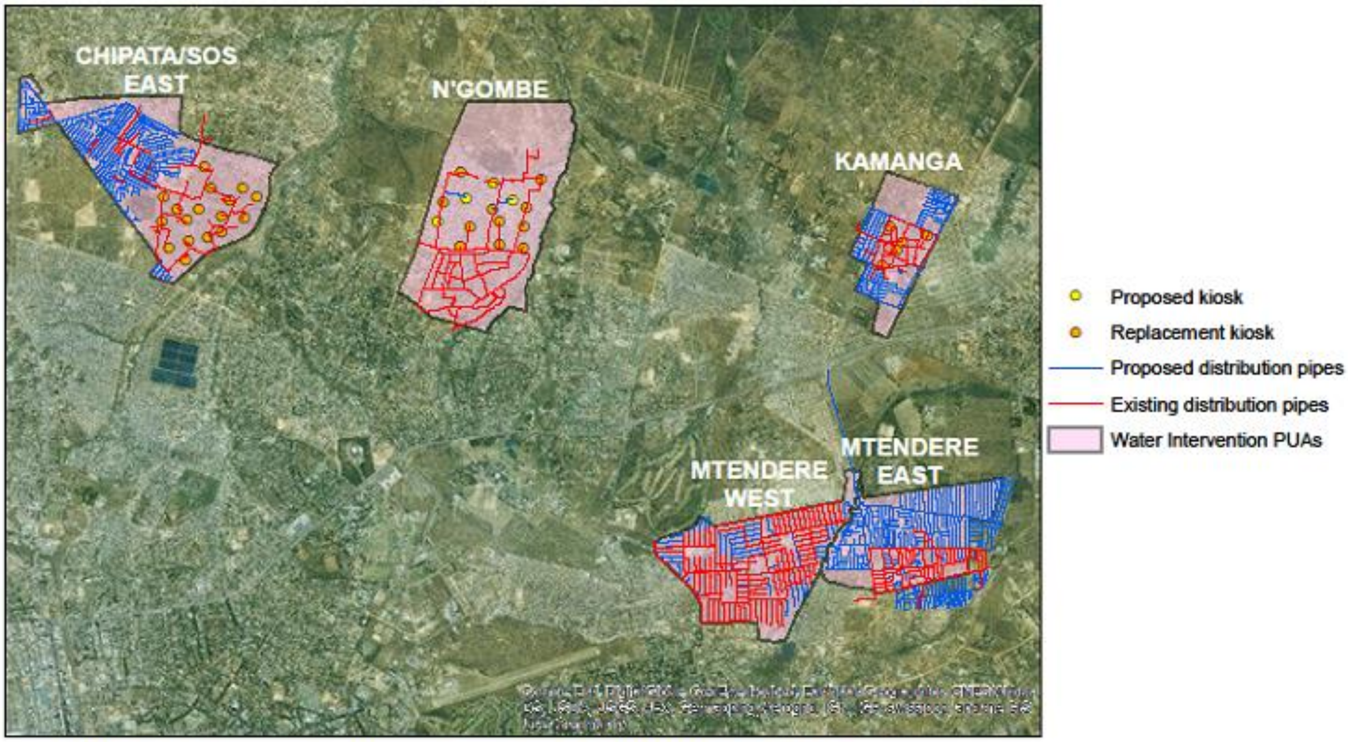


- Chipata/SOS East: Proposed distribution pipes and 15 replacement kiosks to supply 41,000
- Kamanga: Proposed distribution pipes and 5 replacement kiosks to supply 10,590
- Mtendere: Proposed distribution pipes to supply 52,844 people
- N'gombe: 15 proposed and replacement kiosks to supply 12,600

Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files; Gauff Ingenieure: 90% Design Review Report – Water Supply, 2013

Figure 3: Water Supply Interventions and Existing Water Distribution Infrastructure



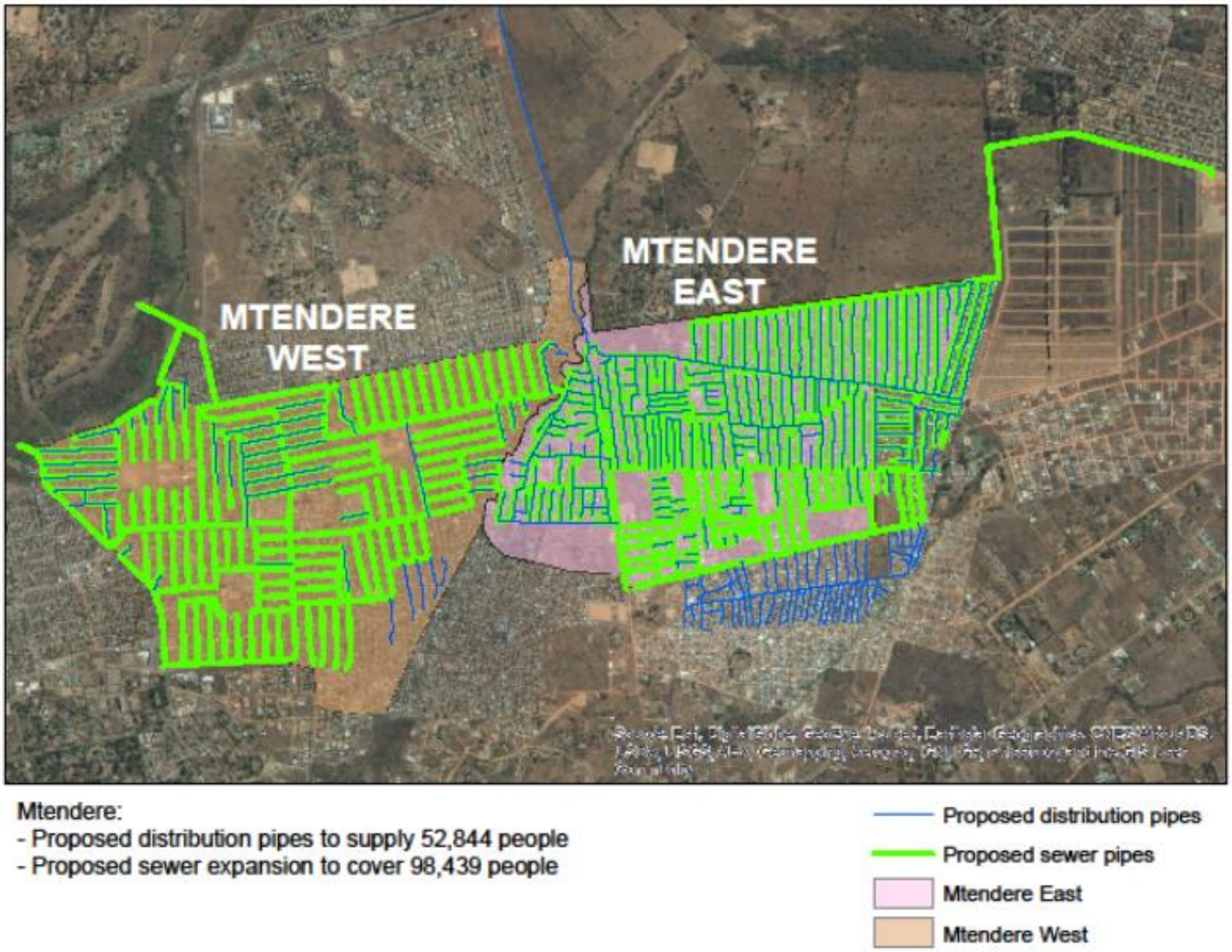
- Chipata/SOS East: Proposed distribution pipes and 15 replacement kiosks to supply 41,000
- Kamanga: Proposed distribution pipes and 5 replacement kiosks to supply 10,590
- Mtendere: Proposed distribution pipes to supply 52,844 people
- N'gombe: 15 proposed and replacement kiosks to supply 12,600

Note:

- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files; Gauff Ingenieure: 90% Design Review Report – Water Supply, 2013

Figure 4: Water Supply and Sanitation Interventions in Mtendere



Source: Gauff Ingenieure: GIS files; Gauff Ingenieure: 90% Design Review Report – Water Supply, 2013; Gauff Ingenieure: 90% Design Review Report – Sanitation, 2012

We will collect data for these evaluations through cross-sectional surveys in households in both intervention and control areas. A brief description of the modules and variables of the household surveys is included in Table 4; full versions of the household surveys can be found in Appendices 4 and 5. Data collection will occur in two separate phases, at baseline and after the implementation of all Compact interventions. In each phase surveys will be administered over the course of 12 months, without repeat at the same household. We have chosen year-round data collection to account for seasonal differences in key outcomes (e.g., illness and water collection time) and for logistical considerations with respect to data collection effort associated with the required sample size for the household survey. Similar methodological approaches (i.e., year-round data collection to account for seasonality and other temporal trends) have been used in previous WASH intervention evaluations (Luby et al., 2011; Boisson et al., 2013; Huda et al, 2012) and studies on diarrheal incidence and prevalence at the population level (Feiken et al., 2011; Omore et al., 2013; Nasrin et al., 2013; Breiman et al., 2012; Njuguna et al., 2013). This evaluation design will allow for identification of health and economic outcomes attributable to Compact interventions by comparing key characteristics of interest among intervention and control groups over time (pre-post) using regression models (difference in difference approach).

Baseline data collection will likely begin in September 2015. A proposed timeline for data collection can be found in Table 5. However, the exact date of baseline and follow-up data collection is subject to change and will depend in part on the implementation timeline for Compact interventions, timelines for IRB approval, and other timelines.

Table 4: Household Survey Modules and Variables

Module	Key Variables
A. Household Demographics	Respondent age and sex, household roster, educational attainment
B. Sickness and Associated Costs	Type and length of illness, activities missed due to illness, cost of treatment
C. Caretaker time Loss	Time and income lost by caretaker, if any
D Water Collection	Water source, availability, consumption, cost, water collectors, and collection time
E. Water Storage and Treatment	Type/frequency of treatment, water storage, test of water quality
F. Sanitation	Sanitation type and observations, use of facilities at night
G. Hygiene	Handwashing knowledge and practices
H. Household Garbage Disposal	Type of garbage disposal and garbage collection
I. Flooding	Frequency of flooding, household property damage, travel time. (This module will only be asked to households included in the evaluation of drainage interventions)
J. Time Use, Expenditures	Employment status, household expenditures and assets
K. Household observations	Household building materials

Table 5: Proposed Data Collection Timeline: Water Supply and Sanitation Interventions

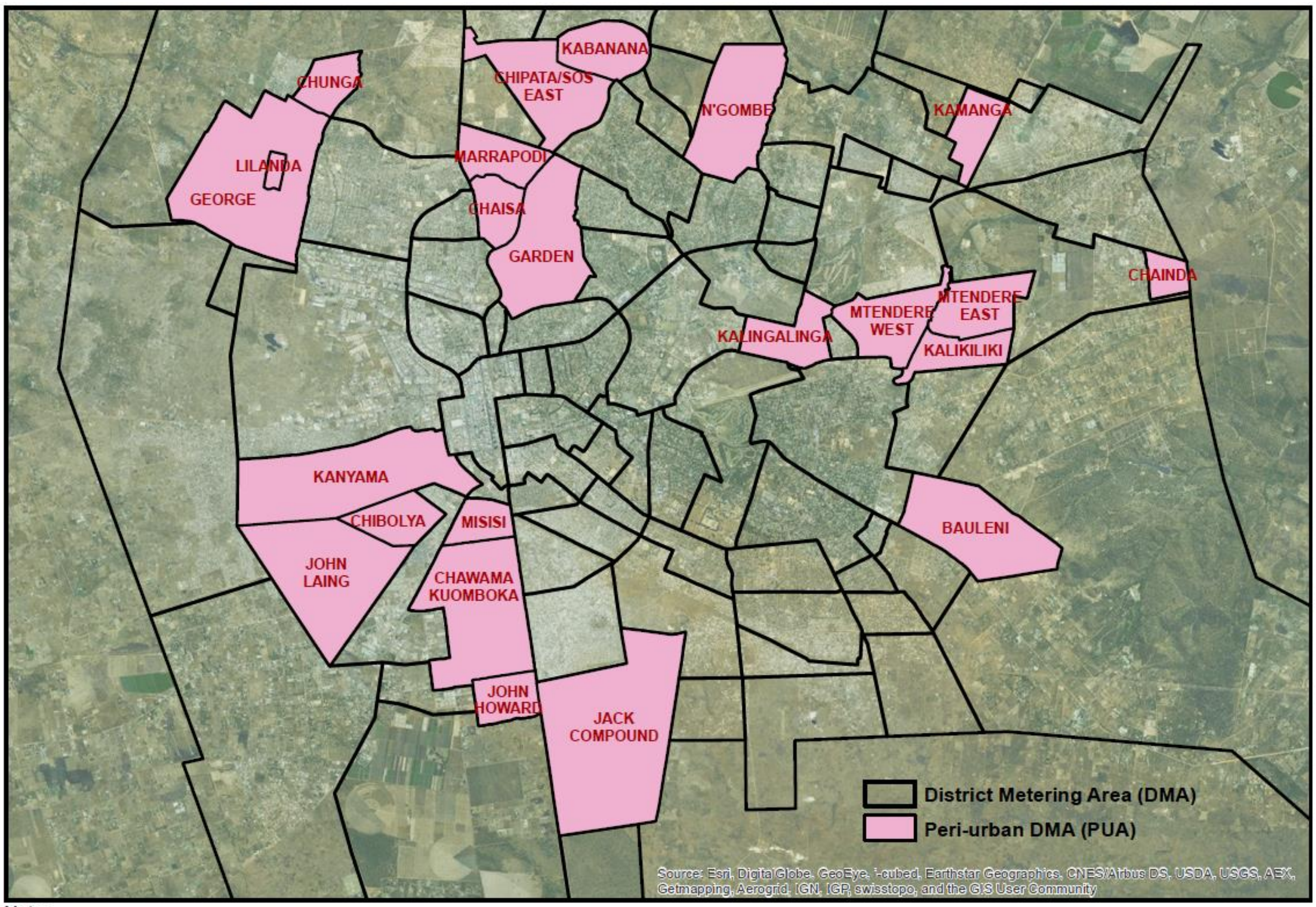
Approximate Date*	Data Collection Activity
Baseline	
September 2015	Initiate year-round household data collection
September 2015 – August 2016	Continuation of household data collection
August 2016	Conclude year-round household data collection
Post-Implementation**	
September 2019	Initiate year-round household data collection
September 2019 – August 2020	Continuation of household data collection
August 2020	Conclude year-round household data collection

*Dates are subject to change based on Compact implementation, IRB, and other timelines
**Dates TBD. The post-implementation survey will likely occur after the end of the Compact in order to effectively measure uptake and impact.

Study Population

LWSC divides Lusaka into service areas known as district metering areas (DMAs). Twenty-two DMAs are considered to be peri-urban areas (PUA) (Figure 5). LWSC characterizes PUAs as unplanned settlements that have low water and sanitation coverage. The study population for the evaluation of the water supply and sanitation interventions is made up of residents living in these PUAs.

Figure 5: Peri-urban District Metering Areas (DMAs) in Lusaka



Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files

Interventions are planned in 4 PUAs. Water supply interventions will be implemented in 3 PUAs: Chipata/SOS East, Ng'ombe, and Kamanga, and a combined water and sanitation intervention is planned in Mtendere (which is further split into Mtendere East and West). Seventeen of the 18 PUAs that were not selected for water supply and sanitation interventions through the Compact will serve as the control area (see Figure 6 and Table 6). These intervention and control areas are highly similar with respect to WASH and other SES characteristics (see Table 7 and Table 8). However, one PUA - Chibolya - will be excluded from the control area due to concerns for enumerator security and safety in the area.

In order to maintain the validity of the control area, PUAs (or portions of them) that will undergo non-Compact hard-infrastructure interventions (e.g., installation of water kiosks or toilets) may be excluded as potential controls in the evaluation. We have coordinated with stakeholders to monitor non-Compact hard-infrastructure interventions that may occur during the course of this evaluation. The details of this agreement and coordination can be found in the Memo of Control Area Issues and Considerations, Appendix 6.

Table 6: Intervention and Control Peri-Urban Areas within Lusaka District

Bauleni	George	Kamanga
Chainda	Jack Compound	Kanyama
Chaisa	John Howard	Lilanda
Chawama/Kuomboka	John Laing	Marapodi
Chibolya	Kabanana	Misisi
Chipata/SOS East*	Kalingalinga	Mtendere** (East and West)
Chunga	Kalikiliki	Ng'ombe
Garden		

*For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.
**Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.

(blue)	Water supply interventions only
(green)	Water supply and sanitation interventions
(white)	Controls
(grey)	Excluded from controls due to safety concerns

Figure 6: Intervention and Control Peri-Urban Areas within Lusaka District

Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files

Water supply interventions only
Water supply and sanitation interventions
Controls
Excluded from controls due to safety concerns

Table 7: Water, Sanitation, and Demographic Characteristics of Households Located in Treatment and Control Areas from the 2010 Zambian Census

Household Characteristic[a]	Treatment Areas[b] n (mean)	Treatment Areas[b] % (min, max)	Control Areas[c] n (mean)	Control Areas[c] % (min, max)
Household Drinking Water Source				
Tap in House or on Plot	12,837	25	42,911	23
Communal Tap or Water Kiosk	26,268	51	113,576	62
Other Tap	3,083	6	14,428	8
Protected Well/Borehole	7113	14	9,253	5
Unprotected Well/Borehole	776	2	1,026	1
Other[d]	1438	3	3,106	2
Type of Toilet				
Private Flush Toilet[e]	4,309	8	16,159	9
Latrine[f]	45,093	88	160,083	87
Other[g]	2,113	4	8,058	4
Own Home	15,286	30	48,035	26
Household Size	4.73	1, 94	4.67	1, 95

a: N = 235,815 households in treatment and control areas

b: Treatment areas include the following peri-urban areas (PUA): Chipata/SOS East, Kamanga, Mtendere, and Ng'ombe

c: Control areas include the following PUAs: Bauleni, Chainda, Chaisa, Chawama/Kuomboka, Chunga, Garden, George, Jack, John Howard, John Laing, Kabanana, Kanyama, Lilanda, Marapodi, and Misisi

d: Refers to surface water, rain water, water vendors, mineral/bottled water, and an unspecified "other" option

e: Toilets connected to sewer systems and stand-alone soak-aways

f: Unimproved pit latrine and ventilated, improved pit latrines

g: Refers to communal flush toilets, buckets, no toilet facilities, and an unspecified "other" option

Source: Central Statistics Office, 2010 Census of Population and Housing Raw Dataset (adapted)

Table 8: Education and Employment Characteristics of Individuals 18 and older Living in Treatment and Control Areas from the 2010 Zambian Census

	Treatment Areas[b]		Control Areas[c]	
Individual Characteristic[a]	**n**	**%**	**n**	**%**
Highest Level of Education				
Less than Grade 12	75,982	58	281,696	61
Grade 12 GCE(O)	23,573	18	78,227	17
Grade 12 GCE(A) or college/university student	500	0	1,739	0
Diploma or Certificate	16,859	13	53,565	12
Bachelor Degree or Higher	1,768	1	4,069	1
Missing	11,660	9	44,177	10
Employment				
Paid, non-seasonal work in last 12 months	47,851	37	168,093	36

a: N = 593,815 individuals 18 or older living in treatment and control area households

b: Treatment areas include the following peri-urban areas (PUA): Chipata/SOS East, Kamanga, Mtendere, and Ng'ombe

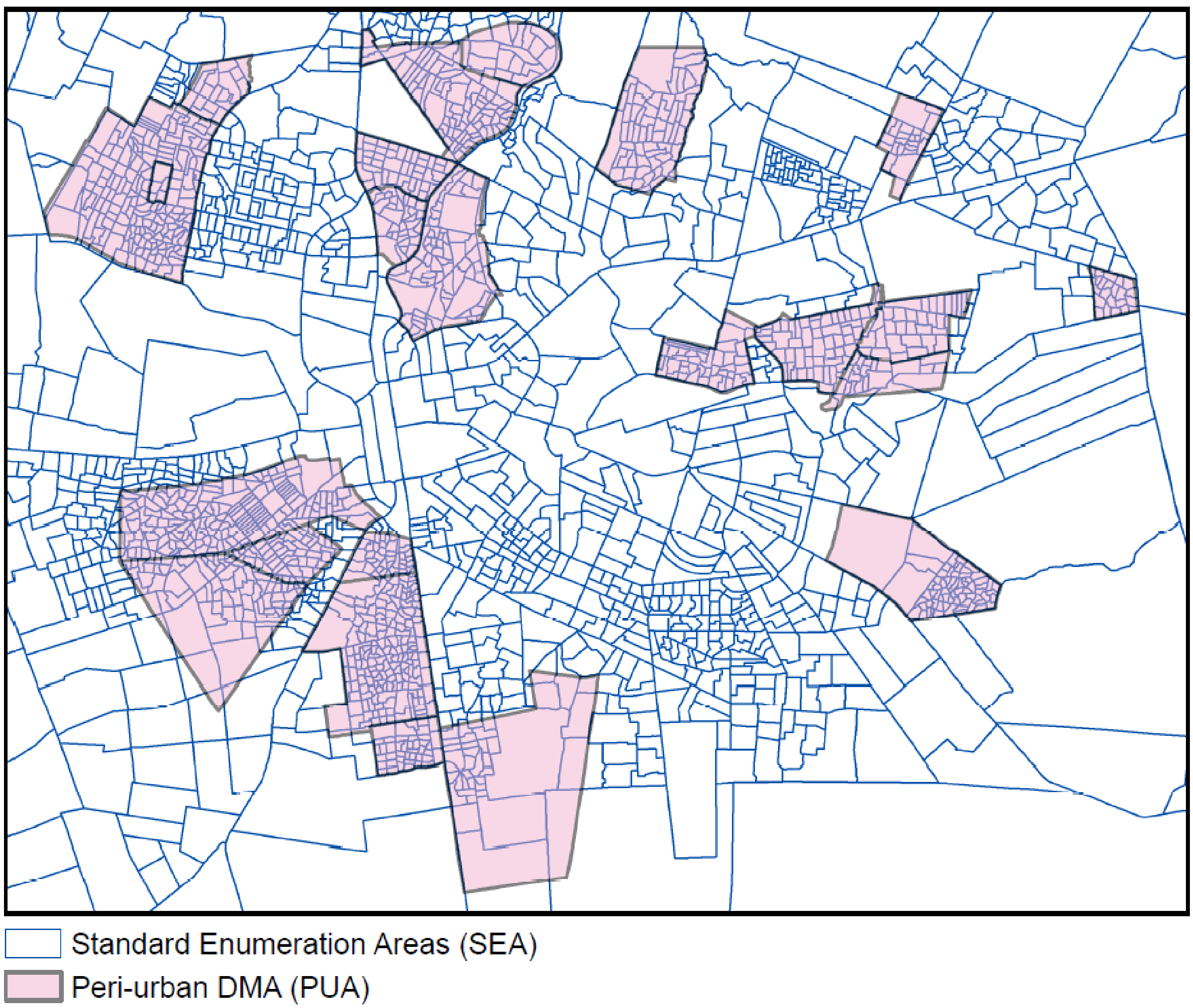
c: Control areas include the following PUAs: Bauleni, Chainda, Chaisa, Chawama/Kuomboka, Chunga, Garden, George, Jack, John Howard, John Laing, Kabanana, Kanyama, Lilanda, Marapodi, and Misisi

Source: Central Statistics Office, 2010 Census of Population and Housing Raw Dataset (adapted)

Sampling Strategy

Because a current list of all households residing in Lusaka is not available to serve as a sampling frame, conducting a simple random sample is not feasible, and we will employ a multi-stage sampling strategy. A two-stage cluster sampling strategy will be used in which geographic areas will be used as the sampling frame to first select primary sampling units (PSUs) and then secondary sampling units (SSUs). Administratively, the Zambian Central Statistics Office (CSO) divides Lusaka into different sized enumeration units for the Census. The smallest enumeration unit is called a Standard Enumeration Area (SEA), and represents approximately 175 households. SEAs will serve as PSUs and households within selected SEAs will be selected as SSUs for the evaluation. We will generate our sampling frame of SEAs by overlaying census SEA boundaries with peri-urban boundaries using ArcView GIS (Figure 7). SEAs that are located within intervention and control areas will be randomly selected with emphasis on selecting at least half the number of SEAs in a given intervention area in order to reduce design effects. Households located in these SEAs will then be randomly selected for inclusion in the evaluation. Households located in SEAs that are on or near borders between treatment and control areas will be evaluated as potential buffer zones in the analysis. Additional information on these border SEAs can be found in the Summary of Control Area Issues and Considerations Memo, Appendix 6. An independent sample of SEAs will be drawn, with replacement, for each time point in the evaluation (baseline and post-Implementation).

Figure 7: Peri-urban Areas and Standard Enumeration Areas



Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Central Statistics Office: 2010 Census GIS Files; Gauff Ingenieure: GIS files

<u>Sample Size and Statistical Power</u>

A total of 15,460 households with children under 5 years of age present will be sampled at each time point (baseline and post-implementation); 3,092 households will be sampled in each of the three intervention areas (water supply only; water supply and sanitation; drainage) and 6,184 from a single control group in order to be 80% powered to detect the smallest hypothesized difference of a 20% relative reduction in diarrhea prevalence from 15% to 12%. Assuming a baseline prevalence of 15%, a 20% relative reduction at post-intervention (in the 2-week period prevalence of diarrheal illness among children under 5) and 80% power, a simple random sample (SRS) would necessitate that 1,546 households be sampled per intervention area and 3,092 from the single control area. However, due to the cluster sampling strategy described, the sample size must take into account the potential design effect of the correlated data. Considerations for these numbers are described below (Table 9) and in Appendix 7.

Table 9: Sample Size for Household Survey Evaluation of Water Supply, Sanitation, and Drainage Interventions

<table>
<tr><th rowspan="2"></th><th colspan="8">Number of Households</th></tr>
<tr><th colspan="2">With Simple Random Sample</th><th colspan="2">Add Design Effect of 2*</th><th>Final Sample Size</th><th colspan="3">With 50% adjustment**</th></tr>
<tr><th>Intervention</th><th>Each Intervention Area</th><th>Single Control Area†</th><th>Each Intervention Area</th><th>Single Control Area†</th><th>Combined Intervention and Control</th><th>Each Intervention Area</th><th>Single Control Area†</th><th>Total</th></tr>
<tr><td>Water Supply</td><td>1,546</td><td rowspan="2">3,092</td><td>3,092</td><td rowspan="2">6,184</td><td rowspan="2">12,368</td><td>4,638</td><td rowspan="2">9,276</td><td rowspan="2">18,522</td></tr>
<tr><td>Water Supply and Sanitation</td><td>1,546</td><td>3,092</td><td>4,638</td></tr>
<tr><td>Drainage</td><td>1,546</td><td>NA</td><td>3,092</td><td>NA</td><td>3,092</td><td>4,638</td><td>NA</td><td>4,638</td></tr>
<tr><td>Total</td><td>4,638</td><td>3,092</td><td>9,276</td><td>6,184</td><td>15,460</td><td>13,914</td><td>9,276</td><td>23,190</td></tr>
</table>

* Sample size must be increased by a factor of 2 to account for the potential design effect introduced by cluster sampling

**Increase sample size by 50% to allow for non-response, refusal, households with no child under 5, etc.

†Control areas are PUAs that do not receive interventions, and are used to assess the impact of water and sanitation interventions

Two-stage cluster sampling has two variance components in which the variability between PSUs (SEAs in our sample) and the variability of SSUs (households in our survey) within the PSUs must be considered. The larger the PSU size, the larger the expected variability (Lohr, 1999). The increase of the standard errors as a result of the clustering requires an increase in sample size to regain the precision lost to larger standard errors. In comparison to SRS of equal size, the complex effects of clustering on the standard errors are defined as the design effect (Kish, 1965). While there are advanced modeling approaches to quantify anticipated design effects for multi-stage samples, they require estimation from directly available survey data. In the absence of available survey data for this study's specific measures in the given geographic areas, we must then apply an estimate of the design effect to estimate the increase in variance and proportionate increase in sample size needed relative to SRS.

The design effect is a way of expressing the precision of a complex sample relative to that of a SRS in the form of a ratio. In our fixed sample size, the design effect for the proposed complex sample is a minimum of 2, thus indicating we would require a sample twice the size of one collected as SRS. Data published regarding household surveys in developing countries indicate that design effects range from 2 to 10, with water supply and sanitation having the highest design effects at the national level (United Nations, 2005). Therefore, the minimum design effect to consider would be 2, indicating that a sample twice the size of a SRS - 3,092 households from each intervention area and 6,184 from the control area - will be needed to maintain adequate statistical power (0.80). While design effects are often larger than 2, we will employ an adaptive strategy to keep the potential design effect to a minimum. As noted earlier, the larger the sample from each PSU, the larger the expected variability, and thus increased loss of precision. In our fixed sample size, by increasing the number of PSUs sampled and decreasing the SSUs sampled per PSU, we can minimize the design effect. Our strategy will include sampling at least 50% of PSUs per each intervention area and control area at baseline and post-intervention. See Appendix 7 for a more detailed discussion of design effect, cluster size and ICC considerations.

Control Areas: In our multi-stage sampling approach control PSUs will be randomly selected across all non-intervention PUAs and, similar to intervention areas, we will aim to maximize the number of PSUs selected to reduce design effects by selecting 50% of SEAs eligible in the comparison area. One control group will be utilized for both water supply and sanitation interventions. Therefore, the control household sample size will be estimated as a 2:1 ratio in which there will be twice as many control households as intervention arm households. The control arm is double in size to that of intervention arms because it will be used in multiple hypothesis tests. By employing this strategy we are able to use the same control group to evaluate the water supply and combined water supply and sanitation interventions. The sampling ratio for controls to treatment arms of 2:1 is close to the optimal allocation that minimizes the variance (calculated as 1.8:1) for the three comparison tests planned for each intervention arm (Fleiss, 1986; Marschner, 2007). By using this ratio to increase the number of control households, this will increase power lost due to multiple comparisons and allow for a greater span of sensitivity analyses as needed. The increased sample size of controls to intervention households will increase the diversity of controls and will increase analytic options when adjusting for covariates in regression models. Without certainty of the proportion of overlap between the control group and intervention groups, control groups samples may be reduced substantially through adjustments in regression models (Ming and Rosenbaum, 2000).

Furthermore, to account for households without children under five, absentee, non-response or refusals by selected households, an additional 50% of the required households per SEA cluster (in both intervention and control areas) will be selected to serve as potential replacement households. This brings the number of households potentially selected to survey across all three interventions to 13,914 (4,638 in each intervention) and the control area to 9,276 for a total of 23,190 households for both pre and post intervention time points (Table 9).

Sample size estimates are based on the assumption that baseline proportions will be the same in both intervention and comparison groups and that changes will occur only in the intervention areas. For example, activities such as rotavirus vaccine campaigns or other NGO activities might provide additional noise to be controlled for in the data and thus require a larger sample size. In addition, for modeling purposes (e.g., adjusting for covariates), we may require additional observations to retain adequate power to report adjusted estimates.

Inclusion Criteria

Individuals: Participants in the evaluation are adults ≥ 18 years of age and are either male or female heads of the household. The Zambian Central Statistics Office (CSO) definition of head of household is the person all members of the household regard as the household head; he/she is the person who normally makes the day-to-day decisions governing the running of the household. We will use the CSO definition in our evaluation. Both renters and home-owners are eligible to participate. The survey contains both household level questions (e.g., water source, type of toilet), and individual-level questions (e.g., was anyone sick with diarrhea in the last two weeks). For individual-level questions, the participant will be asked to respond as a proxy for other individuals in the household. Informed consent must be provided and documented by the enumerator.

Households: CSO defines a household as a group of people that normally cook, eat, and live together who may or may not be related by blood. We will use the CSO definition of household in our evaluation. Furthermore, to be eligible for inclusion, we will require that all households be located in the sampling frame (i.e., intervention or control areas of the LWSSD project area), and that occupants have been living in their current residence for at least 2 months. Both owners and renters are eligible to participate in the survey. If a selected building has more than one house (e.g., an apartment) only one unit from the building will be selected, at random, and surveyed. At least two visits to survey each selected household will be attempted before moving to an alternate household.

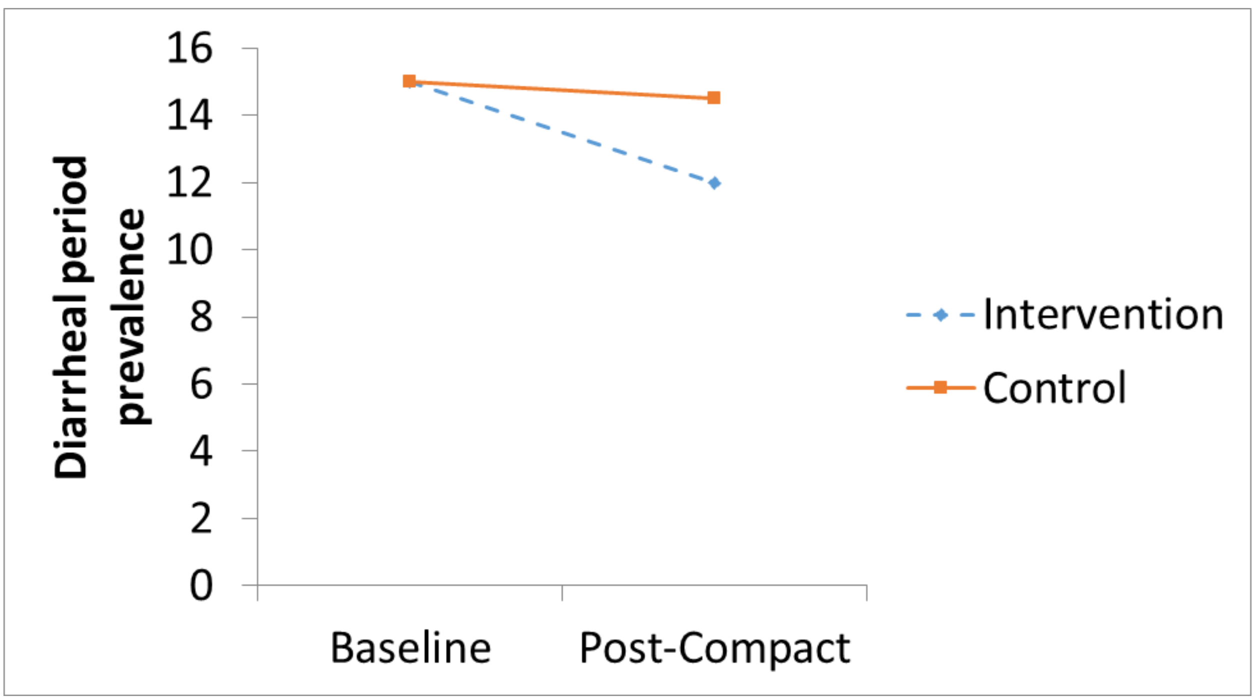
Statistical Analysis

Evaluation Methodologies

The primary quantitative study design will be a prospective, cross-sectional intervention-control and pre-post impact evaluation of new water supply and sanitation interventions. We will evaluate the changes in outcome measures between baseline and post-intervention time periods within the intervention areas and compare these measures to any differences observed in the control areas during the same time period. The initial evaluation will consist of reporting pre- and post- proportions of binary indicators and mean change values for continuous variables. Intervention and comparison group differences will be statistically tested using Rao-Scott design adjusted chi square for binary outcomes and design-adjusted linear regression for continuous outcomes. Both design adjusted methods will utilize Taylor series linearization variance estimates to account for the design effects of cluster sampling. Design effects and intra-cluster correlation coefficients will be reported.

In addition, regression model-based estimates of Difference in Difference (DD) effects will be conducted on the outcomes of interest. A graphical depiction of the DD approach is displayed below in Figure 8. Binary outcomes, such as diarrhea, will be assessed using generalized estimating equations (GEE). Continuous outcomes that are normally distributed will be evaluated using mixed effects linear regression models. The SEA sampling clusters will be treated as random effects and robust estimates of standard errors will be used. Covariates such as socioeconomic status will be considered. Selection of final statistical models and tests will be determined by the characteristics and distribution of the data.

Figure 8: Graphic Depiction of Difference in Difference Estimation



Disaggregation: Understanding the relative contribution of various factors

As shown in Table 2, we are collecting data on a variety of indicators key to measuring the impact of Compact interventions. The impact of the intervention on these indicators will be assessed using a difference in difference approach. In addition, the role of factors such as sex of head of household (HoH), household expenditures, age of HoH, and average age of children will be evaluated using statistical modeling. The following general equation is an example of the type of analysis which will be used to examine the impact of disaggregated factors:

Prevalence of diarrhea = Function of: Household expenditures, sex of HoH, age of HoH, education level of HoH, average age of children, amount water consumed, access to improved water, % children female, intervention status (intervention type, control).

Variables such as household expenditure, which is a proxy for household income, can be used as either a continuous variable, or the sample can be categorized into quintiles or similar form of categories describing relative wealth. Table 10 provides further examples of general equations that can be used to assess the relative contribution of variables such as gender, age, household expenditure, and others on key outcomes of interest.

Table 10: Statistical Modeling: Regression and other types of modeling

Dependent Variable	Possible Explanatory Variables
Illness	Drinking water source, quantity of HH water, water quality (chlorine) or treatment, availability of water (hours or days), water storage, sanitation type, shared toilet, hands washed with soap, sex, age, HH size, maternal education, HH expenditures, sex of HoH
Amount of water HH consumes each day	Drinking water source, time HH spends collecting water/day, availability of water (hours or days), cost of water, HH income, HH size, sex of HoH
Installation of toilet connected to sewer	Location, cost/subsidy of connection and toilet, type of previous toilet, HH size, maternal education, HH income, sex of HoH
Indoor piped water as primary water source	Cost/subsidy of connection, type of previous drinking water source, HH size, maternal education, HH income, sex of HoH
HH income	Location, HH size, maternal education, sex of HoH, drinking water source, time HH spends collecting water/day, number of adults in HH employed, type of work (wage/piecework/etc.), other HH income
Adult employment status	Age, sex, education level, HH size, number or % of adults working in HH, HH income, drinking water source, time HH spends collecting water/day

*All the variables listed in the table will be assessed for effect modification and confounding by gender, age, education, children and other variables identified.

Because the effects of improvements in water and sanitation are likely to be stronger for the most vulnerable groups (poor households, single mother households) compared to other households, the differential impact of interventions by gender of HoH and variables describing socio-economic status (e.g., expenditures, education, employment status) will be explored by first examining the correlations between these variables. If large and statistically significant associations are found, one potential approach would be to then categorize the variables (e.g., 5 categories of household-level expenditures). In the example of categorizing household-level expenditures, this will allow us to study, in a regression equation, the relative impact of both categories of household-level expenditures and gender. If there is significant and practical effect by both category of household-level of expenditure and gender of HoH, then the impact of an interaction term can be evaluated.

Difference in Difference Estimator

That Compact activities will occur in some areas of Lusaka and not others forms the basis of a natural experiment. In contrast to true experiments where the intervention and control areas are randomly and explicitly chosen; in Lusaka they arise from a particular policy or program decision. The Compact activities can therefore be seen as exogenous events which change the environment in which individuals, households and neighborhoods operate. Under these conditions, if we measure health status (e.g., incidence of diarrhea) only in intervention areas before and after the Compact activities, evaluation findings may be confounded by other factors which also influence health status (e.g., outbreaks, hygiene practices). On the other hand, if we measure health status between intervention and control areas only once, after the implementation of Compact activities, we will be vulnerable to systemic differences in the health status of the population across intervention and control areas due to, say, income and wealth differences, rather than the Compact activities. In order to overcome these inherent biases in a natural experiment setting, we have to collect pooled cross sectional data from both intervention and control areas during at least two points of time and adapt a difference in difference analysis to evaluate the impact of Compact activities.

Let T=0,1 where 0 indicates individuals or households which do not receive an intervention (i.e., control areas) and 1 indicates individuals or households that did receive interventions. We will observe the individuals at two points of time t=0,1 –where 0 indicates the time point before the implementation of the Compact activities and 1 indicates the time point after all activities have been implemented. Every individual or household is indexed by the letter i=1,2,…..N.

The outcome of interest Y_i (e.g., prevalence of diarrhea) is modeled by the following equation:

$$Yi = \alpha + \beta Ti + \gamma ti + \delta\ (Ti \cdot ti) + \varepsilon i$$

Where the coefficients given by α, β, γ, δ, are all unknown parameters and εi is a random, unobserved "error" term which contains all determinants of Yi which our model omits.

In the above equation the coefficients have the following interpretation

α = constant term

β = treatment group specific effect (to account for average permanent differences between treatment and control groups)

γ = time trend common to control and treatment groups

δ = true effect of treatment or DD estimator

The purpose of this evaluation will be to identify a difference in difference estimator (δ) given the available data. All households in Lusaka are currently receiving water and sanitation services at a certain level, even if the level is close to 0 (in the case of access to a household flush toilet or household piped water). In order to measure the specific impact of the LWSSD Project, it is necessary to isolate effect estimates in addition to global trends in the outcomes of interest using a difference in difference estimator.

Water Quality Testing

Project Objectives: As part of the larger project goal to evaluate the impact of the water, sanitation, and drainage interventions on the incidence of diarrheal disease, we will use water quality measures to assess improvements in water and sanitation interventions in peri-urban areas in Lusaka. To achieve these goals we have the following objectives:

1. To measure select microbial, chemical, and physicochemical water quality parameters in a random selection of stored household drinking water, point-of-consumption (POC) water, and corresponding source water in intervention and control PUA households prior to interventions (baseline) and after interventions are complete (post-implementation), as part of CDC's health impact evaluation.

2. To routinely measure select microbial, chemical, and physicochemical water quality parameters at various points within the distribution system, including the Iolanda Treatment Plant, boreholes, the Chilanga Booster Station, ten main booster stations within the city, public kiosks and tap stands, and household connections in intervention and control areas throughout the intervention time period. The World Health Organization advises that ongoing water quality assessment is an essential component of a well-managed distribution system.

3. To routinely measure select chemical and physicochemical water quality parameters of influent and effluent streams at the Kaunda Square Stabilization Ponds throughout the intervention time period in order to assess effects of sanitation upgrades in Lusaka.

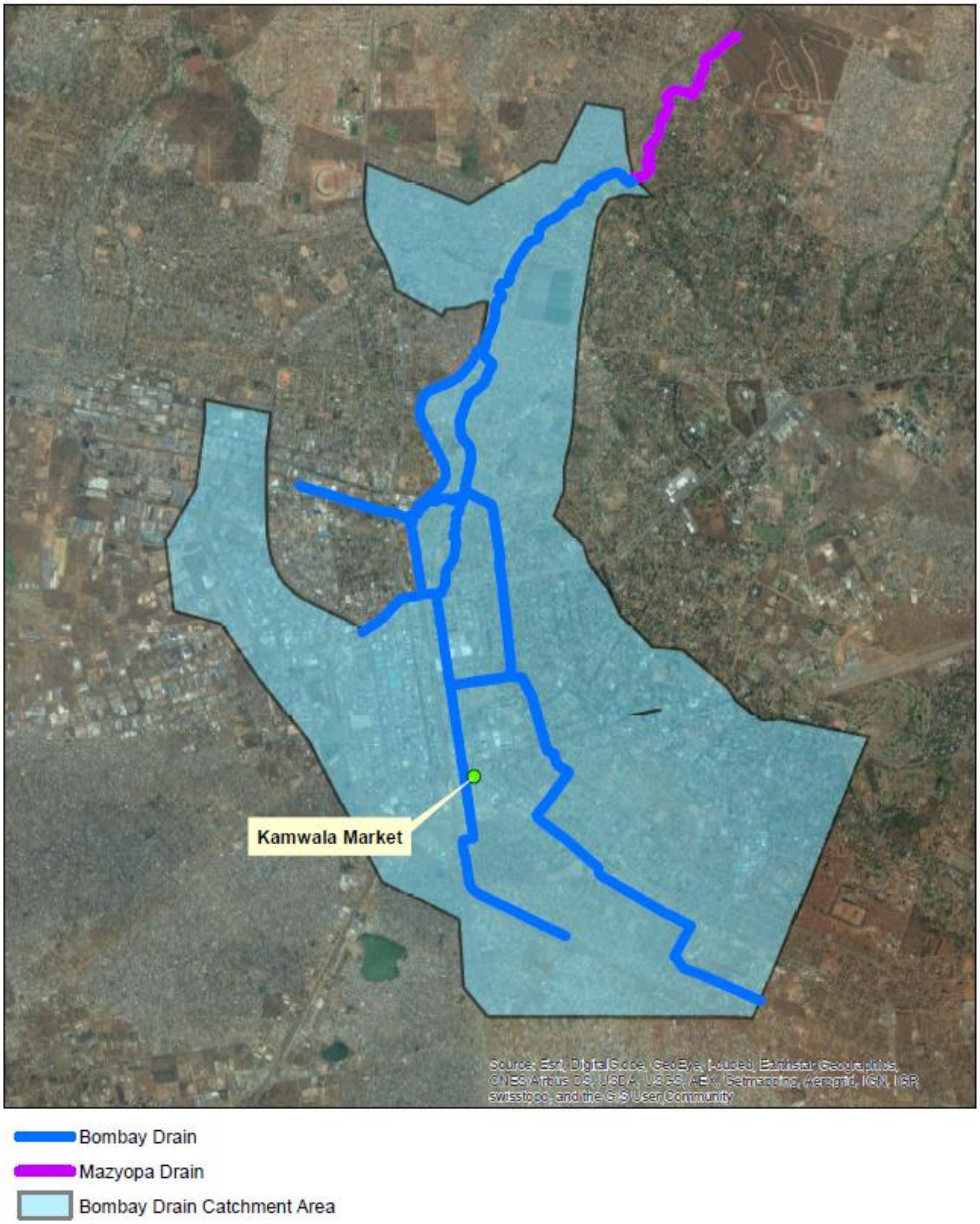
During the household survey, water samples will be collected from 1,516 intervention households and 1,516 control households, as well as from corresponding source waters (see Appendix 8 for water sampling methodology). Water samples will be tested for free chlorine residual, pH, turbidity, conductivity, temperature, pressure, total coliforms, *E. coli*, and nitrates. Throughout the four-year evaluation period, water samples will be collected on a quarterly basis from various points (up to 350 locations) along the water distribution system in Lusaka and tested for the above-mentioned parameters, as well as for heterotrophic plate count bacteria and lead to assess changes that might be due to distribution system interventions. Lastly, influent and effluent streams at the Kaunda Square Treatment Ponds will be tested on a quarterly basis for pH, temperature, chemical oxygen demand, total suspended solids, total phosphorous, and total nitrogen to assess changes that might be due to sanitation interventions made upstream and at the ponds. A full water quality testing study protocol is detailed in Appendix 8.

Drainage Intervention - Household

Changes in household health, economic, and time saving-related indicators that are attributable to Compact drainage investments will be evaluated quantitatively through randomized cross-sectional household surveys. These surveys will be conducted throughout the Bombay drain catchment area (Figure 9), but primarily in the flood-affected communities that are directly adjacent to the Bombay Drain, where the greatest impact from drainage interventions is expected. As previously described, the Bombay drain catchment area is unique to Lusaka, due to the hydrogeology of the drain, drain geography and size, and the characteristics of the residential areas that lie within its catchment area. As a result, a control group for the communities within the Bombay drain catchment area cannot be identified in Lusaka. Consequently, the household-level benefits attributable to the drainage intervention will only be evaluated in a pre and post comparison.

Data collection for this evaluation will occur in two phases: at baseline and after the intervention has been completed. Approximately 3,092 flood-affected households will be surveyed in each phase (Table 9). The rainy season usually ends in March or April and data collection will begin shortly thereafter to minimize recall bias. Baseline data collection is expected to begin in January 2016 and last approximately four months. Post-implementation data collection will likely begin in January of 2019, although data collection timelines will depend on Compact implementation, IRB timelines, and other factors, and are therefore subject to change. See Table 11 for an overview of the data collection timeline. The household drainage survey instrument includes short modules on water, sanitation, and hygiene adapted from the primary household survey instrument, with an additional module specific to the impacts of flooding. An outline of the survey is included in Table 4; the full household drainage survey can be found in Appendix 5.

Figure 9: Bombay Drainage System and Catchment Area



Source: Gauff Ingenieure: GIS files

Table 11: Proposed Data Collection Timeline: Drainage Intervention – Household Impacts

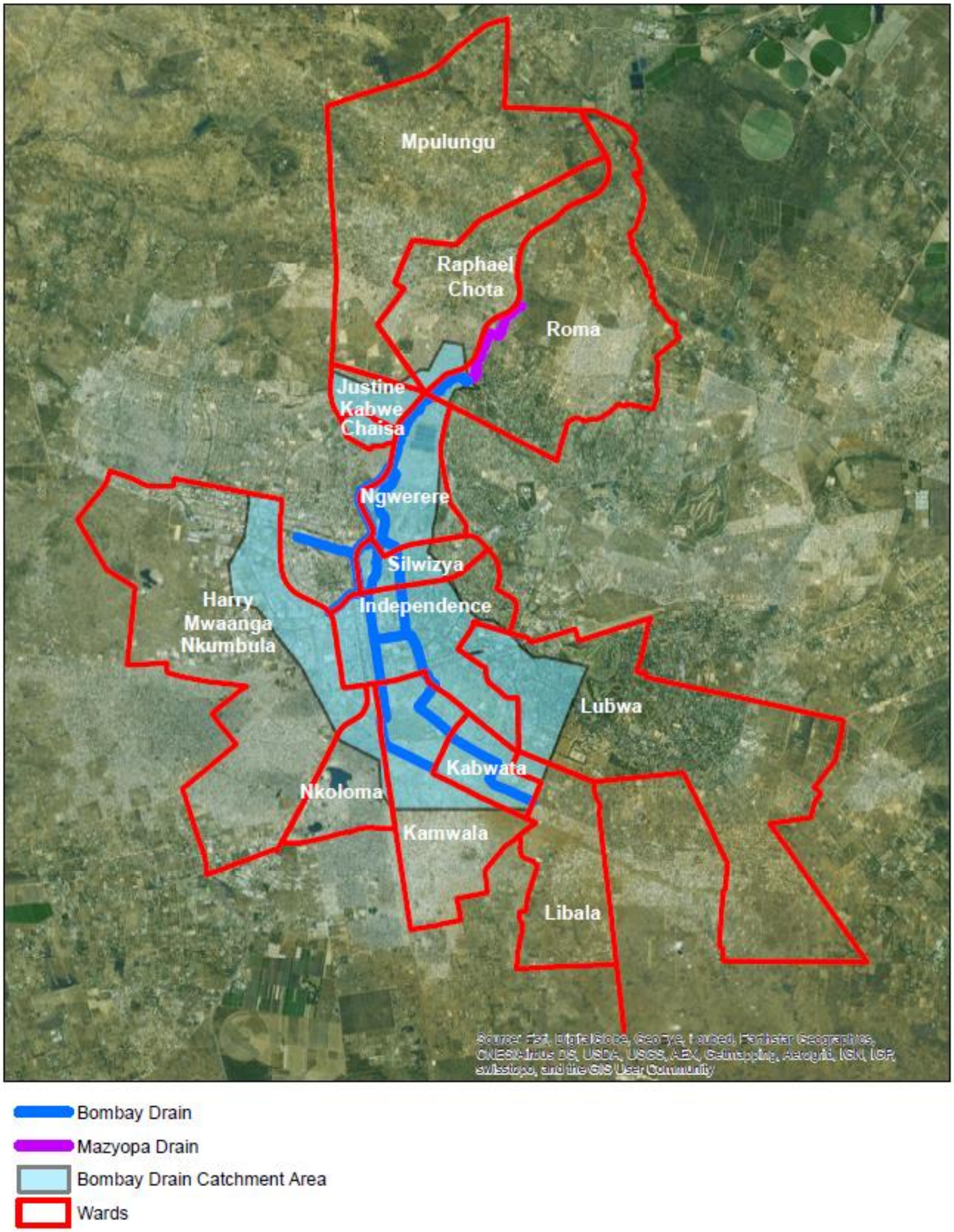
Approximate Date*	Data Collection Activity
January - April 2016	Baseline data collection
January - April 2019	Post-implementation data collection**

*Dates are subject to change based on Compact implementation, IRB, and other timelines.
**Dates TBD. The post-implementation survey will likely occur after the end of the Compact in order to effectively measure impact.

Study Population

The Bombay Drainage System is extensive, has multiple branches, and covers approximately 25 kilometers in urban and peri-urban Lusaka (Figure 9). It drains flood water from both residential areas and the central business district of Lusaka. The Bombay drainage catchment area (i.e., the area whose runoff feeds the Bombay drain) is comprised of approximately 188,000 beneficiaries (39,000 households), which make up the study population for the household drainage evaluation (Gauff Ingenieure, 2013b). The beneficiary population was determined by Gauff and MCC by overlaying large census blocks known as wards over the geographic boundary of the Bombay drainage basin. The proportion of the population in each ward located within the drainage basin boundary was summed to estimate the total of ~188,000 beneficiaries. A map of the Bombay drain, drainage catchment area, and overlapping wards is provided below in Figure 10, and a list of these wards and their populations is included in Table 12.

Figure 10: Bombay Drain Catchment Area and Ward Overlap



Source: Central Statistics Office: 2010 Census GIS Files; Gauff Ingenieure: GIS files

Table 12: Approximate Population and Proportion of Wards in Bombay Drain Catchment Area

Ward	2010 Population	Households	Approximate Percentage of Ward in Catchment Area	Estimated Population in Catchment Area	Estimated Households in Catchment Area
Nkoloma	73,380	16,366	10.0	7,338	1,637
Kamwala	50,711	9,777	85.0	43,104	8,310
Kabwata	21,930	4,629	100.0	21,930	4,629
Libala	21,740	4,396	5.0	1,087	220
Harry Mwaanga	166,420	35,068	11.0	18,306	3,857
Silwizya	6,803	1,521	55.0	3,742	837
Independence	19,379	3,390	74.0	14,340	2,509
Lubwa	41,286	7,195	7.3	3,014	525
Roma	66,435	13,804	1.0	664	138
Ngwerere	65,092	14,120	83.0	54,026	11,720
Chaisa	19,819	4,445	100.0	19,819	4,445
Raphael Chota	93,141	18,667	0.5	466	93
Mpulungu	56,418	11,268	0.3	169	34
Total	702,554	144,646	---	**188,005**	**38,954**

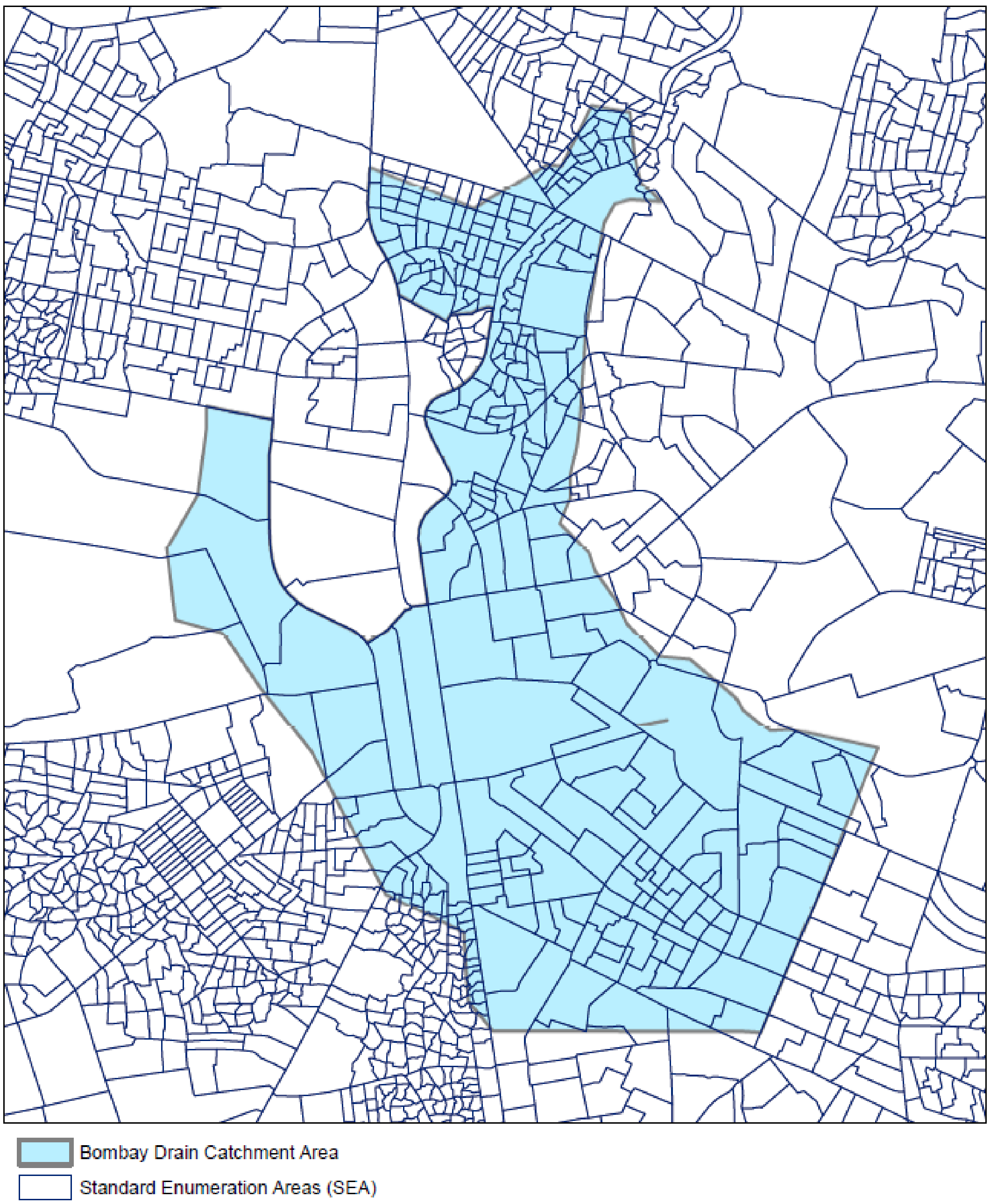
Source: Adapted from Gauff Ingenieure 90% Design Report – Drainage, 2013

Sampling Strategy

Similar to the methodology employed to identify the sample frame for the water supply and sanitation interventions, a two-stage cluster sampling strategy will be utilized to evaluate the household impacts of the drainage intervention. In this approach, geographic areas will be used as the sampling frame to first select primary sampling units (PSUs) and then secondary sampling units (SSUs). Administratively, the Zambian Central Statistics Office (CSO) divides Lusaka into different sized enumeration units for the Census. The smallest enumeration unit is called a Standard Enumeration Area (SEA), and represents approximately 175 households. SEAs will serve as PSUs and households within selected SEAs will be selected as SSUs for the evaluation. We will generate our sampling frame of SEAs by overlaying census SEA boundaries and the boundary of the Bombay drainage catchment area using ArcView GIS (Figure 11). SEAs that are located within approximately 200-250 meters on either side of the Bombay Drain, where the greatest impact is expected, will be randomly selected. In addition, any portion of the proposed 400-500 meter drainage sampling frame corridor that overlaps with the control area sampling frame for the water and sanitation interventions will only be included in the drainage sampling frame (i.e., not available to serve as a control area for the water and sanitation evaluation).

Households located in the selected SEAs will then be randomly selected for inclusion in the evaluation. An independent sample of SEAs will be drawn, with replacement, for each time point in the evaluation (baseline and post-Implementation). Spot checks on a small subset of households (e.g., 10) at varying radii outside of the proposed 500 meter corridor will be conducted to assess if there is wider impact.

Figure 11: Bombay Drain Catchment Area and Standard Enumeration Areas



Source: Central Statistics Office: 2010 Census GIS Files; Gauff Ingenieure: GIS files

Sample Size and Statistical Power

The sample size, and sample size considerations for the household drainage evaluation are the same as those of the water and sanitation evaluation, based on the smallest effect size anticipated with reduction in diarrheal prevalence for children < 5 years of age. A total of 3,092 households with a child under 5 years of age present will be sampled at each time point. Assuming a baseline prevalence of 15%, a 20% reduction (from 15% prevalence to 12% prevalence) at post-intervention in the 2-week period prevalence of diarrheal illness among children under 5, and 80% power, a simple random sample (SRS) would necessitate that 1,546 households be sampled per intervention area. However, due to the cluster sampling strategy described, the sample size must take into account the potential design effect of the correlated data. The minimum design effect would be 2, indicating a sample twice the size of the SRS – 3,092. Furthermore, to account for households without children under five, absentee, non-response or refusals by selected households, an additional 50% of the required households per SEA cluster will be selected to serve as potential replacement households. This brings the number of households potentially selected for sampling to 4,638 (Table 9).

Inclusion Criteria

Individuals: Participants in the evaluation are adults ≥ 18 years of age and are either male or female heads of the household. The Zambian Central Statistics Office (CSO) definition of head of household is the person all members of the household regard as the household head; he/she is the person who normally makes the day-to-day decisions governing the running of the household. We will use the CSO definition in our evaluation. Both renters and home-owners are eligible to participate. The survey contains both household level questions (e.g., water source, type of toilet), and individual-level questions (e.g., was anyone sick with diarrhea in the last two weeks). For individual-level questions, the participant will be asked to respond as a proxy for other individuals in the household. Informed consent must be provided and documented by the enumerator.

Households: CSO defines a household as a group of people that normally cook, eat, and live together who may or may not be related by blood. We will use the CSO definition of household in our evaluation. Furthermore, to be eligible for inclusion, we will require that all households be located in the sampling frame (i.e., intervention area of the LWSSD project area), and that occupants have been living in their current residence for at least 2 months. Both owners and renters are eligible to participate in the survey. If a selected building has more than one house (e.g., an apartment) only one unit from the building will be selected, at random, and surveyed. At least two visits to survey each selected household will be attempted before moving to an alternate household.

Statistical Analysis

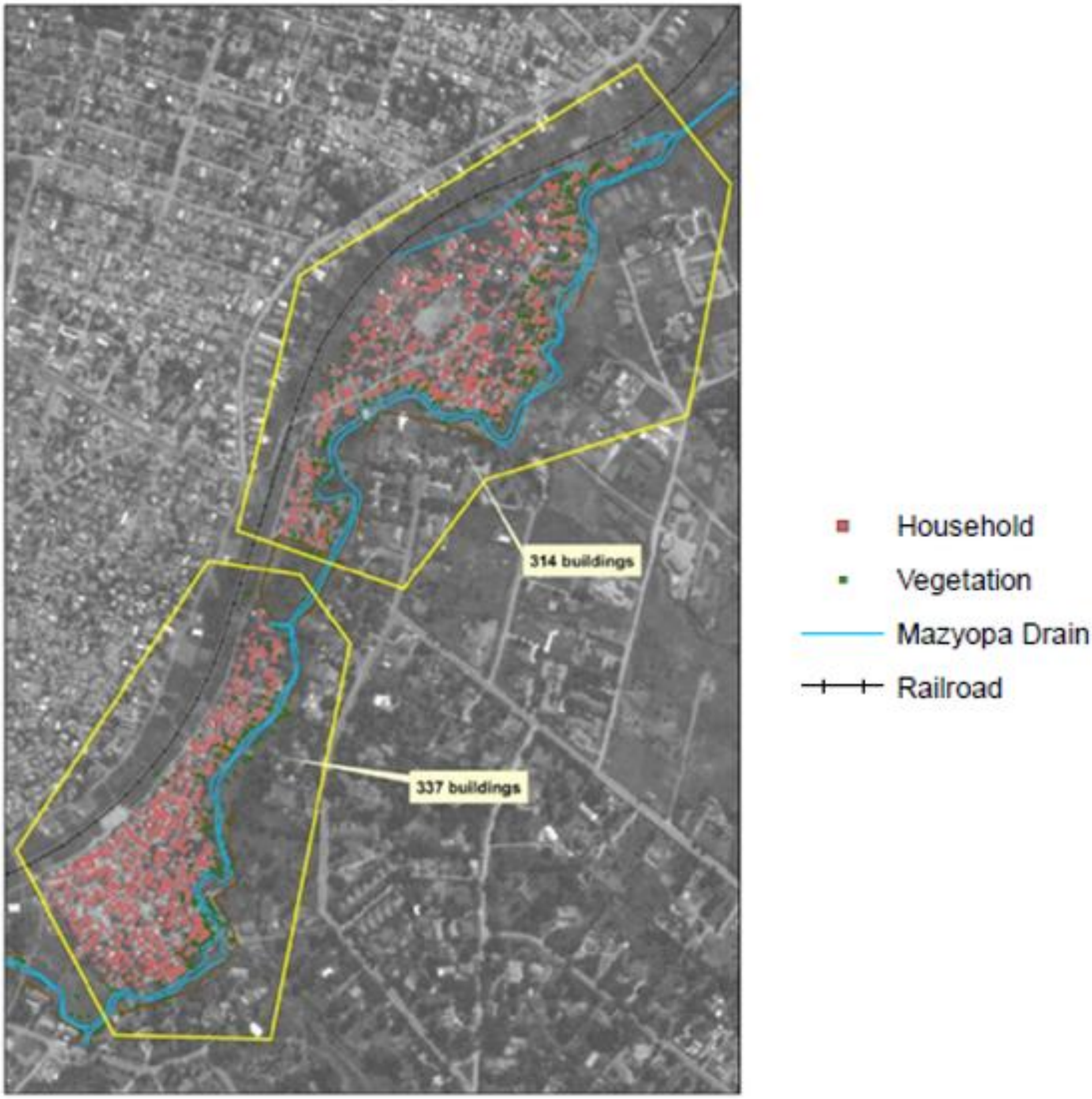
The primary quantitative study design will be a prospective, cross-sectional, pre-post evaluation of drainage improvement interventions. We will evaluate the changes in outcome measures between baseline and post-intervention time periods. The evaluation will consist of reporting pre- and post-proportions of binary indicators and mean change values for continuous variables. All differences will be statistically tested using Rao-Scott design adjusted chi square for binary outcomes and design-adjusted linear regression for continuous outcomes. Both design-adjusted methods will utilize Taylor series linearization variance estimates to account for the design effects of cluster sampling. Design effects and intra-cluster correlation coefficients will be reported. Because of the lack of a control group the analyses will be limited to pre-post comparisons (i.e., the difference in differences approach and other comparisons between intervention and control groups will not be possible).

Because the effects of improvements in drainage may be stronger for the most vulnerable groups (poor households, single mother households) compared to other households, the differential impact of interventions by gender of HoH and variables describing socio-economic status (e.g., expenditures, education, employment status) will be explored by first examining the correlations between these variables. If large and statistically significant associations are found, one potential approach would be to categorize the variables (e.g., 5 categories of household-level expenditures). In the example of categorizing household-level expenditures, this will allow us to study, in a regression equation, the relative impact of both categories of household-level expenditures and gender. If there is significant and practical effect by both category of household-level of expenditure and gender of HoH, then the impact of an interaction term can be evaluated.

Mazyopa Drain

The Mazyopa Drain is located at the very northern point of the Bombay Drainage system (Figure 9). The Mazyopa Settlement is an informal, low-income settlement of approximately 660 households (3,900 people) that is located adjacent to the drain (Figure 12) (Gauff Ingenieure, 2014). The Mazyopa settlement has been identified as potentially negatively impacted by Compact drainage improvements. To mitigate these potential negative effects, the Mazyopa drain will be widened to accommodate the greater flow anticipated as a result of the Bombay Drain improvements. A pre- and post- evaluation of flooding impacts and select health and economic indicators will be implemented in Mazyopa as part of the larger household drainage evaluation. The inclusion criteria and statistical analysis for the larger household drainage evaluation also apply to the Mazyopa evaluation. However, the expected impacts for the Mazyopa drainage area are different (potentially increased flooding, or no flooding) than those anticipated along the Bombay drainage area (anticipated reduced flooding).

Figure 12: Mazyopa Drain and Settlement



Source: Gauff Ingenieure: Updated Assessment for Flood Risk for Mazyopa Settlement arising from Improvements targeted for Bombay and Lumumba Drain, 2014

Drainage Intervention – Business

Improvements to the Bombay Drainage System are expected to decrease the frequency and duration of floods; thereby benefitting the businesses located along the drain by reducing flood-related repair and maintenance costs and minimizing flood related revenue losses. The drainage interventions also aim to decrease employees' travel time and reduce water-related illnesses such as diarrhea.

To evaluate the effects of this intervention, a pre-post assessment of flooding-related business outcomes will be performed by surveying businesses in the affected area. Specifically, the surveys will be administered to businesses located in the Kamwala Market, a major market located along the drain. Businesses located in close vicinity to (exact distance TBD during pilot phase of survey), but outside of the Kamwala Market will also be included. Surveyed businesses will be selected at random to ensure a representative sample. The business survey modules and key variables of interest are listed in Table 13; the full version of the business survey can be found in Appendix 9.

Because of the previously described unique hydrogeological and business/entrepreneurial characteristics of the markets and businesses along the Bombay Drainage System, a control area with similar characteristics was not identified in Lusaka. Subsequently, a pre-post analysis will be conducted; surveys will be administered at baseline and after the intervention is complete. The rainy season usually ends in March or April and data collection will begin shortly thereafter to minimize recall bias. Baseline data collection is expected to begin in May 2016 and last approximately 2 months. Post-implementation data collection will likely begin in May of 2019. Data collection timelines are subject to change based on the implementation of Compact interventions, timelines for IRB approval, and other factors. See Table 14 for an estimated timeline.

Table 13: Business Survey Modules and Key Variables

Module	Key Variables
A. Background	Typical revenue generated, no. of employees, business turnover and inventory status
B. Flooding	Duration and frequency of flooding, property damage and its cost, loss in revenue, days of business closure, impact on employees travel time, downsizing if any
C. Mitigation	Investment in flood protection
D. Other businesses	Other businesses affected and severity, illness

Table 14: Proposed Data Collection Timeline: Drainage Intervention – Business Impacts

Approximate Date*	Data Collection Activity
May - June 2016	Baseline data collection
May - June 2019	Post-implementation data collection**

*Dates are subject to change based on Compact implementation, IRB, and other timelines.
**Dates TBD. The post-implementation survey will likely occur after the end of the Compact in order to effectively measure impact.

Study Population

The study population consists of the businesses within the Kamwala Market and the permanent businesses located outside of, but in close proximity to, the market (exact distance TBD during pilot phase of survey). See Figure 9 for a map of the Bombay Drainage System and Figure 13 for images of the Kamwala Market and surrounding businesses. These businesses are prone to seasonal flooding and have high probability of being impacted by the drainage improvement intervention.

Figure 13: Kamwala Market and Surrounding Area

Source: Google Earth

Sampling Strategy

Randomized sampling will be used for both types of businesses; however, the sampling strategy for businesses located inside the Kamwala Market differs from the strategy for businesses located outside the market.

Businesses Inside Kamwala Market

Kamwala Market is run by a market master. The market master manages day-to-day operations and maintains a list of all businesses located in the market. The businesses that will be surveyed will be selected from this list. We will select these businesses randomly, proportionate to the size and type of business (e.g., clothing store, grocer, etc.). For example, if business type A represents XX% of market stalls then the enumerators will randomly select XX% of the total sample from this business type. This approach, in technical terms, is called stratified random sampling. It will be essential to work with the market master because they have knowledge about the market stalls (businesses) that we will survey. A much higher response rate, approximately 80-90%, can be expected with cooperation and facilitation from market masters.

Businesses Outside Kamwala Market

Permanent businesses located outside of the market are not governed by any central body, and as a result a complete list of the names, numbers, type, and size of these businesses may not be available. Therefore these businesses will be randomly sampled, but not according to characteristics such as type or size. To survey these businesses we will have to approach each business and ask for their cooperation. Therefore, the anticipated response rate would be lower, perhaps around 30-50%.

Sample Size

Computation of confidence intervals to describe the key indicators will be difficult due to the lack of sufficient data on variables such as: number of days business closed, loss of business income, costs of repairing flood-related damage, and the variability of impact of flooding on these businesses. Further, the impact of flooding inevitably has year-to-year variations. Therefore, at this stage, we are not in the position to construct any reasonable estimates of the expected range (confidence interval) of impacts of flooding. Thus, we are also unable to define the potential range of impacts of the proposed drainage intervention.

Based on an approximate estimate of 1,600 businesses within the Kamwala Market, we will sample at least 25% (400) of businesses within the market. We anticipate sampling an additional 200 businesses that are located outside of the Kamwala Market, for a total sample size of approximately 600 businesses. The evaluation will include an initial data collection period (~100-200 businesses) followed by a "stop-and-evaluate" period in which the variability in data of interest is calculated from the data collected to date. We will use these initial estimates to decide if the sample size and sampling methodology needs to be adjusted. Data for this evaluation will be collected in two phases, baseline and post-implementation. A second, independent sample of businesses will be drawn for the post-implementation surveys.

Inclusion Criteria

Business: A business is broadly defined and could be a stall, stand, shop, wholesaler, factory or any unit where revenue-generating activity occurs. It must have a fixed location within the flood-affected area served by the Bombay drainage system. A business may be located inside or outside of the Kamwala Market. Street vendors and/or temporary stalls/stands located outside the Kamwala Market will be excluded from the sampling frame of the business survey.

Statistical Analysis

Impacts of the drainage intervention on businesses will be assessed quantitatively through pre-intervention and post intervention comparisons of key indicators related to flooding and business revenue. Change in frequency, intensity and duration of flooding, and key performance indicators related to businesses such as revenues and profits will be compared. Similarly, changes in business expenses, staff turnovers, availability of business associates, business closure, and travel time could be other indicators that are impacted by flooding. The procedure of statistical analyses will be similar to the approach described in the statistical analysis for impact assessment of the drainage intervention on households. If sufficient sample size permits, differences in effects on outcomes for male-owned and female-owned businesses will be evaluated.

Drainage Intervention – Traffic Evaluation

Improvements to the Bombay Drainage System are expected to decrease the frequency and duration of floods, thereby ensuring smooth flow of traffic in the catchment area and averting travel time lost due to congestion. The main objectives of the traffic evaluation are:

1. To estimate the impact of the drainage intervention on traffic volume by vehicle type
2. To estimate the impact of the drainage intervention on travel time by vehicle type

To evaluate the effects of this intervention we will conduct an observational evaluation of traffic in the catchment area during periods without flooding (dry season) and periods when flooding is anticipated or has occurred (rainy season). The latter will require enumerators to carefully monitor the weather and be able to rapidly deploy whenever flooding seems imminent, or has actually occurred.

This evaluation will be conducted both pre and post Bombay drainage intervention to account for the increase in traffic volume and other exogenous changes in Lusaka (e.g., better roads, better public transit). Prior to baseline (pre-intervention) data collection, during the evaluation design phase, we will conduct an exploratory evaluation to better understand flood affected areas and traffic patterns in Lusaka. We anticipate the exploratory evaluation to be implemented in mid-2015. Baseline data collection will follow. Baseline data collection for periods of non-flooding is expected to begin in September of 2015 and last approximately two months. Similarly, baseline data collection will be repeated during flooding in the rainy season of 2015-2016. The rainy season in Lusaka usually begins in November and ends in March or April; data collection during the rainy season will likely begin in January of 2016 and last approximately three months.

Post-implementation data collection will be implemented after the drainage improvement intervention has been completed. Data collection will likely begin in September of 2019 (non-flooding) and January of 2020 (flooding). Data collection timelines are subject to change based on Compact implementation, IRB, and other timelines. See Table 15 for an estimated timeline of data collection activities.

Table 15: Proposed Data Collection Timeline: Drainage Intervention – Traffic Evaluation

Data Collection Activity*	Non Flood Time	During Flooding
Evaluation Design	May 2015	NA
Baseline data collection	September - October 2015	January – March 2016
Post-drainage improvement data collection**	September - October 2019	January – March 2020***

* Dates are subject to change based on Compact implementation, IRB, and other timelines.
**Dates TBD. Post-implementation data collection will likely occur after the end of the Compact in order to effectively measure impact.
***Flooding may not occur post intervention. The term "During Flooding" is used to indicate a similar period and to document benefits from the intervention.

Evaluation Design Phase

In mid-2015, we will conduct a limited number of key informant interviews among individuals familiar with traffic and flooding issues in Lusaka. Key informants may include City of Lusaka transportation and traffic engineers, traffic police, public transit commuters, taxi drivers, freight movers, and the general public. We will also conduct an observational exercise of traffic flow. The goals of these interviews and exercise are to:

- Obtain an initial idea of the traffic flow in downtown Lusaka
- Understand how traffic flow is interrupted by floods
- Identify intersections and traffic routes along major traffic thoroughfares that are most suitable for a survey of traffic patterns and traffic flow

To identify the most suitable traffic intersections and routes the following additional information will be collected:

- Map of the Bombay drainage improvement area with particular emphasis on areas and regions that regularly flood (i.e., the evaluation area)
- Traffic flow patterns (including pedestrian traffic) in and around the evaluation area
- Traffic flow patterns used when flooding has occurred
- Public transit routes crisscrossing the evaluation area (if any)
- Major intersections within and around the flood affected areas

- Peak and non-peak time for traffic, days of week with high traffic, and other factors which influence traffic (sports events, VIP visits, rallies)
- Identification of major nodes through which traffic passes in Lusaka
- Identification of arterial, major, and minor roads around the evaluation area
- Identification of 5-10 routes driven by vehicles through major Lusaka traffic intersections and roads that are considered “main driving routes”
- Identification of 5-10 routes walked by pedestrians through major Lusaka traffic intersections and roads that are considered “main pedestrian routes”
- Identification of meteorological data sources to measure precipitation and flooding
- Availability of sources of secondary data such as the total number of vehicles registered and tags renewed by vehicle type, traffic congestion reports (traffic jams), traffic cameras, and smartphone apps (WAZE, google maps)
- Explore the feasibility of options to measure traffic speed and volume, such as Laser Speed Measuring Devices (LSMDs) and GPS Enabled Trackers (GETs). If available and feasible, LSMDs could be used to measure the average speed along roads in and around the evaluation area according to vehicle type.

The information collected above will help us to adjust and refine the data collection protocols for the traffic evaluation in the subsequent phase.

Data Collection Activities

The baseline (pre-Compact improvement period) and follow-up (post-Compact improvement period) data collection phases will consist of the following two components:

Component 1: Screen Line Survey-Traffic Volume

A screen line is an imaginary line connecting approximately 10 locations. These locations will be intersections or other heavily trafficked locations in the evaluation area that are regularly flooded. The exact number and location of these intersections will be determined after examining the data collected during the evaluation design phase. In the screen line survey enumerators will count the number of vehicles, passengers, and pedestrians that cross the screen line in any direction at the (approximately)

10 intersections identified. A more detailed description of the data that will be collected for this component can be found below:

- Observation period: The observation period will last up to 12 hours, encompassing peak and non-peak traffic times. Data will be collected during each observation period at consecutive 15 minute intervals. There will be three days of data collection (selected randomly) during both dry and rainy seasons. The average of the three randomly chosen days will be used. During the evaluation design phase we will explore the feasibility of using traffic cameras or installing video cameras at the intersections to aid traffic counts.
- Number and type of vehicle: The number of vehicles that cross the screen line will be counted per unit time (15 minute interval). Vehicles will be categorized by the direction they are travelling, and by vehicle type: car & pickup truck, taxi, minibus (16 seats), medium bus (26 seats), large bus, light commercial vehicle (< 3 ton), rigid truck, articulated truck, and others.
- Number of passengers in each vehicle: This will be recorded to provide the number of passengers crossing the screen line per unit time.
- Pedestrians: Pedestrian traffic will also be counted per unit time (15 minute interval). Pedestrian counts will be categorized into the direction the person is walking. This will provide the number of pedestrians passing a screen point, by direction, per unit time. [Note: If it is found that pedestrian traffic follows different routes than vehicular traffic during the evaluation design phase, the pedestrian screen lines will be set up along the appropriate pedestrian routes].
- The number of data collection teams will depend on the final number of locations chosen. Each team will not observe more than 5 locations over the two to three month data collection period, and each team will observe the same location during non-flooding and flooding times.
- See Table 16 for the estimated sample size of this component.

Table 16: Sample Size for Traffic Volume Count Evaluations – Vehicular and Pedestrian*

Number of Intersections	Observation Days per Intersection**	Total Observation Days per Season**	Observation Days for Entire Evaluation** (pre-post, rainy-dry)
10	3	30	120

*Applies to both vehicular and pedestrian traffic count evaluations
**Observation days last 12 hours. Observations are recorded in consecutive 15 minute intervals.

Component 2: Travel Time Evaluation

This evaluation will measure the average travel time for vehicles and pedestrians along identified routes during periods of flooding and non-flooding. Routes will be identified between selected major traffic nodes in Lusaka, and will cut through areas that are affected by flooding. We propose to identify at least 10 routes. The data collected will be the following:

- Vehicle travel time over specified routes: The travel time will be recorded by driving a round trip on each selected route. Round trips will be completed in one to three different sized vehicles (e.g., car, truck, etc.) during a peak and non-peak time each day, on three different days. Drivers will attempt to minimize time taken to cover the pre-set routes, but stay within the posted speed limits and obey all relevant traffic laws. This will provide the time per unit distance per designated route. We may also measure travel time on public transit by taking rides on public transit vehicles (e.g., minibuses).
- Pedestrian travel time over specified routes: Travel time will be recorded as enumerators walk pre-specified pedestrian routes. Pedestrian enumerators will walk each route 3-5 times a day during peak and non-peak times, on three different days. Pedestrian enumerators will walk with the intention to minimize time taken to cover the pre-set routes, but obey all relevant traffic laws (e.g., not jay-walking or crossing streets outside designated crossing points). This will provide the time per unit distance per designated route.
- See Table 17 for the estimated sample size of this component.

Table 17: Sample Size for Travel Time Evaluations

Travel Time Evaluation	Number of Routes	Types of Vehicle	Round Trips Per Day*	Data Collection Days per Route, per Season	Total Round Trips per Season	Round Trips for Entire Evaluation (pre-post, rainy-dry)
Vehicular	10	3	2 (per vehicle)	3	180	720
Pedestrian	10	NA	3-5 (per route)	3	90-150	360-600

*Trips taken at times of both peak and non-peak traffic congestion

Statistical Analysis

Impacts of the drainage intervention on traffic will be assessed quantitatively through pre-intervention and post-intervention comparisons of traffic volume and travel time during periods of flooding and non-flooding. The statistical analyses will be done via comparisons of mean and medians of the vehicular traffic and pedestrian traffic collected before and after Compact drainage improvements.

The exact statistical method used (i.e., parametric or non-parametric) will be decided upon after a preliminary examination of the data. We anticipate using a form of regression analyses, in which we will control for factors such as dry/flooded and pre/post drainage improvement. The following analyses will be carried out:

Before Compact Drainage Intervention:

- Difference in average and median percentage and actual traffic numbers, for each screening location, by vehicle type and time of day, in dry and flooded situations.
- Difference in average and median percentage and actual pedestrian traffic numbers, for each screening location, by time of day, in dry and flooded situations.
- Difference in average and median time taken to drive pre-set routes, in dry and flooded situations.
- Difference in average and median time taken to walk pre-set routes, in dry and flooded situations.

After Compact Drainage Intervention:

- Repeat the four analyses above.
- Pre and post intervention comparison: Estimate the impact of drainage improvements by comparing pre and post intervention data to determine any statistically significant changes in traffic and traffic speed before and after drainage improvements, in dry and in flooded situations.

Qualitative Methods

Qualitative data collection activities may be undertaken midway through Compact implementation and/or after all interventions are complete. Potential qualitative data collection activities include focus group discussions (FGD) with community members in intervention and control areas and in depth interviews (IDI) with business owners and with sub-groups identified as important for uptake of Compact interventions. To our knowledge, IEC activities related to the primary Compact interventions have not yet been determined or developed; however it is anticipated that IEC messaging around sanitation, in particular, will be essential for uptake of the sanitation intervention and sustainable maintenance and functioning of the sewerage network. Potential IEC topics to be explored may include access to water, sanitation, and hygiene infrastructure; opinions about existing infrastructure; WASH knowledge, attitudes, and practices (KAP); water treatment and storage; behavioral change around sanitation practices, and menstrual hygiene options.

ENUMERATION FIRM

An enumeration firm will be procured by MCA Zambia to implement baseline data collection at both households and businesses. The firm will be managed by MCA Zambia with technical input and oversight by CDC. CDC, in consultation with MCA Zambia and MCC, is developing the terms of reference (TOR) for the data collection activities. MCA Zambia will advertise the TOR when it is finalized, at which point enumeration firms will submit bids. It is anticipated that the selected firm will have the technical capacity to program tablets or other mobile devices for electronic survey administration. However, this will be dependent on the capabilities and proposals of the potential enumeration firms. Data management staff will be included on the enumeration firm team and will have a detailed scope of work with respect to data management, data quality assurance, and routine data reporting, as outlined in the TOR. All enumerators will receive extensive training by CDC and each field team (of approximately 3-5 enumerators) will be managed by a field supervisor.

HEALTH FACILITY SENTINEL SURVEILLANCE FOR DIARRHEA

CDC is proposing a complementary data collection activity at health facilities to characterize diarrheal etiologies for patients presenting with diarrhea in Lusaka. This will primarily focus on collaborating with the Zambian Ministry of Health to strengthen the existing surveillance at health facilities in intervention and control areas to assess the impact of the intervention on the burden of diarrheal illness among residents presenting at these health facilities. CDC also proposes establishing stool specimen collection from patients presenting to participating health facilities with acute diarrhea including dysentery (bloody diarrhea) and cholera-like diarrhea. The specimens will be tested for a suite of enteric pathogens, possibly including toxigenic *E. coli, V. cholerae, Salmonella, Shigella, Campylobacter,* rotavirus, *Giardia,* and *Cryptosporidium*. CDC is collaborating with the Ministry of Health (MOH), District and Provincial Health Offices, University Teaching Hospital (UTH), and health facilities in intervention and control areas on the proposed laboratory-based surveillance activities associated with the evaluation of the Compact interventions. See Appendix 10 for a copy of the Sentinel Surveillance Protocol.

ETHICAL REVIEW

Evaluation protocols will be submitted to the Institutional Review Board (IRB) of CDC in Atlanta and to the Biomedical Research Ethics Committee at the University of Zambia for approval prior to the start of data collection.

POTENTIAL RISKS TO THE EVALUATION AND RISK MITIGATION STRATEGIES:

- Risk: Lack of uptake of the sanitation intervention in Mtendere due to high connection or construction costs associated with purchasing a flush toilet;
    - Risk Mitigation: Subsidies for purchase of flush toilets may be provided to residents in the Mtendere area targeted to receive the sanitation intervention. The survey instrument will measure household decisions to access new sanitation infrastructure and whether financial assistance was provided to connect to new infrastructure.
- Risk: Lack of true control group for the water and sanitation interventions;
    - Risk Mitigation: We compared a number of Census variables related to education, employment, housing and WASH characteristics between intervention and control areas and found them to be highly similar across all variables considered (see Tables 7 and 8). If we find that covariates are significantly different between intervention and control area populations during baseline data collection, we will consider analytic methods to account for these differences.
- Risk: Courtesy bias (a grateful intervention population reports the outcomes that they think the investigators desire, i.e., no diarrhea):
    - Risk Mitigation: This risk will be mitigated by training the enumerators to elicit honest responses from study subjects by asking questions in a clear, standardized manner across all survey participants and by using visual aids such as calendars to assist with recall.
- Risk: Classification bias for infrastructure (e.g., if another organization installs WASH infrastructure in intervention or control communities).
    - Risk Mitigation: WASH activities within the intervention and control areas will be closely monitored by the CDC M&E staff posted at the CDC Zambia Office and staff from LWSC will inform CDC of significant activities anticipated or occurring in intervention and control DMAs. A memo describing control area selection and strategies to ensure the

validity of control areas for evaluation purposes and interpretation of findings has been delivered to and agreed upon by LWSC and LCC. Additionally, CDC and MCA Zambia M&E personnel will participate in the WASH NGO forum, which tracks all WASH-related programs occurring in Lusaka, most of which are IEC-focused.

- Risk: Classification bias for self-reported diarrhea and ARI: Because of resource and logistical limitations, self-reported diarrhea and ARI will be the primary health outcomes measured in the quantitative data collection; previous studies have found that this approach can bias the results for diarrhea by up to 25%.
    - Risk Mitigation: We will account for this possibility in reports of study findings, and we will conduct sentinel surveillance for diarrhea at health facilities in the primary intervention and control areas for water supply and sanitation interventions. Systematic collection and testing of stools from patients within the respective clinic catchment areas who present with acute watery or bloody diarrhea will be conducted to assess diarrhea prevalence and diarrhea etiologies within a subset of intervention and control areas over time.
- Risk: Variable rainfall: The interpretation of flooding impact associated with the drainage intervention is subject to exogenous factors such as inter-annual variability of precipitation, which has a direct correlation to flooding risk.
    - Risk Mitigation: To mitigate this risk we will collect long-term rainfall data on a daily or weekly frequency spanning the course of the evaluation (and several years before) to assess variance in rainfall measurements that may contribute to inter-annual variability in flooding risk.

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APPENDICES

Appendix 1: Compact Program Logic

Appendix 2: Compact Activity Details

Appendix 3: Economic Rate of Return

Appendix 4: Household questionnaire – no flooding

Appendix 5: Household questionnaire – with flooding

Appendix 6: Memo: Summary of Control Area Issues and Considerations

Appendix 7: Sample Size Considerations – Household Evaluation

Appendix 8: Water Quality Monitoring Protocol

Appendix 9: Business questionnaire

Appendix 10: Sentinel Surveillance Protocol

Appendix 1: Compact Program Logic

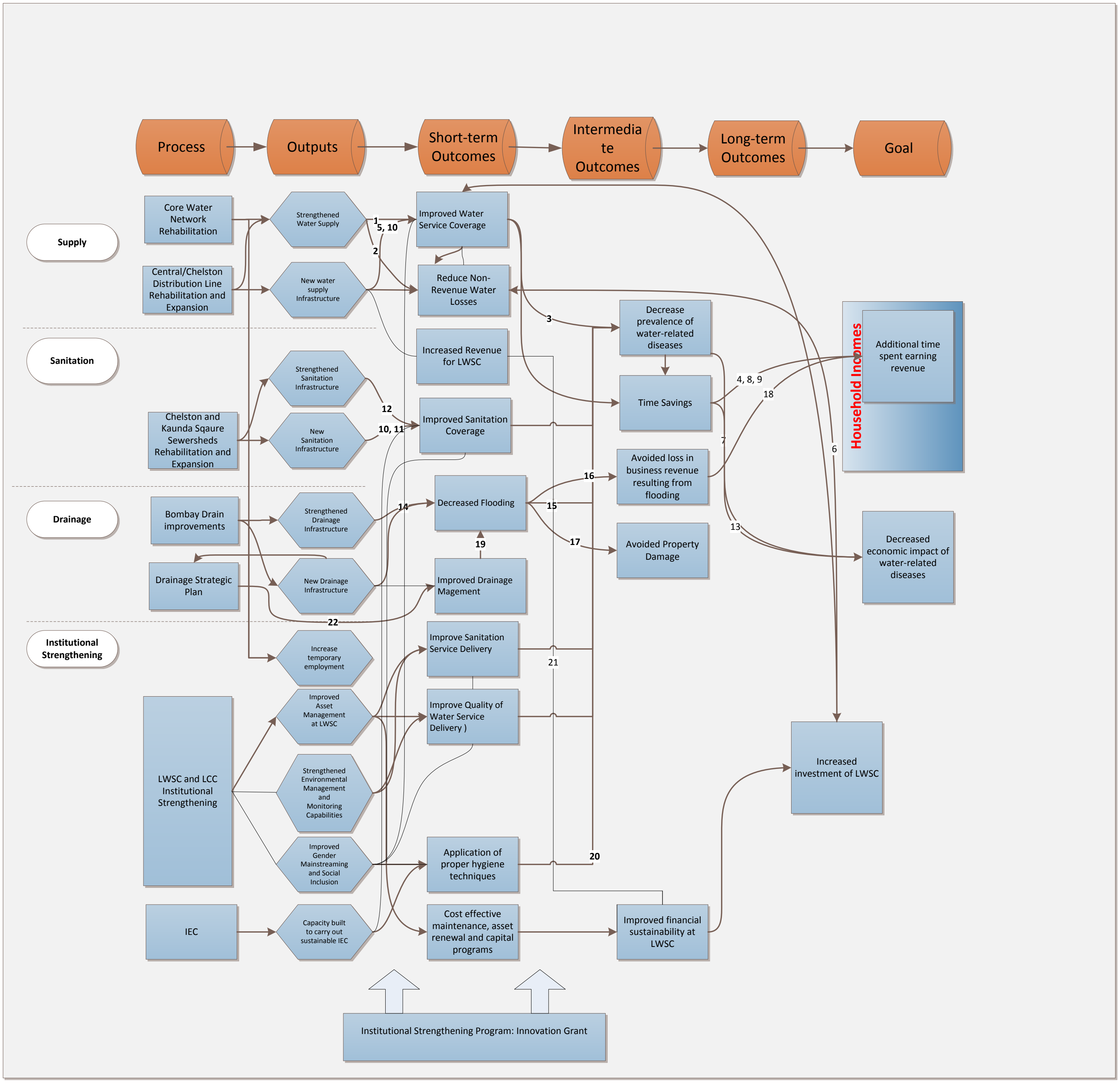
Logic Models of Compact Activities

The Water Supply Compact Activities will rehabilitate the Iolanda Water Treatment plant, extend the water distribution network to peri-urban areas with few household connections, rehabilitate poorly functioning water kiosks, construct new water kiosks, and meter household connections. The Sanitation Compact Activities will extend the sewerage network to a large peri-urban area (Mtendere) and rehabilitate the Kaunda Square Waste Stabilization Ponds. Both the Water Supply and Sanitation activities are expected to provide new infrastructure and rehabilitate existing infrastructure. These Compact activities are expected to lead to improved water coverage, improved sanitation coverage, a decrease in the prevalence of water-related diseases, time savings for households related to water collection, time savings related to illness and care-taking from the prevention of waterborne diseases, and an overall decrease in the economic impact of water-related diseases on Lusaka. Time savings are also expected to translate into additional time adults can spend earning revenue.

The Drainage Compact Activities will expand and pave the Bombay Drain, which runs through a busy commercial and residential area of Lusaka. The drainage activities are expected to create new drainage infrastructure and improve the existing infrastructure which MCC anticipates will lead to decreased flooding, minimized losses in business revenue from resulting floods, and avoided property damage.

Cross Cutting Activities such as Asset Management and Environmental Management; and Information, Education and Communication (IEC) activities are expected to complement Compact Activities by building capacity among residents to adopt good sanitation and hygiene practices and increasing the capacity of LWSC and LCC staff to manage and sustain the provided assets and upgraded infrastructure. These cross-cutting activities will not be evaluated by CDC and are outside the scope of this evaluation design report. The logic model displaying the inputs, outputs, short-term outcomes, intermediate outcomes, long-term outcomes, and the overall end goal of all Compact activities can be found in Figure 1.

Figure 1: Zambia Compact LWSSD Logic Model



Source: MCC and MCA Zambia

Antecedents and Intervening Variables

Table 1 outlines the expected benefits from the Lusaka Water Supply, Sanitation, and Drainage project. The logic parameters and antecedents closely follow the program logic. Listed in the third column are intervening variables that could threaten the expected benefits.

Table 1: Antecedents and Intervening Variables

Logical Parameter	Antecedents	Intervening Variables
Improved water service coverage and increased household water consumption	- Completed projects to create new and strengthen existing water supply	- Water availability (hours/day) - New water supplies are accessible - Residents choose to and can afford to hook-up to household water connections - Water bills are affordable
Increased sanitation coverage	- Completed projects to provide new sanitation infrastructure	- Residents choose to and can afford to hook-up to sewer system
Decreased flooding	- Completed projects to create new and strengthen existing drainage infrastructure	- New drainage capacity not sufficient - Increased rainfall due to varying climate - Efficacy of drainage systems impeded due to dumping trash in drains
Decreased prevalence of waterborne disease	- Improved water service coverage - Improved sanitation coverage - Decreased flooding	- Adequate household water consumption - Water quality - Proper use of household sanitation - Household hygiene behaviors (water storage/treatment, hand washing, food preparation, cleaning, bathing)
Time savings	- Improved water service coverage and access - Decreased flooding - Decrease prevalence of waterborne disease	- Insufficient water availability, number of new water kiosks, or number of new household connections - Inadequate garbage collection or maintenance of the drainage intervention - No change in prevalence of waterborne disease
Increase in household income	- Additional time spent earning revenue - Decreased economic impact of water-related disease	- Residents are able to and healthy enough to work - Residents choose to use time saved to work - Local labor market supply and demand - Cost of treatment for waterborne illness
Increase in business revenue	- Avoided loss in business revenue resulting from flooding	- Consumer choices - Economic environment of Lusaka

Critical Assumptions

Critical assumptions that could significantly jeopardize the effects of the project are the following.

1. Completion of interventions: If some or all of the planned interventions are not carried out the expected benefits would be significantly diminished. Specifically:
    a. Water: LP-1/LP-6/LS-1: If the Iolanda treatment plant is not properly rehabilitated to its expected capacity of 110,000 m^3/day and the primary distribution systems are not strengthened, the water supply to the city of Lusaka will not be adequate to meet demand. This may limit the effects of the new and restored water kiosks and the extended water supply network.
    b. Water: LS-2 and LS-3: If the infrastructure (pipes, kiosks, taps, etc.) required to complete this activity is not built, the estimated 152,256 beneficiaries to water supply expansion and 416,412 beneficiaries to water supply rehabilitation will not be impacted as expected, if at all.
    c. Sanitation: CSE-44: Expansion of Lusaka's sanitation infrastructure aims to facilitate household connections to flush toilets for 98,349 beneficiaries. However, if the proper sewerage network infrastructure is not created, in whole or in part, benefits attributable to sanitation will not be achieved.
    d. Flooding: Bombay and ZESCO Link Drains: If the new and improved drainage systems are not completed as expected, benefits attributed to better drainage, such as less flooding and less property damage, are unlikely to be achieved.
2. Households unable or unwilling to pay for connection fees and service fees for in-home taps and toilets: The logic assumes that eligible households will opt-in to have household water connections (LS-2, LS-3) and flush toilets (CSE-44) installed. However, households may choose not to opt-in if they are unable to pay the connection fee, or if they live in Ndeke-Vorna Valley, or Kwamwena and have already paid to construct a private borehole. Similarly, renters may not enjoy the benefits of in-home taps and toilets if landlords choose not to connect their properties due to the increased water bills. Further, if connected households are unable to pay service fees they may choose to use community kiosks and latrines rather than newly installed

household facilities. The expected impacts of the interventions will be significantly reduced if one or more of these prove to be true.

3. Fair rental practices: The logic assumes that landlords will not increase the rental price of properties with in-home taps and toilets to a point that prices out current tenants. If this occurs and tenants with a higher income move in, the impacts of the water supply and sanitation interventions may be diminished from the target beneficiary point of view.
4. Free or low-cost healthcare: One of the expected benefits of the project is decreased household expenditures for the treatment of waterborne illness. However, as Zambia has recently transitioned to a free, universal healthcare system, a decrease in waterborne illness may have little impact on the amount of money households spend on healthcare. However, from a societal perspective, the amount of money spent on curative health care (treatment) would decrease.
5. Allocation of time saved: The logic model also assumes that households will experience significant time savings for a number of reasons, including spending less time collecting water, less time caring for sick children, not missing work due to illness, not missing school, and spending less travel time commuting through Lusaka during flooding. The logic assumes that time savings will be used for additional revenue generating activities; however, individuals may choose to use this time in different ways including leisure and socializing.

Appendix 2: Project Summaries

WATER SUPPLY[a] - $83.3 million

Code	Compact Activities & Tasks	Communities & Populations Impacted	Estimated Number of Beneficiaries
LP-1 **(LP-1, LP-6 and LS-1)** **$106.38** **Admin** **$16.05**	***Rehabilitation of Iolanda Treatment Plant*** *[page 0-1]* 1. Rehabilitation of intake works at Kafue. 2. Rehabilitation of Iolanda treatment plant and pumps. 3. Rehabilitation of Chilanga booster pumping station. 4. Rehabilitation of raw and treated water transmission main. 5. Rehabilitation of 9 distribution centers. 6. Extension of the SCADA system.	Iolanda WTP to Stuart Park. Lusaka Water Works, Lumumba, High Court, Woodlands, Mass Media, Mtendere, Quarry, Chelston & Chawama.	**860,000** [Page 0-9] ******Infrastructure rehabilitation projected to impact all communities served by LWSC. (Page 4-1).*
LP-6	***Strengthening of Primary (backbone)Distribution System*** *[page 0-3]*	All communities supplied by LWSC	**860,000** [Page 0-9] ******Infrastructure rehabilitation projected to impact all communities served by LWSC. [Page 5-1]*
LS-2 **Total:** **$15.87** **Admin:** **$2.3**	***Distribution Network in Central Branch*** *[Page 0-5]* ***(increase water coverage)*** 1. Extension of secondary and tertiary networks into central branch District Metering Areas (DMA) specifically to Ng'ombe, SOS East and Chipata. 2. Supply and installation of consumer connections and water meters. 3. Construction of water kiosks (30).	**Ng'ombe -21,600 people** [Pages: 0-5; 2-11; 6-2; 6-6] 15 kiosks to supply 12,600 [Page 6-2] **SOS East - 5,808 people** [Pages: 0-5; 2-11; 6-3; 6-6] **Chipata – 35,090 people** [Pages: 0-5; 2-11; 6-4; 6-7] *(North & East Chipata- 2,500 household connections & 15 kiosks [Pages:6-4; 6-5])*	**318,565** (41,500 new consumers) [Page 0-9]
LS-3 **Total:** **$41.84** **Admin:** **$6.31**	***Distribution Network in Chelston Branch*** *[Page 0-6]* 1. Extension of secondary and tertiary networks into Chelston branch DMAs. 2. Supply and installation of consumer connections and water meters. 3. Construction of kiosks. 4. Drilling and equipping of 14 boreholes. ***5.*** Construction of 1 elevated and 1 ground reinforced concrete reservoirs.	**Mtendere – 52,844 people** [Pages: 0-6; 0-7; 7-1; 7-7] **Kamanga - 10,590 people** [Pages: 0-6; 0-7; 7-1; 7-7] **Kwamwena – 39,667 people** [Pages: 0-6; 0-7; 7-1; 7-8] **Ndeke-Vorna Valley-31,169 people** [Pages: 0-6; 0-7; 7-1; 7-8]	**250,000** (121,000 new consumers) [Page 0-9]

SANITATION[b] – Total: $48.58 million. Admin: $7.33 million

Code	Compact Activities & Tasks	Communities & Populations Impacted	Estimated Number of Beneficiaries
CSU-15	***Chelston Sewage Pumping Station*** *[Page 0-2]* 1. Provision of 2 new pumps designed to operate on a duty/standby basis with a capacity of 55 l/s at 27m total head. 2. Provision of two new 2,050m long force main in PE100 HDPE pipe, 250mm diameter PN10 pressure rated. 3. Improvements to the pumping station to raise wet well wall levels and the land levels within the station to prevent inundation of the station with flood waters. 4. Provision of a new 30m² operator's building to replace the existing structures which will be demolished to make way for raising of ground levels.	**Chelston**- Area between Great East Road and Palm Drive. [Page 3-3] High cost- **1,249 people** (227 households) [Page 3-4] **Medium cost- 3,806 people** (692 households) [Page 3-4]	**5,055**
CSE-44	***Sewer Expansion in Mtendere [Page 0-3]*** 1. New sewer network covering	Mtendere- **98,349 people** [Pages: 2-1; 4-1]	**98,349** **74 commercial properties**
CSU-4	***Kaunda Square Interceptor Upgrade*** *[Page 0-4]*	Kaunda Square	**Not available**
TU-5 & TE-3	***Kaunda Square Stabilization Ponds Upgrade & Expansion****[Pages: 0-5; 6-1] (Current capacity 18,000 household, but caters for 56,000; and not meeting effluent standards)* ***Rehabilitation, upgrading (TU-5)*** 1. Modification of existing structures where possible. 2. Demolition and rebuilding of the rest of existing structure. 3. Removal of vegetation. 4. Dredging of ponds. 5. Construction of new sludge drying beds. 6. Construction of new pond across the road. 7. Construction of utility building and guard house. 8. Erection of fence around the ponds. ***Expansion (TE-3) of dilapidated ponds*** 1. A floating sludge removal facility (to be shared with other ponds) *2.* Access roads to the ponds site and service road around the ponds.	Kaunda Square (low cost residential area) [Page 2-1] Mtendere- **156,000 people by 2015** [Page 6-3] Local farmers [Page 6-2]	

DRAINAGE[c] -

Code	Compact Activities & Tasks	Communities and Populations Impacted^	Estimated Number of Beneficiaries
Total: $80.37 million **Admin:** $12.13 million	***The Bombay Drain****[Pages: 2-10; 3-1]* 1. Segment 1 (11.6 km) 2. Segment 2 (5.2 km) 3. Segment 3 (2.2 km) 4. Segment 4 (2.6 km) 5. Segment 5 (2.1 km)	[Pages: 2-11; 2-12] Kamwala Kabwata Silwizya Independence Chaisa Nkoloma Libala Harry Mwaanga Nkumbula Ngwerere Lubwa Roma Raphael Chota Mpulungu	**188,005^** **[Page 2-12]** **Direct: 2,760 (DIPP 2011), 3,717 (2030) [Page 2-10]** **Indirect non-priority areas: 127,200 (DIPP 2011), 204,403 (2030) [Page 2-10]**
	The ZESCO Link Drain(1 km) *[Page 3-7]*	Kalambo road Cairo Road	

a: Information and numbers for water supply interventions drawn from Gauff Ingenieure: 90% Design Review Report – Water Supply, 2013.
b: Information and numbers for sanitation interventions drawn from Gauff Ingenieure: 90% Design Review Report – Sanitation, 2012.
c: Information and numbers for drainage interventions drawn from Gauff Ingenieure: 65% Design Report – Drainage, 2013.
^The list of communities affected and beneficiary estimates have been updated from that which originally appears in the Gauff Design Reports to reflect the de-scoping of the Lumumba Drain.

Miscellaneous: Drainage Study: $7.5 million

Innovation Fund: $10 million

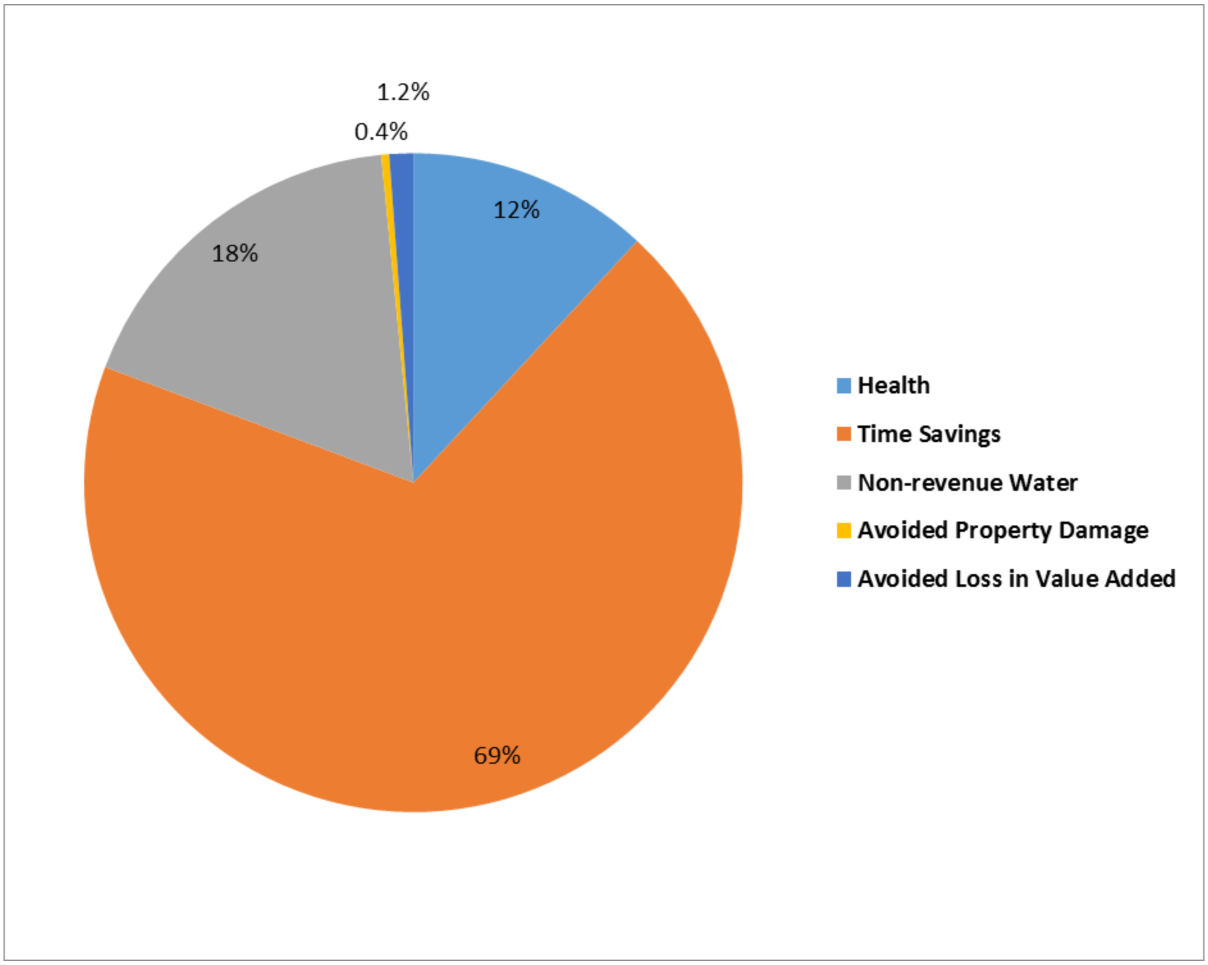
Overall Compact Total: $354.76 million

Appendix 3: Economic Rate of Return

MCC develops an Economic Rate of Return (ERR) to project the financial benefits of their Compacts. The expected economic impacts of the LWSSD Compact are derived from 5 benefit streams which are described below. See Figure 1 for a graphical representation of the contribution from each benefit stream.

- Health: Lower incidence of water- and sanitation-related diseases (e.g., diarrheal disease and acute respiratory infections) will decrease the time and years of life lost due to illness. The benefit stream of decreased illness is calculated by assigning a dollar value to the productive time saved.
- Time Savings: Time savings are expected from the water supply and drainage interventions in the form of less time spent collecting water and commuting (travel time) in Lusaka, respectively. This benefit stream is calculated by assigning a dollar value to time saved.
- Non-revenue Water: LWSC is expected to increase their income and profitability by decreasing the amount of non-revenue water in the system and increasing the number of legal customers with water meters.
- Avoided Property Damage: Decreased flooding is expected to translate into avoided property damage and repair costs among households situated in the floodplain of the Bombay drainage system.
- Avoided Loss in Value Added: Flooding can force businesses to close temporarily and can also limit customers' ability to shop at these businesses. Decreased flooding is expected to minimize these disruptions and increase the profitability of businesses located in the Bombay drain floodplain catchment area.

Figure 1: Projected Benefit Stream Contributions to LWSSD Compact's Economic Impact



Source: MCC: ERR, 2014

Appendix 4: Household Questionnaire – No Flooding

Impact Evaluation of Lusaka Water Supply, Sanitation, and Drainage Project

Survey Instrument

Water and Sanitation Evaluation – No Flooding

04/22/15 Version

Draft: Please, do not copy or circulate!!

Evaluation by CDC for Millennium Challenge Corporation

Household Identifiers

Today's date: _ _/_ _/ _ _ _ _ (Day/Month/Year) **Household Unique Identifier:** _____________

Township: ___________________________ **Interviewer's name:** ________________________

A. Household Demographics

ENUMERATOR: Ask to speak to the male or female head of the household. If the male or female head of household is not there, arrange to come back when one of them will be present.

1) **ENUMERATOR: Are you interviewing the male or female head of the household?**
____ Male (1) ____ Female (2)

2) **Has your family been living in this house for 2 or more months?**
____ Yes (1)
____ No (0) **End Survey**. **Thank respondent for their time.**
____ Don't Know (99) **End Survey**. **Thank respondent for their time.**

3) **Can you please tell me your age?**
____ Years ____ Don't Know (99) ____ Refused (77)

4) **How many years of schooling have you completed?**
____ Years ____ Don't Know (99)

5) **ENUMERATOR:** If you are interviewing the **male** head of the household **go to question 6.**
If you are interviewing the **female** head of the household **go to question 7.**

6) **How many years of schooling has the female head of household completed?**
____ Years
____ Don't Know (99)
____There is no female head of household (77)

7) **Do you own or rent this house?**
____ Own (1) ____ Rent (2) **Go to Q9** ____ Other, specify(88):_____________

8) **Do you have a title or deed?**
____ Yes (1) ____ No (0) ____ Don't Know (99)

9) **Do you have any tenants in this compound? That is, are you the landlord of a building in this compound?**
____ Yes (1) ____ No (0) ____ Don't Know (99)

10) Can you tell me how long your family has lived in this house or the year that you moved into this house? (*If less than one year specify in months, otherwise answer in years. Fractions are ok e.g., 4.5 years*)

______ Years in house ***OR*** _______Months in house
______ Year moved in
______ Don't Know (99)

11) How many rooms are in the house, excluding the kitchen or bathroom?

______ rooms

12) How many people currently live in this house? I am only talking about people who normally sleep and eat at the house, not visitors or people staying temporarily.

______ people

13) I would like to ask you to tell me a few things about each person living the house, starting with yourself. (*Complete the table below for all persons living in your household. Fill out one row per person before moving to next household member. Don't count visitors.)*

ID	Place 'X' for Head of House	Initials	Year OR date of birth (*If unknown record age)*	Sex: M/F	In School: Y/N	If less than or equal to 5 years of age:			
						A	B	C	D
						Is the child's vaccination card available? Y/N *(If Yes go to B; If No go to D)*	Record the number of rotavirus vaccination doses from the card: 0/1/2/>2/DK (*Go to C*)	Record the date of the last rotavirus vaccine from the card (MM/ YYYY) (*Go to Q 14*)	If no card, how many rotavirus vaccinations do you remember him or her receiving? 0/1/2/>2/DK
1								___/_____	
2								___/_____	
3								___/_____	
4								___/_____	
5								___/_____	
6								___/_____	
7								___/_____	
8								___/_____	
9								___/_____	
10								___/_____	
11								___/_____	
12								___/_____	
13								___/_____	
14								___/_____	
15								___/_____	

B. Sickness and Associated Costs

Now I would like to ask you about people in your household who may have been sick in the last 7 days

1. **Has anyone in your house been sick with diarrhea or flu-like illness in the past 7 days? By flu-like illness I mean having a fever and a cough or a sore throat. (*Utilize calendar as a memory aid if needed*)**
   ____ Yes (1)
   ____ No (0) **Go to Section D**
   ____ Don't know (99) **Go to Section D**

2. **How many members of your household were sick in the past 7 days?**
   ____ Ill household members
   ____ Don't know (99)

3. **Now I would like to ask you more about the illness they had (*Use one column per person. Fill out each column all the way to the bottom of the table before starting a column for the next ill person)***

	Sick Household Members				
Q		Initials & Age (e.g., MT 29)			
A	Did _(name)_ have….? (*circle a response for EACH symptom*)				
i	**Diarrhea** (*3+ loose or watery stools in 24 hours*)	Y N DK	Y N DK	Y N DK	Y N DK
ii	**Fever** (*at least 38°C or parental perception*)	Y N DK	Y N DK	Y N DK	Y N DK
iii	**Cough**	Y N DK	Y N DK	Y N DK	Y N DK
iv	**Sore Throat**	Y N DK	Y N DK	Y N DK	Y N DK
B	**If sick person had diarrhea answer questions in section B**				
i	When did diarrhea begin? (*Enter date as DD/MM/YYYY)*	__/__/__	__/__/__	__/__/__	__/__/_
ii	Number of days with diarrhea? (*If a range, take average and round up*)	___Days	___Days	___Days	__Days
iii	Is diarrhea ongoing?	Y N DK	Y N DK	Y N DK	Y N DK
iv	Maximum number of loose stools in a 24 hour period *(If exact number unknown, ask for and record one of the following ranges: "3 to 5" "6 to 7" or "too numerous to count (TNTC)")*				
v	Was there blood in the stool?	Y N DK	Y N DK	Y N DK	Y N DK
C	**If sick person had fever AND cough or sore throat answer questions in section C**				
i	When did the illness begin? (*Enter date as DD/MM/YYYY*)	__/__/__	__/__/__	__/__/__	__/__/_
ii	Number of days ill? (*If a range, take average and round up*)	___Days	___Days	___Days	__Days
iii	Is illness ongoing?	Y N DK	Y N DK	Y N DK	Y N DK
D	**Activities missed due to illness (*ask for all types of illness*)**				
i	Miss work because they were sick? (*If no go to Dii)*	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A

	Number of days missed (*If a range, take average and round up*)	___Days	___Days	___Days	___Days
	Did he/she lose wages/earnings for the days they took time off for illness? (*If no go to Dii*)	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	If yes, amount of wages lost **per day** (ZMW)				
ii	Miss school because they were sick? (*if no go to Diii)*	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	Number of days missed	___Days	___Days	___Days	___Days
iii	Have to skip household chores/work like fetching water, cooking, cleaning, or caring for kids (*if no go to Q Ei)*	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	Number of days skipped	___Days	___Days	___Days	___Days
E	**Treatment and Cost (*ask for all types of illness*)**				
i	Did the sick person get treatment for the illness, such as visiting a clinic, hospital, pharmacist, or healer, taking medication, or having lab tests done? (*If no, go to Q Fi)*	Y N DK	Y N DK	Y N DK	Y N DK
ii	Did your household spend any money on the treatment for this illness? Treatment includes any money you spent on clinic or doctor visits, medications, lab tests, and hospitalizations (*If no go to Q Eiii)*	Y N DK	Y N DK	Y N DK	Y N DK
	If yes, how much did you spend? (ZMW) (*Enter a number or DK [don't know])*				
iii	Did you have to spend any money on transportation for this person's illness? This includes going to or from the clinic, pharmacy, hospital, etc. (*If no, go to Q Fi)*	Y N DK	Y N DK	Y N DK	Y N DK
	If yes, how much did you spend on transportation? (ZMW) (*Enter a number or DK [don't know])*				
F	**Time Use: (*ask for all types of illness*)**				
i	If _(name)_ visited a clinic or health center, how many times did they go? (*Enter a number or DK [don't know]. Skip this question and go to Q Fii if did not visit clinic or Health Center)*				
	On average, how long did it take you to see the doctor or nurse, including round-trip travel time? (*Enter a number or DK [don't know]. Specify hours or minutes*)				
ii	Did_(name)_ need to be hospitalized for this illness? (*Hospitalized means spending at least one night in the hospital. Go to Section C if No or DK [Don't Know])*	Y N DK	Y N DK	Y N DK	Y N DK
	How many days were they hospitalized? (*Enter a number or DK [don't know])*				

C. Caretaker Time Loss

1. **Did anyone stay home from work or did you have to pay someone to take care of ___ (sick household member)?**
   ____ Yes (1)
   ____ No (0) **Go to Section D**

2. **Did anyone stay home to care for the sick person, other than the person who was sick?**

	People who stayed home to care for sick household members			
Q		Initials and Age (e.g., MT 29)		
A	Does this person (the caretaker) live in the house? *(Circle one. If yes, go to Q B; if no go to Q Ai)*	Y N DK	Y N DK	Y N DK
i	What is their gender?	M F	M F	M F
B	How many days did they stay at the home to take care of __(name) __?	___Days	___Days	__Days
C	Did they get paid to take care of __(name)__? *(Circle one)*	Y N DK	Y N DK	Y N DK
i	How much were they paid for caregiving, **in total?** (ZMW) (*Enter a number or DK [don't know])*			
D	Did they lose wages or earnings for the days they were at home to take care of __(name)__? *(Circle one. If no, go to Section D)*	Y N DK	Y N DK	Y N DK
i	How much did they lose **in total?** (ZMW) (*Enter a number or DK [don't know])*			

D. Water Collection

Now I am going to ask you questions about the water your household uses.

1) During the past week, where did you get your DRINKING WATER? What was your main source of drinking water? (*Select the best answer. Observe source if respondent is cannot describe it or you are unsure.)*

____ Communal tap/Water kiosk (1)
____ Protected well/Borehole (2)
____ Unprotected well/Borehole (3)
____ Piped water inside house (4)
____ Piped water outside house within stand/plot (5)
____ Piped water from neighbor (6)
____ Surface water (stream/pond) (7)
____ Other, specify (88):________
____ Don't know (99)
____ Refused (77)

2) In the past week, how many days was water available from this source?

______ Days
______ Don't know (99)

3) On average, how many hours per day was water available from this source?

______ Hours
______ Don't know (99)

4) During the past week did you get DRINKING WATER from any other source(s)?

____ Yes (1)
____ No (0) ***go to Q6***
____ Don't know (99) ***go to Q6***

5) What was/were the other source(s)? (*DO NOT read answers. Select all that are stated)*.

____ Communal tap/Water kiosk
____ Protected well/Borehole
____ Unprotected well/Borehole
____ Piped water inside house
____ Piped water outside house within stand/plot
____ Piped water from neighbor
____ Surface water (stream/pond)
____ Other, specify:________
____ Don't know
____ Refused

6) **How many days in the past week was your household unable to get ENOUGH WATER (that is water for ALL USES, including water for drinking, bathing, cleaning, and so on)?**
   ______ Days ***If response is "0" go to Q9***
   ______ Don't know (99)

7) **How many days in the past week was your household unable to get enough water for DRINKING ONLY?**
   ______ Days ***If response is "0" go to Q9***
   ______ Don't know (99)

8) **Why couldn't your household get enough water for DRINKING? (*DO NOT read responses. Select all that apply.*)**
   ____ Water is not available at all times during day
   ____ Water source is not open all days of the week
   ____ Water kiosk is broken or not working
   ____ Water queue is too long
   ____ Takes too long to collect water
   ____ Water source is too far from home
   ____ Costs too much/don't have enough money
   ____ Don't have a reliable person to fetch water
   ____ I have difficulty transporting enough water
   ____ Water pressure is too low
   ____ Lack storage facility
   ____ Other, specify __________

9) **Now I would like to ask about how much your household spends on water.**

10) **ENUMERATOR: Does the household collect water from a tap in their house or on their plot?**
   ____ Yes (1)
   ____ No (0) ***go to Q16***
   ____ Don't know (99) ***go to Q16***

11) **Did you pay an initial connection fee for your piped water?**
   ____ Yes (1)
   ____ No (2) **Go to Q14**
   ____ Don't know (99) **Go to Q14**

12) **What was the cost of the connection fee, in cash, for your household?**
   ____ ZMW
   ____ Don't know (99)

13) **Did your household receive financial assistance for the initial connection fee?**
   ____ Yes (1)
   ____ No (2)
   ____ Don't know (99)

14) In a typical month, how much does your household spend on water from the tap in your home or plot?

____ ZMW

____ Don't Know (99)

15) Is the tap in your home or your plot metered by the water company?

____ Yes (1)

____ No (0)

____ Don't know (99)

16) In a typical day, does your household buy any water from water kiosks or communal taps?

____ Yes (1)

____ No (0) ***go to Q18***

____ Don't know (99) ***go to Q18***

17) How much does your household spend on kiosk water in a typical day or week?

____ ZMW per**: day week** (circle one)________

____ Don't Know (99)

18) In a typical day does your household spend any money on bottled or packaged water?

____ Yes (1)

____ No (0) ***go to Q20***

____ Don't know (99) ***go to Q20***

19) How much does your spend on bottled water in a typical day?

____ ZMW

____ Don't Know (99)

20) In a typical day, does your household spend any money on other types of water, like buying water from a neighbor?

____ Yes (1), specify:______________

____ No (0) ***go to Q22***

____ Don't know (99) ***go to Q22***

21) How much does your household spend on this water in a typical day?

____ ZMW ____ Don't Know (99)

22) **How much water does your household use in a typical day, measured in buckets and liters? I am asking about ALL of the water your household uses in a day, whether for drinking, bathing, cleaning or something else. This water could come from ANYWHERE, including taps in your home or plot, water kiosks, communal taps, wells, boreholes, neighbors, etc. (*If household collects water in buckets of multiple sizes, list the number and capacity of each that is used in Bucket A, B, C.)***

Bucket A: Capacity of 1 bucket (liters)__________ Don't Know (99) _____
Number of buckets_______________ Don't Know (99) _____

Bucket B: Capacity of 1 bucket (liters)__________ Don't Know (99) _____
Number of buckets_______________ Don't Know (99) _____

Bucket C: Capacity of 1 bucket (liters)__________ Don't Know (99) _____
Number of buckets_______________ Don't Know (99) _____

____ Don't know

23) **Next I'd like to know how much time people in your house spend collecting water. I'd like to know who the main water collectors are, that is, people who collect water at least twice per week? And, I'd like to know how much time they spend collecting water each day. *(Please fill out the following table for the main water collectors. We want to know how much time they spend collecting water from all water sources. If the household does not spend ANY time collecting water, enter "0"in the first box)***

Main household water collectors					
Q		**Initials & Age (e.g., MT 29)**			
A	**Time in minutes spent collecting water per day. This includes time spent walking, waiting, filling buckets, and bringing them back to the house**				
B	**Number of days person collects water each week**				

E. Water Storage and Treatment

Now I would like to ask you about how you keep drinking water in your house

1) ENUMERATOR: Does the household collect water from a water kiosk or communal tap?

____ Yes (1)
____ No (0) ***go to Q4***
____ Don't know (99) ***go to Q4***

2) When you collect water from a kiosk or communal tap do the kiosk operators treat the water or do something to it like add bleach when you collect it?

____ Yes (1)
____ Sometimes (2)
____ No (0) ***go to Q4***
____ Don't know (99) ***go to Q4***
____ Do not collect water from a kiosk (98) ***go to Q4***

3) What do the kiosk operators do to the water you collect?

____ Pour bleach into water (1)
____ Put a tablet into the water (2)
____ Other (88), specify:__________
____ Don't know (99)

4) Do you normally treat or do something to your drinking water, such as adding chlorine, boiling it, or filtering it?

____ Yes (1)
____ No (0)
____ Don't know (99)

5) Did you treat or do something to the drinking water in your home today, such as adding chlorine, boiling it, or filtering it?

____ Yes (1)
____ No (0) **Go to Q8**
____ Don't know (99) **Go to Q8**

6) What did you do to your water? ***(DO NOT read answers. Mark all that apply)***

____ Boil water (0/1)
____ Bleach/chlorine (0/1)
____ Filter water (0/1)
____ Other (0/1) Specify: _________

7) **Please show me the boiling pot, tablet, filter, or other item that you used.** ***(Enumerator: Confirm presence of pot, tablet, filter, or other item.)***

____ Item present (1)
____ Item not present (0)

8) **Please show me the containers you mainly put your <u>drinking</u> water in inside your house? (*OBSERVE and select the main container type(s) the household identifies as using.)***

____ Buckets (1)
____ Plastic jerrycan (2)
____ Barrel (3)
____ Container with screw top (e.g., plastic bottle) (4)
____ Other (88), specify:_________
____ Do not use a container (5) **Go to Q11**
____ Unable to observe (6) **Go to Q10**
____ Don't know (99) **Go to Q10**
____ Refused (77) **Go to Q10**

9) ***OBSERVE - How many of the water storage containers are covered?***

____ All (1)
____ Some (2)
____ None (0)
____ Unable to observe (3)

10) **How do you get water from this container to drink? Can you please show me how? (*OBSERVE and select what the respondent does)***

____ Dipping (w/ ladle, cup, or hand) (1)
____ Pouring (2)
____ Through a spigot or tap (3)
____ Other(88), specify:_________
____ Don't know (99)
____ Refused to show (77)

11) **Test drinking water and record result. Explain to the respondent what you are doing. Make sure you rinse/clean the column with water before you test.**

______ Positive (yellow) (1)
______ Negative (clear) (0)
______ No water in the container/No water available for testing (9)

F. Sanitation Module

1) **Now we are going to talk about sanitation and toilets. Can you show me the toilet facility your house NORMALLY uses?** ***OBSERVE: What type of toilet is it? If respondent will not show you, ask them to describe it. Choose the best answer.***

____ Pit latrine with slab (1) **Go to Q3**
____ Pit latrine without slab (2) **Go to Q3**
____ Ventilated improved pit latrine (VIP) (3) **Go to Q3**
____ Bucket/chamber pot (4) **Go to Q12**
____ Flush toilet (5) **Go to Q2**
____ No facilities/bushes/plastic bags (6) **Go to Q12**
____ Other (88), specify **Go to Q3**
____ Don't know (99) **Go to Q9**
____ Refused (77) **Go to Q9**

2) **Where is the waste flushed to?**
____ Piped sewer system (1)
____ Septic tank (2)
____ Latrine hole (3)
____ Some other place (i.e., river, drainage ditch) (4)
____ Other (88), specify ___________
____ Don't know (99)

3) **Beside this toilet, do you have another toilet facility within or outside your home?**
____ Yes (1)
____ No (2) **If Household has Flush Toilet Go to Q6; Otherwise Go to Q9**
____ Don't know (99) **Go to Q9**

4) **Can you show me this other toilet facility?** ***OBSERVE: What type of toilet is it? If respondent will not show you, ask them to describe it. Choose the best answer.***

____ Pit latrine with slab (1) **Go to Q9**
____ Pit latrine without slab (2) **Go to Q9**
____ Ventilated improved pit latrine (VIP) (3) **Go to Q9**
____ Bucket/chamber pot (4) **Go to Q12**
____ Flush toilet (5) **Go to Q5**
____ No facilities/bushes/plastic bags (6) **Go to Q12**
____ Other (88), specify _________ **Go to Q9**
____ Don't know (99) **Go to Q9**
____ Refused (77) **Go to Q9**

5) Where is the waste flushed to?

____ Piped sewer system (1)
____ Septic tank (2)
____ Latrine hole (3)
____ Some other place (i.e., river, drainage ditch) (4)
____ Other (88), specify __________
____ Don't know (99)

6) Did you have to pay for the toilet or to connect the toilet to the sewer?

____ Yes (1)
____ No (2) **Go to Q9**
____ Don't know (99) **Go to Q9**

7) How much did you pay, in cash?

____ ZMW
____ Don't know (99)

8) Did your household receive financial assistance to help pay for this?

____ Yes (1)
____ No (2)
____ Don't know (99)

9) Is your toilet or latrine just for this household or shared with other households?

____ Just this household (1) **Go to Q12**
____ Shared (2)
____ Don't know (99) **Go to Q12**
____ Refused (77) **Go to Q12**

10) How many households share it, not counting your own?

Number of households __________ Don't know (99) _____

11) How many people share it, including those in your household?

Number of people __________ Don't know (99) _____

12) How do you dispose of the feces of young children that do not use the toilet or latrine? (*Select all that apply. Read options if interviewee does not understand the question)*

____ Chamber rinsed into latrine (1)
____ Chamber rinsed into drain/ditch (2)
____ Newspaper/plastic bag with feces thrown into latrine (3)
____ Newspaper/plastic bag with feces thrown into garbage (4)
____ Nothing/left where it is (5)
____ Buried (6)
____ Moved off of plot (7)

____ Do not have young children (8)
____ Other (88), specify ________________
____ Don't know (99)

13) ***If household has a pit latrine or a flush toilet go to Q14. Otherwise go to Q19***

14) **Do you feel that your toilet is safe to use at night?**
____ Yes (1) **Go to Q18**
____ No (0)
____ Don't know (99) **Go to Q16**
____ Refused (77) **Go to Q16**

15) **Why is it not safe to use at night?**

____ Fear of attack (1)
____ May step in refuse (2)
____ Fear of falling in (3)
____ Other (88), specify ________
____ Don't know (99)
____ Refused (77)

16) **What do women use at night for the toilet? *(Mark all that apply.)***

____ Same toilet as during day (1)
____ Wait to use toilet until morning (2)
____ Chamber pot or bucket (3)
____ Plastic bag (4)
____ Other (88), specify ________
____ Don't know (99)
____ Refused (77)

17) **What do children under age 12 use at night for the toilet? *(Mark all that apply.)***

____ Same toilet as during day (1)
____ Wait to use toilet until morning (2)
____ Chamber pot or bucket (3)
____ Plastic bag (4)
____ Other (88), specify ________
____ Don't know (99)
____ Refused (77)
____ N/A (00)

18) In addition to human waste, do you dispose of anything else in your toilet? I will read you a short list. (*Read all options.)*

Item	Dispose in toilet or latrine? Yes = 1; No = 0; Don't know = 2; Refused = 3
Toilet Paper	
Newspaper	
Sanitary Pads	
Garbage	
Nappies/Diapers	
Other, specify:____________	

19) *OBSERVE – Are there feces (human or animal) visible in the yard/plot?*

____ Yes (1)
____ No (0)
____ Not evaluable (3)

G. Hygiene Module

1) When do you usually wash your hands? (C*ontinue to prompt "ANY OTHER TIMES?" Select all that apply.)*

____ Before eating
____ After cleaning child who defecated
____ After disposing the chamber
____ After handling trash
____ After contact with animals
____ Other, specify_____________
____ Before cooking/preparing baby food
____ After using toilet
____ Before you nurse
____ After working
____ Never ***Go to Section H***

2) What do you usually wash your hands with?

____ Water only (1) ***Go to Section H***
____ Water and soap (2) ***Go to Q3***
____ Water and something else (3), specify:________________ ***Go to Section H***
____ Don't know (99) ***Go to Section H***
____ Refuse (77) ***Go to Section H***

3) Please show me the soap that you use. *(Enumerator: Confirm presence of soap.)*

____ Soap present (1)
____ Soap not present (0)

H. Household Garbage Disposal

1) What are the ways that you dispose of garbage? (*Select all that apply.)*

____ Garbage collected from house **go to Q2**
____ Burn
____ Drainage ditch
____ Put in latrine/toilet
____ Don't Know
____ Bury/pit
____ Roadside dump
____ Garbage bay/Council bins
____ Other, specify _________
____ Refused

2) Who collects your garbage? (*Mark the best answer.)*

____ LCC/the city (1)
____ Private Company or community based enterprise (2)
____ Hired individuals (3)
____ Other (88), specify ________
____ Don't know (99)
____ Refused (77)

3) How much do you pay per month, in cash?

____ ZMW
____ Don't know (99)

I. Time Use and Expenditures

Now I would like to ask some questions about working, looking for work, and household expenditures during the last month.

1. **I will start by asking you about time spent working and looking for work in household members age 18 and older.** ***(Fill out a column in this table for each member of the household who is 18 or older. Answer all questions for one household member before moving to the next.)***

	Adult Household Members				
Q	**In the last month did _(name)_:**	**Initials and Age (e.g., MT 29)**			
A	**Are you/are they doing any activities where you/they earned money? This includes things like working for a wage, doing piecework, running a shop, or selling things on the road. (*Circle one. If No go to B)***	Y N DK	Y N DK	Y N DK	Y N DK
i	Days worked per week, on average				
ii	Hours worked per day, on average				
B	**Are you/are they looking for work? (*Circle one. If no, got to question 2)***	Y N DK	Y N DK	Y N DK	Y N DK
i	Days spent looking for work per week, on average				
ii	Hours spent looking for work per day, on average				

Expenditures:

2. Now I would like to ask you about different things your household has spent money on. Focusing on the last 7 days, has your household purchased any following <u>food items</u>?

Consumption Items	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	If yes, how much was spent (ZMW)?	If amount spent not known, how much was purchased?	Notes
Cereals and grains	**5-1**				
Mealie meal (kg)	i				
Bread (loaf/buns)	ii				
Rice (kg)	iii				
Other (e.g., flour, maize, noodles, sampo), Specify:	iv				
Meats, Eggs, and Fish	**5-2**				
Kapenta (kg)	i				
Other fish (any) (kg)	ii				
Eggs (dozen)	iii				
Poultry (kg)	iv				
Other (e.g., beef, pork, sausage), Specify:	v				
Vegetables	**5-3**				
Tomato (kg)	i				
Onion (kg)	ii				
Green vegetables (kg)	iii				
Other, Specify (kg):	iv				
Fruits/Local fruits	**5-4**				
All (kg)	i				
Sugar, Salt, oil and Spices	**5-5**				
Cooking oil (liter)	i				
Sugar (kg)	ii				
Salt (pack)	iii				
Other, Specify:	iv				
Dairy Products	**5-6**				
Milk (fresh, powdered)	i				
Butter/Margarine (kg)	ii				
Other (e.g., yogurt, cremora), Specify:	iii				
Pulses/Legumes	**5-7**				
Dry beans (kg)	i				
Ground nuts/Peanuts (kg)	ii				
Other (e.g., soya chunks, soybeans), Specify:	iii				

Beverages	5-8				
Tea, coffee (pack)	i				
Soft drinks/fruit juice (liter)	ii				
Alcohol (liter)	iii				

3. **Have you or any members of your household had any expenses for the following <u>non-food items</u> during past month? I will read you a list.**

	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	If Yes, how much did you spend in a month? (ZMW)
Non-food items	6-1		
Electricity	i		
Rent or mortgage	ii		
Cell phone minutes/bill (for the WHOLE household)	iii		
Public transport – Taxi, Bus, Minibus	iv		
Personal products such as soap, shampoo, razor blades, toothbrush and tooth paste, or cosmetics and skin cream (*Read all options)*	v		
Hair braiding or hair care	vi		
Clothing	vii		
Charcoal/ firewood /kerosene	viii		
Cigarettes/tobacco	ix		
Tithe/Offering	x		

4. **Has your household had any expenses for the following <u>healthcare items</u> during past month?**

Healthcare Expenses	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Specify the amount spent (ZMW) and a time period if 1 month total not known
Doctor/clinic/health center visit fees	i		
Medications: All (e.g., from pharmacy/chemist or drugstore [self-prescribed])	ii		
Other, specify:	iii		

5. **Has your household had any education related expenses in the past year? This includes things like tuition, daily fees, uniforms, school supplies, or transportation**

____ Yes (1)

____ No (0) **Go to Q7**

____ Don't know (99) **Go to Q7**

____ Refused (77) **Go to Q7**

6. **How many household members are in school?** ***(Enumerator: check this response matches question A13)***

   ______

   If "0" go to Q8

7. **I will now start asking you about the money your household may have spent on household members in school. (*Use one section per household member. Fill out each section for all the education expenses before starting a new section for the next household member)***

Q	Household School-attendee 1			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	No. terms per year	Kwacha (ZMW) per term
7.a.i	Did your household spend money on tuition for this person in the last year?			
7.a.ii	During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Amount spent (ZMW) per day	
7.a.ii.A	Daily school fees			
7.a.ii.B	Transport (e.g., minibus, petrol)			
7.a.iii	During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)	
7.a.iii.A	Uniform/Shoes			
7.a.iii.B	School supplies like stationaries or textbooks			
7.a.iii.C	Other, specify:			

Q	Household School-attendee 2			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	No. terms per year	Kwacha (ZMW) per term
7.b.i	Did your household spend money on tuition for this person in the last year?			
7.b.ii	During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Amount spent (ZMW) per day	
7.b.ii.A	Daily school fees			
7.b.ii.B	Transport (e.g., minibus, petrol)			
7.b.iii	During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)	

7.b.iii.A	Uniform/Shoes			
7.b.iii.B	School supplies like stationaries or textbooks			
7.b.iii.C	Other, specify:			
Q	**Household School-attendee 3**			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	**No. terms per year**	**Kwacha (ZMW) per term**
7.c.i	**Did your household spend money on tuition for this person in the last year?**			
7.c.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) per day**	
7.c.ii.A	Daily school fees			
7.c.ii.B	Transport (e.g., minibus, petrol)			
7.c.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.c.iii.A	Uniform/Shoes			
7.c.iii.B	School supplies like stationaries or textbooks			
7.c.iii.C	Other, specify:			
Q	**Household School-attendee 4**			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	**No. terms per year**	**Kwacha (ZMW) per term**
7.d.i	**Did your household spend money on tuition for this person in the last year?**			
7.d.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) per day**	
7.d.ii.A	Daily school fees			
7.d.ii.B	Transport (e.g., minibus, petrol)			
7.d.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.d.iii.A	Uniform/Shoes			
7.d.iii.B	School supplies like stationaries or textbooks			

7.d.iii.C	Other, specify:			
Q	**Household School-attendee 5**			
		No = 0 **Yes = 1** **Don't Know = 2** **Refused = 3**	**No. terms per year**	**Kwacha (ZMW) per term**
7.e.i	**Did your household spend money on tuition for this person in the last year?**			
7.e.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0** **Yes = 1** **Don't Know = 2** **Refused = 3**	**Amount spent (ZMW) per day**	
7.e.ii.A	Daily school fees			
7.e.ii.B	Transport (e.g., minibus, petrol)			
7.e.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0** **Yes = 1** **Don't Know = 2** **Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.e.iii.A	Uniform/Shoes			
7.e.iii.B	School supplies like stationaries or textbooks			
7.e.iii.C	Other, specify:			

8. **Does your household have any of the following durable goods?**

	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Purchased within past two years? No = 0 Yes = 1 Don't Know = 2 Refused = 3	If yes, how much did you spend on it? (ZMW)
Durable goods	8-1			
Cell phones	i			
Radio	ii			
Refrigerator/Freezer	iii			
Television	iv			
Cooker	v			
Bicycle	vi			
Car	vii			
Sofa	viii			
DVD Player	ix			
Computer	x			

9. What is the MAIN type of fuel used for cooking in your household? ***(Choose the best answer)***

____ Charcoal (1)
____ Electricity (2) ***Go to Section J***
____ Wood (3)
____ Paraffin (4)
____ Other (88), specify _________
____ Don't know (99)
____ Refused (77)

10. Is there electricity in your house?

____ Yes (1)
____ No (0)
____ Don't know (99)

J. Observations

Thank you very much for taking the time to speak with me and answering our questions. Now I would like to observe a few things about your house and then I will be finished with the interview

1) ***OBSERVE - What type of roofing does this house have? (Select all that apply)***

____ Metal/Iron sheets (1)
____ Asbestos (2)
____ Wood planks (3)
____ Ceramic tiles/Harvey tiles (4)
____ Cardboard (5)
____ Wood (6)
____ Cement (7)
____ Roofing shingles (8)
____ Mud tiles (9)
____ Other (88), specify _________________
____ Don't know (99)

2) ***OBSERVE - What is the flooring material? (Select all that apply)***

____ Concrete (1)
____ Cement (2)
____ Brick (3)
____ Tiles (4)
____ Mud (5)
____ Wood (not wooden tiles) (6)
____ Other (88), specify _________________
____ Don't know (99)

3) ***OBSERVE - What is the material used for the walls? (Select all that apply)***

____ Concrete blocks/slab (1)
____ Cement blocks (2)
____ Compressed cement bricks (3)
____ Burnt bricks (4)
____ Mud bricks (5)
____ Compressed mud (6)
____ Iron sheets (7)
____ Asbestos/hardwood/wood (8)
____ Other (88), specify _________________
____ Don't know (99)

Appendix 5: Household Questionnaire – With Flooding

Impact Evaluation of Lusaka Water Supply, Sanitation, and Drainage Project

Survey Instrument

Drainage Evaluation; Brief Water and Sanitation Evaluation

04/22/15 Version

Draft: Please, do not copy or circulate!!

CENTERS FOR DISEASE CONTROL AND PREVENTION

Evaluation by CDC for Millennium Challenge Corporation

MILLENNIUM CHALLENGE CORPORATION
MCC
UNITED STATES OF AMERICA

Household Identifiers

Today's date: _ _ /_ _ / _ _ _ _ (Day/Month/Year) **Household Unique Identifier:** _____________

Township: ___________________________ **Interviewer's name:** ________________________

A. Household Demographics

ENUMERATOR: Ask to speak to the male or female head of the household. If the male or female head of household is not there, arrange to come back when one of them will be present.

1) **ENUMERATOR: Are you interviewing the male or female head of the household?**
____ Male (1) ____ Female (2)

2) **Has your family been living in this house for 2 or more months?**
____ Yes (1)
____ No (0) **End Survey**. **Thank respondent for their time.**
____ Don't Know (99) **End Survey**. **Thank respondent for their time.**

3) **Can you please tell me your age?**
____ Years ____ Don't Know (99) ____ Refused (77)

4) **How many years of schooling have you completed?**
____ Years ____ Don't Know (99)

5) **ENUMERATOR:** If you are interviewing the **male** head of the household **go to question 6.**
If you are interviewing the **female** head of the household **go to question 7.**

6) **How many years of schooling has the female head of household completed?**
____ Years
____ Don't Know (99)
____There is no female head of household (77)

7) **Do you own or rent this house?**
____ Own (1) ____ Rent (2) **Go to Q9** ____ Other, specify(88):____________

8) **Do you have a title or deed?**
____ Yes (1) ____ No (0) ____ Don't Know (99)

9) **Do you have any tenants in this compound? That is, are you the landlord of a building in this compound?**
____ Yes (1) ____ No (0) ____ Don't Know (99)

10) Can you tell me how long your family has lived in this house or the year that you moved into this house? (*If less than one year specify in months, otherwise answer in years. Fractions are ok e.g., 4.5 years*)

______ Years in house ***OR*** _______Months in house
______ Year moved in
______ Don't Know (99)

11) How many rooms are in the house, excluding the kitchen or bathroom?

______ rooms

12) How many people currently live in this house? I am only talking about people who normally sleep and eat at the house, not visitors or people staying temporarily.

______ people

13) I would like to ask you to tell me a few things about each person living the house, starting with yourself. (*Complete the table below for all persons living in your household. Fill out one row per person before moving to next household member. Don't count visitors.)*

ID	Place 'X' for Head of House	Initials	Year OR date of birth (*If unknown record age)*	Sex: M/F	In School: Y/N	If less than or equal to 5 years of age:			
						A	B	C	D
						Is the child's vaccination card available? Y/N *(If Yes go to B; If No go to D)*	Record the number of rotavirus vaccination doses from the card: 0/1/2/>2/DK (*Go to C*)	Record the date of the last rotavirus vaccine from the card (MM/ YYYY) (*Go to Q 14*)	If no card, how many rotavirus vaccinations do you remember him or her receiving? 0/1/2/>2/DK
1								___/_____	
2								___/_____	
3								___/_____	
4								___/_____	
5								___/_____	
6								___/_____	
7								___/_____	
8								___/_____	
9								___/_____	
10								___/_____	
11								___/_____	
12								___/_____	
13								___/_____	
14								___/_____	
15								___/_____	

B. Sickness and Associated Costs

Now I would like to ask you about people in your household who may have been sick in the last 7 days

1. **Has anyone in your house been sick with diarrhea or flu-like illness in the past 7 days? By flu-like illness I mean having a fever and a cough or a sore throat. (*Utilize calendar as a memory aid if needed*)**
 ____ Yes (1)
 ____ No (0) **Go to Section D**
 ____ Don't know (99) **Go to Section D**

2. **How many members of your household were sick in the past 7 days?**
 ____ Ill household members
 ____ Don't know (99)

3. **Now I would like to ask you more about the illness they had (*Use one column per person. Fill out each column all the way to the bottom of the table before starting a column for the next ill person)***

	Sick Household Members				
Q		**Initials & Age (e.g., MT 29)**			
A	**Did _(name)_ have….? (*circle a response for EACH symptom*)**				
i	**Diarrhea** (*3+ loose or watery stools in 24 hours*)	Y N DK	Y N DK	Y N DK	Y N DK
ii	**Fever** (*at least 38°C or parental perception*)	Y N DK	Y N DK	Y N DK	Y N DK
iii	**Cough**	Y N DK	Y N DK	Y N DK	Y N DK
iv	**Sore Throat**	Y N DK	Y N DK	Y N DK	Y N DK
B	**If sick person had <u>diarrhea</u> answer questions in section B**				
i	When did diarrhea begin? (*Enter date as DD/MM/YYYY)*	__/__/__	__/__/__	__/__/__	__/__/_
ii	Number of days with diarrhea? (*If a range, take average and round up*)	___Days	___Days	___Days	__Days
iii	Is diarrhea ongoing?	Y N DK	Y N DK	Y N DK	Y N DK
iv	Maximum number of loose stools in a 24 hour period *(If exact number unknown, ask for and record one of the following ranges: "3 to 5" "6 to 7" or "too numerous to count (TNTC)")*				
v	Was there blood in the stool?	Y N DK	Y N DK	Y N DK	Y N DK
C	**If sick person had <u>fever AND cough or sore throat</u> answer questions in section C**				
i	When did the illness begin? (*Enter date as DD/MM/YYYY*)	__/__/__	__/__/__	__/__/__	__/__/_
ii	Number of days ill? (*If a range, take average and*	___Days	___Days	___Days	__Days

	round up)				
iii	Is illness ongoing?	Y N DK	Y N DK	Y N DK	Y N DK
D	**Activities missed due to illness (*ask for all types of illness*)**				
i	Miss work because they were sick? (*If no go to Dii)*	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	Number of days missed (*If a range, take average and round up*)	___Days	___Days	___Days	___Days
	Did he/she lose wages/earnings for the days they took time off for illness? (*If no go to Dii*)	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	If yes, amount of wages lost **per day** (ZMW)				
ii	Miss school because they were sick? (*if no go to Diii)*	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	Number of days missed	___Days	___Days	___Days	___Days
iii	Have to skip household chores/work like fetching water, cooking, cleaning, or caring for kids (*if no go to Q Ei)*	Y N DK N/A	Y N DK N/A	Y N DK N/A	Y N DK N/A
	Number of days skipped	___Days	___Days	___Days	___Days
E	**Treatment and Cost (*ask for all types of illness*)**				
i	Did the sick person get treatment for the illness, such as visiting a clinic, hospital, pharmacist, or healer, taking medication, or having lab tests done? (*If no, go to Q Fi)*	Y N DK	Y N DK	Y N DK	Y N DK
ii	Did your household spend any money on the treatment for this illness? Treatment includes any money you spent on clinic or doctor visits, medications, lab tests, and hospitalizations (*If no go to Q Eiii)*	Y N DK	Y N DK	Y N DK	Y N DK
	If yes, how much did you spend? (ZMW) (*Enter a number or DK [don't know])*				
iii	Did you have to spend any money on transportation for this person's illness? This includes going to or from the clinic, pharmacy, hospital, etc. (*If no, go to Q Fi)*	Y N DK	Y N DK	Y N DK	Y N DK
	If yes, how much did you spend on transportation? (ZMW) (*Enter a number or DK [don't know])*				
F	**Time Use: (*ask for all types of illness*)**				
i	If _(name)_ visited a clinic or health center, how many times did they go? (*Enter a number or DK [don't know]. Skip this question and go to Q Fii if did not visit clinic or Health Center)*				
	On average, how long did it take you to see the doctor or nurse, including round-trip travel time? (*Enter a number or DK [don't know]. Specify hours or minutes*)				

ii	Did_(name)_ need to be hospitalized for this illness? (*Hospitalized means spending at least one night in the hospital. Go to Section C if No or DK [Don't Know]*)	Y N DK	Y N DK	Y N DK	Y N DK
	How many days were they hospitalized? (*Enter a number or DK [don't know]*)				

C. Caretaker Time Loss

1. **Did anyone stay home from work or did you have to pay someone to take care of ___ (sick household member)?**
   ____ Yes (1)
   ____ No (0) **Go to Section D**

2. **Did anyone stay home to care for the sick person, other than the person who was sick?**

	People who stayed home to care for sick household members			
Q		**Initials and Age (e.g., MT 29)**		
A	Does this person (the caretaker) live in the house? *(Circle one. If yes, go to Q B; if no go to Q Ai)*	Y N DK	Y N DK	Y N DK
i	What is their gender?	M F	M F	M F
B	How many days did they stay at the home to take care of __(name) __?	___Days	___Days	__Days
C	Did they get paid to take care of __(name)__? *(Circle one)*	Y N DK	Y N DK	Y N DK
i	How much were they paid for caregiving, **in total?** (ZMW) (*Enter a number or DK [don't know]*)			
D	Did they lose wages or earnings for the days they were at home to take care of __(name)__? *(Circle one. If no, go to Section D)*	Y N DK	Y N DK	Y N DK
i	How much did they lose **in total?** (ZMW) (*Enter a number or DK [don't know]*)			

D. Brief Water Collection

Now I am going to ask you questions about the water your household uses.

1) **During the past week, where did you get your DRINKING WATER? What was your main source of drinking water? (*Select the best answer. Observe source if respondent is cannot describe it or you are unsure.)***
   ____ Communal tap/Water kiosk (1)
   ____ Protected well/Borehole (2)
   ____ Unprotected well/Borehole (3)
   ____ Piped water inside house (4)
   ____ Piped water outside house within stand/plot (5)
   ____ Piped water from neighbor (6)
   ____ Surface water (stream/pond) (7)
   ____ Other, specify (88):________
   ____ Don't know (99)
   ____ Refused (77)

2) **In the past week, how many days was water available from this source?**
   ______ Days
   ______ Don't know (99)

3) **On average, how many hours per day was water available from this source?**
   ______ Hours
   ______ Don't know (99)

4) **During the past week did you get DRINKING WATER from any other source(s)?**
   ____ Yes (1)
   ____ No (0) ***go to Q6***
   ____ Don't know (99) ***go to Q6***

5) **What was/were the other source(s)? (*DO NOT read answers. Select all that are stated)*.**

____ Communal tap/Water kiosk
____ Protected well/Borehole
____ Unprotected well/Borehole
____ Piped water inside house
____ Piped water outside house within stand/plot
____ Piped water from neighbor
____ Surface water (stream/pond)
____ Other, specify:________
____ Don't know
____ Refused

6) **How much water does your household use in a typical day, measured in buckets and liters? I am asking about ALL of the water your household uses in a day, whether for drinking, bathing, cleaning or something else. This water could come from ANYWHERE, including taps in your home or plot, water kiosks, communal taps, wells, boreholes, neighbors, etc. (*If household collects water in buckets of multiple sizes, list the number and capacity of each that is used in Bucket A, B, C.)***

Bucket A:	Capacity of 1 bucket (liters)__________	Don't Know (99) _____
	Number of buckets_______________	Don't Know (99) _____
Bucket B:	Capacity of 1 bucket (liters)__________	Don't Know (99) _____
	Number of buckets_______________	Don't Know (99) _____
Bucket C:	Capacity of 1 bucket (liters)__________	Don't Know (99) _____
	Number of buckets_______________	Don't Know (99) _____

____ Don't know

E. Water Storage and Treatment

Now I would like to ask you about how you keep drinking water in your house

1) ENUMERATOR: Does the household collect water from a water kiosk or communal tap?
____ Yes (1)
____ No (0) ***go to Q4***
____ Don't know (99) ***go to Q4***

2) When you collect water from a kiosk or communal tap do the kiosk operators treat the water or do something to it like add bleach when you collect it?
____ Yes (1)
____ Sometimes (2)
____ No (0) ***go to Q4***
____ Don't know (99) ***go to Q4***
____ Do not collect water from a kiosk (98) ***go to Q4***

3) What do the kiosk operators do to the water you collect?
____ Pour bleach into water (1)
____ Put a tablet into the water (2)
____ Other (88), specify:__________
____ Don't know (99)

4) Do you normally treat or do something to your drinking water, such as adding chlorine, boiling it, or filtering it?
____ Yes (1)
____ No (0)
____ Don't know (99)

5) Did you treat or do something to the drinking water in your home today, such as adding chlorine, boiling it, or filtering it?
____ Yes (1)
____ No (0) **Go to Q8**
____ Don't know (99) **Go to Q8**

6) What did you do to your water? *(DO NOT read answers. Mark all that apply)*
____ Boil water (0/1)
____ Bleach/chlorine (0/1)
____ Filter water (0/1)
____ Other (0/1) Specify: _________

7) **Please show me the boiling pot, tablet, filter, or other item that you used.** ***(Enumerator: Confirm presence of pot, tablet, filter, or other item.)***

____ Item present (1)
____ Item not present (0)

8) **Please show me the containers you mainly put your <u>drinking</u> water in inside your house? (*OBSERVE and select the main container type(s) the household identifies as using.)***

____ Buckets (1)
____ Plastic jerrycan (2)
____ Barrel (3)
____ Container with screw top (e.g., plastic bottle) (4)
____ Other (88), specify:_________
____ Do not use a container (5) **Go to Q11**
____ Unable to observe (6) **Go to Q10**
____ Don't know (99) **Go to Q10**
____ Refused (77) **Go to Q10**

9) ***OBSERVE - How many of the water storage containers are covered?***

____ All (1)
____ Some (2)
____ None (0)
____ Unable to observe (3)

10) **How do you get water from this container to drink? Can you please show me how? (*OBSERVE and select what the respondent does)***

____ Dipping (w/ ladle, cup, or hand) (1)
____ Pouring (2)
____ Through a spigot or tap (3)
____ Other(88), specify:_________
____ Don't know (99)
____ Refused to show (77)

11) **Test drinking water and record result. Explain to the respondent what you are doing. Make sure you rinse/clean the column with water before you test.**

______ Positive (yellow) (1)
______ Negative (clear) (0)
______ No water in the container/No water available for testing (9)

F. Brief Sanitation Module

1) **Now we are going to talk about sanitation and toilets. Can you show me the toilet facility your house NORMALLY uses? *OBSERVE: What type of toilet is it? If respondent will not show you, ask them to describe it. Choose the best answer.***

____ Pit latrine with slab (1) **Go to Q3**
____ Pit latrine without slab (2) **Go to Q3**
____ Ventilated improved pit latrine (VIP) (3) **Go to Q3**
____ Bucket/chamber pot (4) **Go to Q6**
____ Flush toilet (5) **Go to Q2**
____ No facilities/bushes/plastic bags (6) **Go to Q6**
____ Other (88), specify **Go to Q3**
____ Don't know (99) **Go to Q3**
____ Refused (77) **Go to Q3**

2) **Where is the waste flushed to?**
____ Piped sewer system (1)
____ Septic tank (2)
____ Latrine hole (3)
____ Some other place (i.e., river, drainage ditch) (4)
____Other (88), specify __________
____ Don't know (99)

3) **Is your toilet or latrine just for this household or shared with other households?**
____ Just this household (1) **Go to Q6**
____ Shared (2)
____ Don't know (99) **Go to Q6**
____ Refused (77) **Go to Q6**

4) **How many households share it, not counting your own?**
Number of households __________ Don't know (99) _____

5) **How many people share it, including those in your household?**
Number of people __________ Don't know (99) _____

6) ***OBSERVE – Are there feces (human or animal) visible in the yard/plot?***
____ Yes (1)
____ No (0)
____ Not evaluable (3)

G. Hygiene Module

1) **When do you usually wash your hands? (C*ontinue to prompt "ANY OTHER TIMES?" Select all that apply.)***

____ Before eating
____ After cleaning child who defecated
____ After disposing the chamber
____ After handling trash
____ After contact with animals
____ Other, specify____________
____ Before cooking/preparing baby food
____ After using toilet
____ Before you nurse
____ After working
____ Never ***Go to Section H***

2) **What do you usually wash your hands with?**

____ Water only (1) ***Go to Section H***
____ Water and soap (2) ***Go to Q3***
____ Water and something else (3), specify:_______________ ***Go to Section H***
____ Don't know (99) ***Go to Section H***
____ Refuse (77) ***Go to Section H***

3) **Please show me the soap that you use. *(Enumerator: Confirm the presence of soap.)***

____ Soap present (1)
____ Soap not present (0)

H. Household Garbage Disposal

1) **What are the ways that you dispose of garbage? (*Select all that apply.)***

____ Garbage collected from house **go to Q2**
____ Burn
____ Drainage ditch
____ Put in latrine/toilet
____ Don't Know
____ Bury/pit
____ Roadside dump
____ Garbage bay/Council bins
____ Other, specify _________
____ Refused

2) **Who collects your garbage? (*Mark the best answer.)***

____ LCC/the city (1)
____ Private Company or community based enterprise (2)
____ Hired individuals (3)
____ Other (88), specify ________
____ Don't know (99)
____ Refused (77)

I. Flooding

*****NOTE:* many questions in the section ask about the effects of flooding in "month XX." The periodicity of household flooding surveys has not yet been determined, as such, the month will be adjusted based on when surveys of HH drainage beneficiaries are implemented.**

Now I would like to ask you about flooding and how it affects you, your household, community, and compound

1) **Did you experience flooding in the month XX? This could be flooding at your home, in the streets, or in your community or compound.**
   ____ Yes (1)
   ____ No (0) **go to Q5**
   ____ Don't know (99)

2) **During month XX, about how many days was there flooding in or around your house, compound, or the streets outside? (*If no flooding in a month, enter "0". If they say "after every rain" prompt for a number of days, and if they can't give a number then enter "DK")***
   ____ Days ____ Don't Know (99)

3) **During month XX did flood waters damage or destroy any property at your house?**
   ____ Yes (1)
   ____ No (0) **go to Q5**

4) **What type of property did it damage or destroy? *(Do not read list. Continue to prompt, "anything else." Select all that apply.)***
   ____ Building/Walls
   ____ Groceries/pantry
   ____ Electronic equipment
   ____ Vehicles/bicycles
   ____ Other appliances
   ____ Cell phones
   ____ Books/stationeries
   ____ Clothes/shoes
   ____ Furniture
   ____ Plants/garden
   ____ Other, specify____________

5) **Have you done anything or spent any money to protect against FUTURE flooding, like purchasing sand-bags or water-proof equipment in month XX?**

____ Yes (1)
____ No (0) **go to Q7**
____ Don't know (99) **go to Q7**

6) **How much did you spend on those investments? (*If something was done but no money was spent, enter "0".)***

____ ZMW
____ Don't know (99)
____ Refuse (77)

7) **Were there any deaths (from drowning or injury associated with floods) of people living in your household associated with the flooding during the last year?**

____ Yes (1)
____ No (0)
____ Don't know (99)

Now I am going to ask you about the amount of time it took household members to travel around town in month XX.

8) **On average, how long did it take household members to get to school in month XX, in minutes? I would like to know this for all household members that attend school. (*Fill out table below for all household members that attend school)***

	HH members that goes to school				
	1	**2**	**3**	**4**	**5**
Sex					
Age (*In years)*					
Time in minutes to get to school. *(Enter a number or DK)*					
Nobody attends school (*Check this box and Go to Q11)*					

9) **Did flooding during month XX prevent anyone from going to school entirely?**

____ Yes (1)
____ No (0) **go to Q11**
____ Don't know (99) **go to Q11**

10) **How many days of school did each child miss during month XX? (*Collect this for the same household members as the last question)***

	HH members that goes to school				
	1	**2**	**3**	**4**	**5**
Days of school missed					

11) **On average, during month XX, how long did it take to get to the market , in minutes?**
    ____ Minutes
    ____ Don't know (99)

12) **On average, how long did it take household members to get to work in month XX, in minutes? I would like to know this for all household members that are 18 or older and are working. (*Fill out table below for all working household members that are 18 years of age or older)***

	HH members that go to work				
	1	**2**	**3**	**4**	**5**
Sex					
Age (*In years)*					
Time in minutes to get to work. ***(Enter a number or DK)***					
Nobody is working (*Check this box Go to Section J)*					

J. Time Use and Expenditures

Now I would like to ask some questions about working, looking for work, and household expenditures during the last month.

1. **I will start by asking you about time spent working and looking for work in household members age 18 and older.** ***(Fill out a column in this table for each member of the household who is 18 or older. Answer all questions for one household member before moving to the next.)***

	Adult Household Members				
Q	**In the last month did _(name)_:**	**Initials and Age (e.g., MT 29)**			
A	**Are you/are they doing any activities where you/they earned money? This includes things like working for a wage, doing piecework, running a shop, or selling things on the road. (*Circle one. If No go to B)***	Y N DK	Y N DK	Y N DK	Y N DK
i	Days worked per week, on average				
ii	Hours worked per day, on average				
B	**Are you/are they looking for work? (*Circle one. If no, got to question 2)***	Y N DK	Y N DK	Y N DK	Y N DK
i	Days spent looking for work per week, on average				
ii	Hours spent looking for work per day, on average				

Expenditures:

2. **Now I would like to ask you about different things your household has spent money on. Focusing on the last 7 days, has your household purchased any following <u>food items</u>?**

Consumption Items	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	If yes, how much was spent (ZMW)?	If amount spent not known, how much was purchased?	Notes
Cereals and grains	**5-1**				
Mealie meal (kg)	i				
Bread (loaf/buns)	ii				
Rice (kg)	iii				
Other (e.g., flour, maize, noodles, sampo), Specify:	iv				
Meats, Eggs, and Fish	**5-2**				
Kapenta (kg)	i				
Other fish (any) (kg)	ii				
Eggs (dozen)	iii				
Poultry (kg)	iv				
Other (e.g., beef, pork, sausage), Specify:	v				
Vegetables	**5-3**				
Tomato (kg)	i				
Onion (kg)	ii				
Green vegetables (kg)	iii				
Other, Specify (kg):	iv				
Fruits/Local fruits	**5-4**				
All (kg)	i				
Sugar, Salt, oil and Spices	**5-5**				
Cooking oil (liter)	i				
Sugar (kg)	ii				
Salt (pack)	iii				
Other, Specify:	iv				
Dairy Products	**5-6**				
Milk (fresh, powdered)	i				
Butter/Margarine (kg)	ii				
Other (e.g., yogurt, cremora), Specify:	iii				
Pulses/Legumes	**5-7**				
Dry beans (kg)	i				
Ground nuts/Peanuts (kg)	ii				
Other (e.g., soya chunks, soybeans), Specify:	iii				

Beverages	5-8				
Tea, coffee (pack)	i				
Soft drinks/fruit juice (liter)	ii				
Alcohol (liter)	iii				

3. **Have you or any members of your household had any expenses for the following <u>non-food items</u> during past month? I will read you a list.**

	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	If Yes, how much did you spend in a month? (ZMW)
Non-food items	6-1		
Electricity	i		
Rent or mortgage	ii		
Cell phone minutes/bill (for the WHOLE household)	iii		
Public transport – Taxi, Bus, Minibus	iv		
Personal products such as soap, shampoo, razor blades, toothbrush and tooth paste, or cosmetics and skin cream (*Read all options)*	v		
Hair braiding or hair care	vi		
Clothing	vii		
Charcoal/ firewood /kerosene	viii		
Cigarettes/tobacco	ix		
Tithe/Offering	x		

4. **Has your household had any expenses for the following <u>healthcare items</u> during past month?**

Healthcare Expenses	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Specify the amount spent (ZMW) and a time period if 1 month total not known
Doctor/clinic/health center visit fees	i		
Medications: All (e.g., from pharmacy/chemist or drugstore [self-prescribed])	ii		
Other, specify:	iii		

5. **Has your household had any education related expenses in the past year? This includes things like tuition, daily fees, uniforms, school supplies, or transportation**
   ____ Yes (1)
   ____ No (0) **Go to Q7**
   ____ Don't know (99) **Go to Q7**
   ____ Refused (77) **Go to Q7**

6. **How many household members are in school? *(Enumerator: check this response matches question A13)***

   ______
   If "0" go to Q8

7. **I will now start asking you about the money your household may have spent on household members in school. (*Use one section per household member. Fill out each section for all the education expenses before starting a new section for the next household member)***

Q	**Household School-attendee 1**			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	**No. terms per year**	**Kwacha (ZMW) per term**
7.a.i	**Did your household spend money on tuition for this person in the last year?**			
7.a.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) per day**	
7.a.ii.A	Daily school fees			
7.a.ii.B	Transport (e.g., minibus, petrol)			
7.a.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.a.iii.A	Uniform/Shoes			
7.a.iii.B	School supplies like stationaries or textbooks			
7.a.iii.C	Other, specify:			
Q	**Household School-attendee 2**			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	**No. terms per year**	**Kwacha (ZMW) per term**

7.b.i	**Did your household spend money on tuition for this person in the last year?**			
7.b.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) per day**	
7.b.ii.A	Daily school fees			
7.b.ii.B	Transport (e.g., minibus, petrol)			
7.b.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.b.iii.A	Uniform/Shoes			
7.b.iii.B	School supplies like stationaries or textbooks			
7.b.iii.C	Other, specify:			
Q	**Household School-attendee 3**			
		No = 0 Yes = 1 Don't Know = 2 Refused = 3	**No. terms per year**	**Kwacha (ZMW) per term**
7.c.i	**Did your household spend money on tuition for this person in the last year?**			
7.c.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) per day**	
7.c.ii.A	Daily school fees			
7.c.ii.B	Transport (e.g., minibus, petrol)			
7.c.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0 Yes = 1 Don't Know = 2 Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.c.iii.A	Uniform/Shoes			
7.c.iii.B	School supplies like stationaries or textbooks			
7.c.iii.C	Other, specify:			
Q	**Household School-attendee 4**			
		No = 0 Yes = 1 Don't Know = 2	**No. terms per year**	**Kwacha (ZMW) per term**

		Refused = 3		
7.d.i	**Did your household spend money on tuition for this person in the last year?**			
7.d.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0** **Yes = 1** **Don't Know = 2** **Refused = 3**	**Amount spent (ZMW) per day**	
7.d.ii.A	Daily school fees			
7.d.ii.B	Transport (e.g., minibus, petrol)			
7.d.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0** **Yes = 1** **Don't Know = 2** **Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.d.iii.A	Uniform/Shoes			
7.d.iii.B	School supplies like stationaries or textbooks			
7.d.iii.C	Other, specify:			
Q	**Household School-attendee 5**			
		No = 0 **Yes = 1** **Don't Know = 2** **Refused = 3**	**No. terms per year**	**Kwacha (ZMW) per term**
7.e.i	**Did your household spend money on tuition for this person in the last year?**			
7.e.ii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0** **Yes = 1** **Don't Know = 2** **Refused = 3**	**Amount spent (ZMW) per day**	
7.e.ii.A	Daily school fees			
7.e.ii.B	Transport (e.g., minibus, petrol)			
7.e.iii	**During the past year, has your household spent money on any other items for __(name's)__ schooling, such as:**	**No = 0** **Yes = 1** **Don't Know = 2** **Refused = 3**	**Amount spent (ZMW) last year. If 1-yr total is not known try to get total for a different time period (e.g., 200 ZMW last month)**	
7.e.iii.A	Uniform/Shoes			
7.e.iii.B	School supplies like stationaries or textbooks			
7.e.iii.C	Other, specify:			

8. Does your household have any of the following durable goods?

	Q	No = 0 Yes = 1 Don't Know = 2 Refused = 3	Purchased within past two years? No = 0 Yes = 1 Don't Know = 2 Refused = 3	If yes, how much did you spend on it? (ZMW)
Durable goods	8-1			
Cell phones	i			
Radio	ii			
Refrigerator/Freezer	iii			
Television	iv			
Cooker	v			
Bicycle	vi			
Car	vii			
Sofa	viii			
DVD Player	ix			
Computer	x			

9. What is the MAIN type of fuel used for cooking in your household? *(Choose the best answer)*

____ Charcoal (1)
____ Electricity (2) ***Go to Section J***
____ Wood (3)
____ Paraffin (4)
____ Other (88), specify __________
____ Don't know (99)
____ Refused (77)

10. Is there electricity in your house?

____ Yes (1)
____ No (0)
____ Don't know (99)

K. Observations

Thank you very much for taking the time to speak with me and answering our questions. Now I would like to observe a few things about your house and then I will be finished with the interview

1) ***OBSERVE - What type of roofing does this house have? (Select all that apply)***

____ Metal/Iron sheets (1)
____ Asbestos (2)
____ Wood planks (3)
____ Ceramic tiles/Harvey tiles (4)
____ Cardboard (5)
____ Wood (6)
____ Cement (7)
____ Roofing shingles (8)
____ Mud tiles (9)
____ Other (88), specify ________________
____ Don't know (99)

2) ***OBSERVE - What is the flooring material? (Select all that apply)***

____ Concrete (1)
____ Cement (2)
____ Brick (3)
____ Tiles (4)
____ Mud (5)
____ Wood (not wooden tiles) (6)
____ Other (88), specify ________________
____ Don't know (99)

3) ***OBSERVE - What is the material used for the walls? (Select all that apply)***

____ Concrete blocks/slab (1)
____ Cement blocks (2)
____ Compressed cement bricks (3)
____ Burnt bricks (4)
____ Mud bricks (5)
____ Compressed mud (6)
____ Iron sheets (7)
____ Asbestos/hardwood/wood (8)
____ Other (88), specify ________________
____ Don't know (99)

Appendix 6: Memo: Summary of Control Area Issues and Considerations

Supported By The American People

Impact Evaluation of the Lusaka Water Supply, Sanitation, and Drainage Project

Summary of Control Areas Issues and Considerations

Table of Contents

Introduction

As part of its work in Zambia, the Millennium Challenge Corporation (MCC) is conducting an evaluation to determine the impact of its investments. In order for this evaluation to be effective MCC and its MCA-Zambia needs the cooperation of LWSC in staying current on hard-infrastructure interventions that are planned in the geographic areas critical to the evaluation and outlined in this document. This request for information is in line with the Implementing Entity Agreement between LWSC and MCA-Zambia

Besides outlining geographic areas of the evaluation, this document provides the type of information required to ensure the evaluation remains effective. It is requested that LWSC simply acknowledge receipt and agreement of this document by sending an email.

Background

MCC in partnership with the Government of Zambia (Millennium Challenge Account-Zambia [MCA-Zambia]) is implementing a large-scale, $350 million upgrade and extension of the water, sanitation, and drainage infrastructure in Lusaka to increase population access to potable water, sanitation, and flood protection. The Lusaka Water Supply, Sanitation and Drainage (LWSSD) project (the Compact) will strengthen and upgrade the main surface water treatment plant for Lusaka, extend water supply and sanitation networks into areas with limited household water connections and toilets, build new water kiosks, rehabilitate existing water kiosks, and improve the drainage network for the primary business district and surrounding residential communities in Lusaka.

MCC and the Centers for Disease Control and Prevention (CDC) signed an Inter-agency Agreement in April 2013 for CDC to serve as the Independent Evaluator for the LWSSD Compact. CDC will conduct monitoring and evaluation activities to assess the project's impact on health outcomes; economic indicators; water availability, access, cost and time spent collecting water; water, sanitation, and hygiene knowledge and behavior; and flood-related impacts. Evaluation activities will be conducted, in large part, through household surveys that will be administered before the interventions begin (2015-2016) and after the Compact interventions have been implemented (2018-2019).

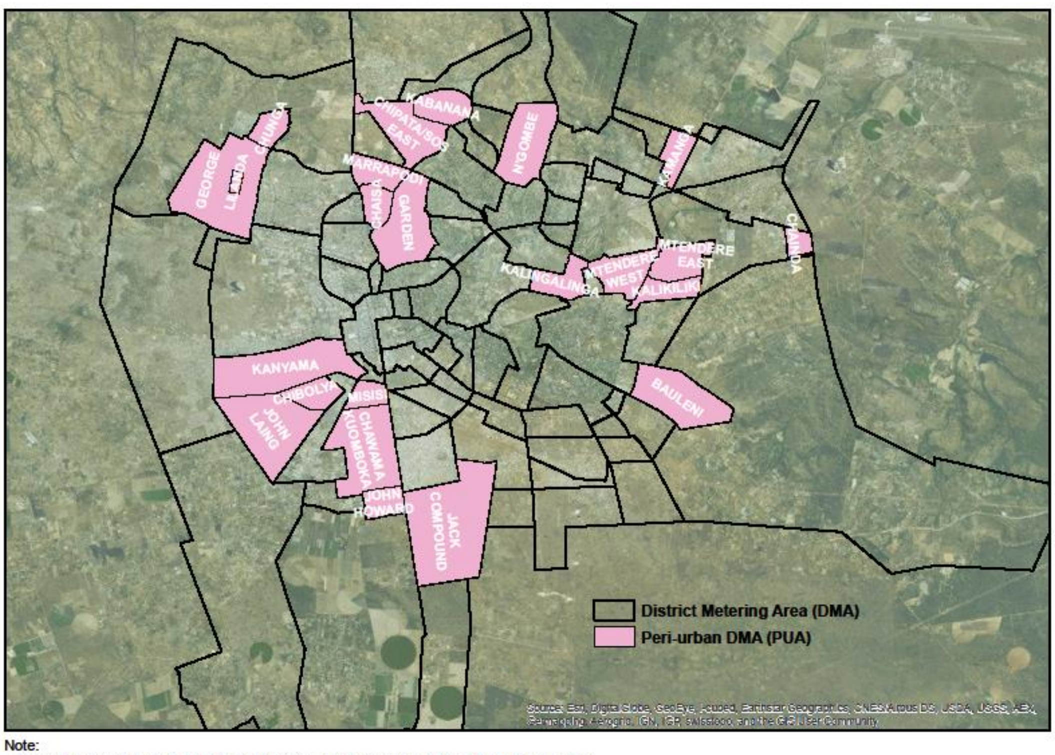
The impact of interventions to extend water supply and sanitation networks to residential areas will be evaluated by comparing pre and post outcome measures in both intervention and control (non-intervention) areas. Because the evaluation spans several years, it is critically important to ensure the validity of control areas between baseline (2015-2016) and follow-up (2018-2019) surveys. This will require MCC, MCA Zambia, stakeholders, and the CDC to keep informed of all *non-Compact* water and sanitation infrastructure interventions that occur in control areas over the life of the Compact. The primary objective of this document is to work with stakeholders to ensure the exchange of this information and maintain the validity of control areas and reliability of evaluation findings. This document also seeks to describe the sampling frame, the selection of control areas, and the overall sampling strategy, and to reach consensus with stakeholders on these methodologies.

Note that, unlike the water supply and sanitation interventions, the impact of interventions to improve drainage in Lusaka will only be evaluated by comparing pre and post outcome measures in intervention areas. Comparison to control areas is not possible due to the unique hydrogeological, residential, and business characteristics of the communities along the Bombay Drain. Therefore, the scope of this document pertains only to the water supply and sanitation interventions.

Sampling Frame

The Lusaka Water and Sewerage Company (LWSC) divides Lusaka into service areas known as district metering areas (DMAs). LWSC characterizes peri-urban areas (PUAs) as unplanned settlements that have low water and sanitation coverage. Twenty-two of the DMAs in Lusaka District are considered to be PUAs. The study population (i.e., the sampling frame) for the evaluation of the water supply and sanitation interventions includes residents living in PUAs within Lusaka. Gauff Ingenieure, the engineering firm that consulted on the design of Compact interventions, developed a map of DMAs within Lusaka, provided below (Figure 1).

Figure 1: Peri-urban District Metering Areas (DMAs) in Lusaka



Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files

Control Area Selection

Compact water supply and sanitation interventions will be implemented in 4 PUAs in Lusaka: Chipata/SOS East, Ng'ombe, Kamanga, and Mtendere. These PUAs are considered to be *intervention areas*. We will assess the impact of Compact interventions by comparing the health and economic outcomes in intervention and control areas (i.e., areas not receiving Compact interventions). Therefore, the identification of a control area with characteristics similar to the intervention area is a critical step in planning the evaluation. Due to the similarity of PUAs with respect to water and sanitation access, and demographic and economic characteristics, our control area will be comprised of those PUAs that will not receive Compact interventions (Table 1 and Figure 2). However, we will exclude Chibolya due to safety and security concerns there.

Table 1: Classification of PUAs by Intervention/Control Status

Bauleni	George	Kamanga
Chainda	Jack Compound	Kanyama
Chaisa	John Howard	Lilanda
Chawama/Kuomboka	John Laing	Marapodi
Chibolya	Kabanana	Misisi
Chipata/SOS East*	Kalingalinga	Mtendere** (East and West)
Chunga	Kalikiliki	Ng'ombe
Garden		

*For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

**Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.

(blue)	Water supply interventions only
(green)	Water supply and sanitation interventions
(white)	Controls
(grey)	Excluded from controls due to safety concerns

Figure 2: Intervention and Control Peri-Urban Areas within Lusaka District

Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files

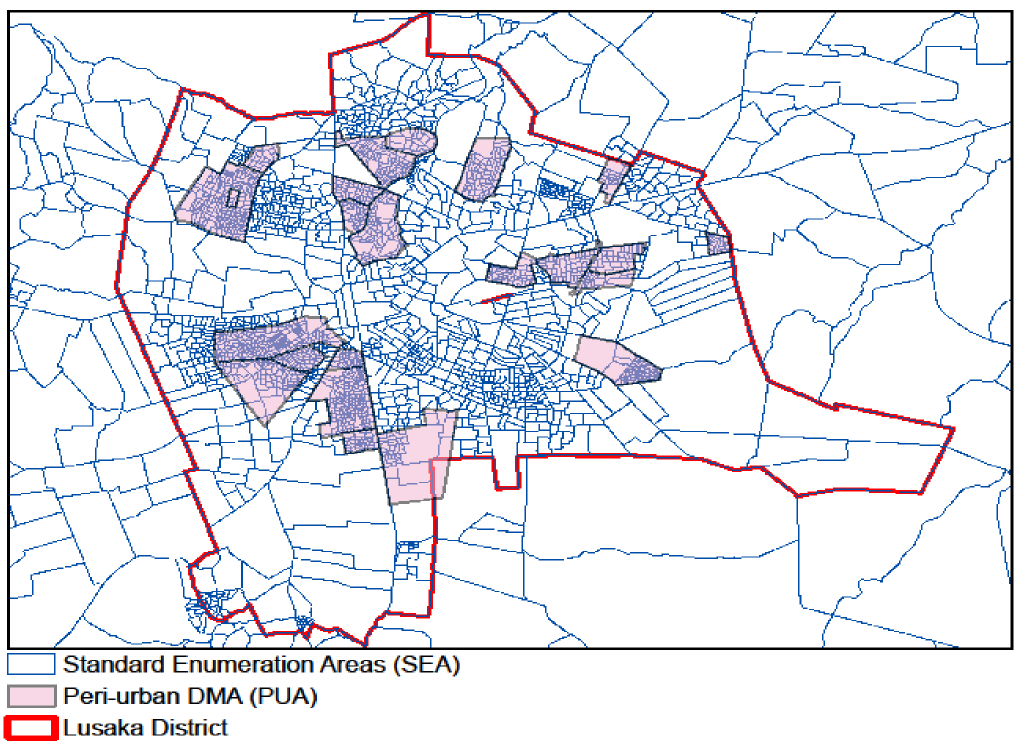
Colour	Meaning
Blue	Water supply interventions only
Green	Water supply and sanitation interventions
White	Controls
Grey	Excluded from controls due to safety concerns

Sampling Strategy

Administratively, the Zambian Central Statistics Office (CSO) divides Zambia into different sized administrative units for the census. The city of Lusaka falls within a large administrative unit known as the Lusaka *District*. Districts are further subdivided into different sized enumeration units; the smallest enumeration unit is a Standard Enumeration Area (SEA), and represents approximately 175 households. An image of the Lusaka District and its SEAs is provided below in Figure 3.

We will utilize both PUAs and SEAs to select the households that will be surveyed in the evaluation. We will generate our sampling frame by overlaying SEA boundaries and PUA boundaries using ArcView GIS (Figure 3). Then, we will select a random sample of the SEAs that are located within PUA boundaries. Next, we will randomly select households located within these SEAs for inclusion in the evaluation (i.e., surveyed). This process will be repeated for the post-Compact household survey, with a new sample of SEAs and households drawn at that time.

Figure 3: Lusaka District, Peri-urban Areas and Standard Enumeration Areas



Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

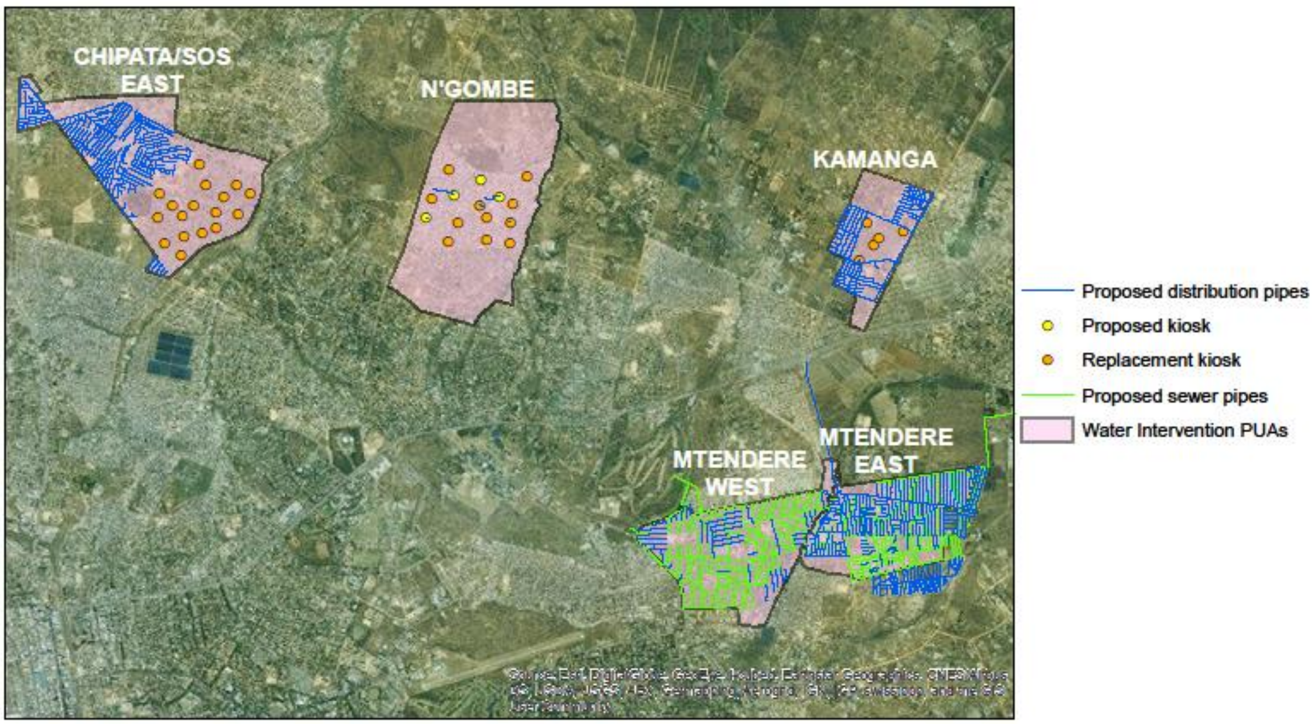
Source: Central Statistics Office: 2010 Census GIS Files; Gauff Ingenieure: GIS files

Specific Sampling Issues

<u>Sampling Entire PUA in both Intervention and Control Areas</u>

As seen in Table 1 and Figure 2, we categorized PUAs as either control or intervention areas. Within the intervention PUAs, water and sanitation interventions generally extend throughout the entire PUA (see Figure 4), with the exception of Ng'ombe. However, the beneficiaries of Compact interventions, especially water kiosk interventions, may be located at varying distances from the new/rehabilitated infrastructure. To maintain consistency, sample households in both intervention and control areas will be selected at random from the entire PUA.

Figure 4: Water and Sanitation Interventions



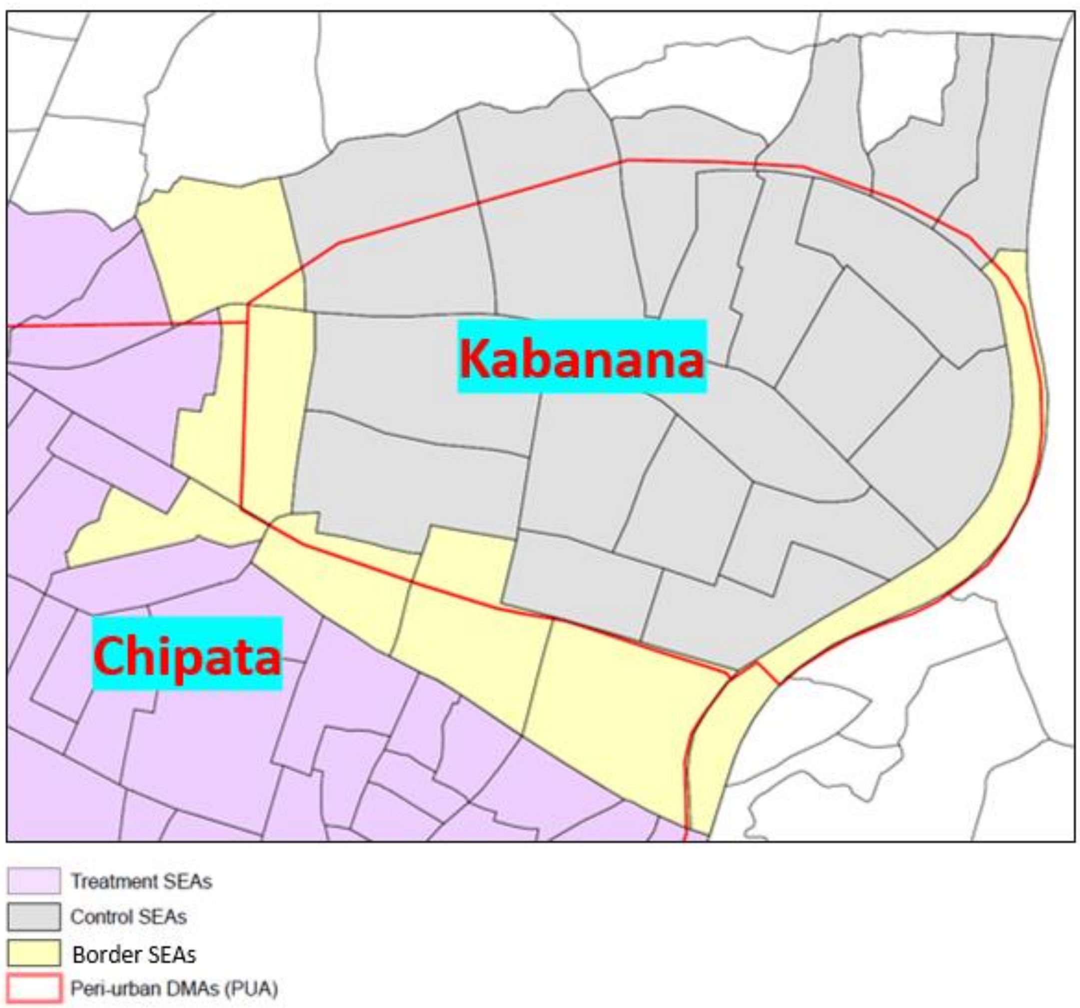
Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.
- For this evaluation the small area of SOS East that will receive interventions and the Chipata PUA were joined, thus creating the Chipata/SOS East PUA.

Source: Gauff Ingenieure: GIS files

Border SEAs

Our sampling strategy consists of randomly sampling households in SEAs that are located either in intervention or control PUAs. However some SEAs cross the boundaries of both an intervention and a control PUA (see Figure 5). This is because SEA boundaries and PUA boundaries were created by different agencies in Zambia. There are about 40 of these border SEAs in our sample (out of approximately 1,400 total SEAs). These border SEAs, and the households within them, will be categorized as controls. However, we may explore analyzing these border SEAs independently of the control group to determine if outcomes at the border differ from outcomes in control or intervention areas.

Figure 5: Border SEAs

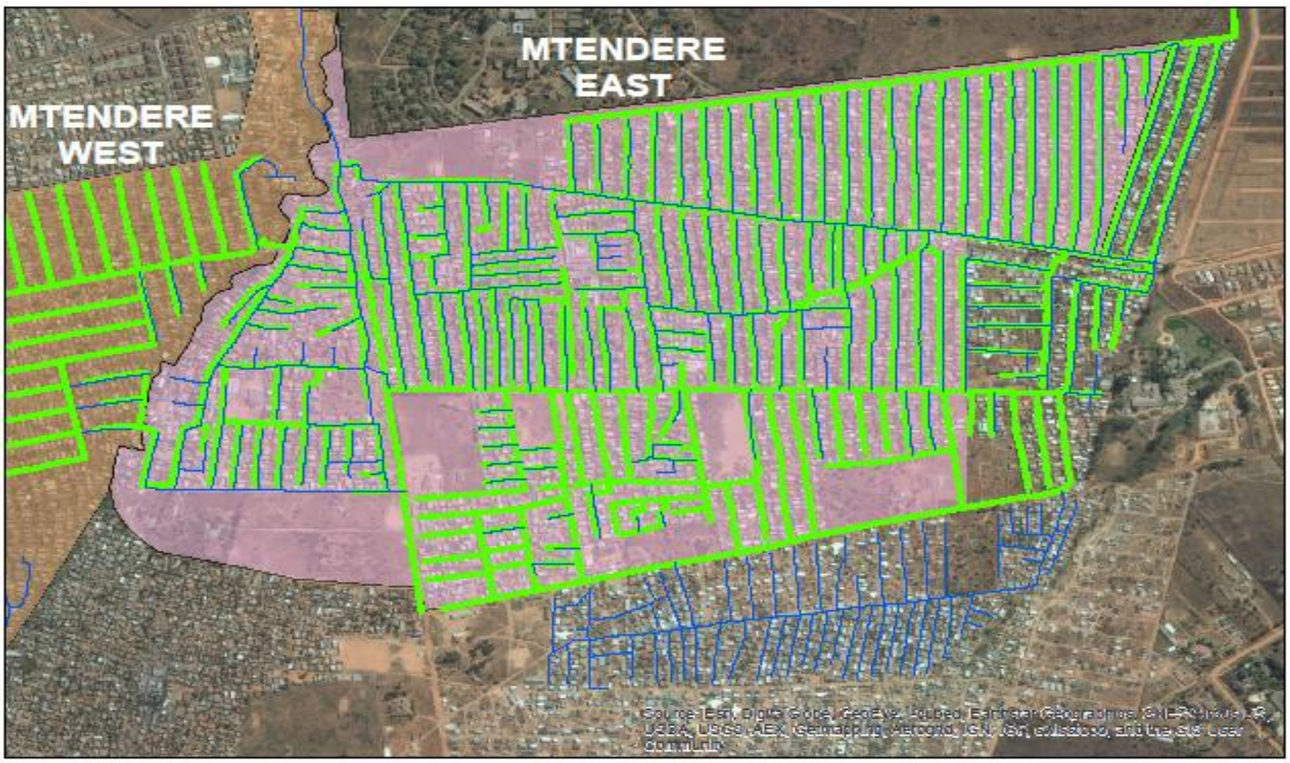


Source: Central Statistics Office: 2010 Census GIS Files; Gauff Ingenieure: GIS files

Mtendere East: Interventions beyond the PUA Boundary

Water and sanitation interventions in Mtendere East extend beyond the formal PUA boundary, to the south and east (Figure 6). This is likely in part due to some differences between the development and design of intervention blueprints from an engineering perspective and the exact layout of designated DMA/PUA boundaries from a geographic/municipal perspective. In addition, the population of Mtendere has grown and expanded beyond the formal peri-urban boundary over the years. For our evaluation, these intervention areas that extend beyond the Mtendere East PUA boundary will be considered part of Mtendere East.

Figure 6: Mtendere East



Note:
- Mtendere East and West are not individual PUAs, rather two halves of the Mtendere PUA.

Source: Gauff Ingenieure GIS files

Proposed distribution pipes
Proposed sewer pipes
Mtendere East
Mtendere West

Maintenance of Control Area Validity

In this evaluation we seek to assess the health benefits that result from the new and rehabilitated water and sanitation infrastructure that will be provided as part of the Compact. To assess these benefits we will compare health outcomes between PUAs that receive interventions and PUAs that do not receive interventions (control areas) both before and after the Compact interventions. Therefore, the results of the evaluation are dependent upon maintaining a valid and representative control group.

Prior to the Compact intervention we expect the level of access to water and sanitation infrastructure to be roughly equivalent between both intervention and control groups. In intervention areas, we expect households to gain better access to water and sanitation infrastructure over the course of the Compact (2015-2018). While natural, small-scale, increases in the amount of water and sanitation infrastructure will likely occur in control areas over the course of the Compact, we do not expect changes at the same scale. However, if *non-Compact*, hard-infrastructure interventions (such as piped water or network sanitation systems) do occur in control areas during the course of the Compact, it will be important to be informed of these activities so we can account for them in our evaluation (e.g., by excluding an area that receives such interventions from our control group). An example of a hard-infrastructure intervention would be if an NGO planned to extend household water connections and install new water kiosks in Jack Compound in 2016. If such an intervention did occur, we may consider excluding the Jack Compound from our control group.

Accordingly, we seek to work with LWSSD Compact stakeholders to develop a strategy to keep informed of any non-Compact, hard infrastructure, water supply and sanitation interventions that may occur throughout the timespan of the Compact. Soft-infrastructure interventions (e.g., promotion of household water treatment or hand washing) are less of a priority as our evaluation primarily focuses on the effects of hard-infrastructure interventions. The information we seek with respect to these non-Compact, hard-infrastructure interventions is the following:

- Type of hard-infrastructure intervention (e.g., new household water connections; refurbished kiosks)
- Extent of intervention (e.g., 200 household taps installed; 8 water kiosks refurbished)
- Specific intervention location, including geographic (street) and/or GIS boundaries
- Number of beneficiaries
- Date that construction will begin; date that intervention infrastructure will be complete/functional
- An example format of this information, previously provided by LWSC, is included in Annex 1

Reach Consensus on Described Strategies

Reaching a consensus on the strategy for selecting controls and maintaining the validity of control areas is key to the evaluation methodology and interpretation of its findings. Therefore we request that key stakeholders review and sign this document to indicate their approval, or suggest any modifications needed to reach agreement on the proposed strategy and obtain approval. Please do not hesitate to contact us if you have questions or would like further information or clarification.

Stakeholders to Review

Lusaka Water and Sewerage Company
Lusaka City Council

Annex 1: Non-LWSSD-Compact Water and Sanitation Interventions in Lusaka (Example)

BAULENI	
Funding	Bauleni Compound water and sanitation improved project is funded by The Cocoa Cola Africa Foundation (TCCAF) and Irish Aid.
Start Date	
Completion Date	The project is slated for completion in February 2015
Scope of Work	The project involves network replacement, tank construction and kiosk rehabilitations, and pre-paid metering: - **18 km** of water supply network - Installation of pre-paid meters to individual households connecting to network - underway - Construction of a new **250m³** concrete ground reservoir (site to be determined – no GPS coordinates) and rehabilitation of about **25 water kiosks and communal taps** - This new reservoir will be fed by 4 new boreholes Under Irish Aid funding: - Another **87m³** overhead tank will be constructed - In addition, a new borehole will be drilled to supply the existing **50m³** tank
Target Population	**~ 38,000** people to benefit
Intervention Location	*Geographic (street) and/or GIS boundaries*
CHAINDA	
Funding	The Cocoa Cola Africa Foundation (TCCAF) and Irish Aid
Start Date	
Completion Date	The project is slated for completion in February 2015
Scope of Work	Network replacement, tank construction and kiosk rehabilitations, and metering - **15.4** km of water supply network - Installation of pre-paid meters to individual households connecting to network - underway - Construction of a new **100m³** water reservoir and rehabilitation of **25 water kiosks and communal taps** - This new reservoir will be fed by 3 existing boreholes (one borehole was funded by LWSC) - *Chainda did not previously have any water supply reservoir tanks
Target Population	**~ 28,000** people to benefit
Intervention Location	*Geographic (street) and/or GIS boundaries*
LINDA	
Funding	
Start Date	

<table>
<tr><td>Completion Date</td><td colspan="2">2014</td></tr>
<tr><td>Scope of Work</td><td colspan="2">SOW included tank construction, network replacement, construction of new water kiosk and hygiene promotion activities:
- 7.5 km of water supply network
- Construction of new 150m³ elevated steel water tank
- Construction of 10 water kiosks
- Hygiene Promotion: - hygiene education in schools, community centers and households
- Distribution of hygiene promotion materials (leaflets, bags, pens and book)
- Training of 20 local artisans (2 working on the project)
- Establishment of a Water Committee to manage water supply at community level
- Training if 5 community based organization in governance and in water, sanitation & hygiene</td></tr>
<tr><td>Target Population</td><td colspan="2">~ 20,000 people to benefit</td></tr>
<tr><td>Intervention Location</td><td colspan="2">Geographic (street) and/or GIS boundaries</td></tr>
<tr><td colspan="3">KALINGALINGA</td></tr>
<tr><td>Funding</td><td colspan="2">- LWSC: Water Network and Hygiene promotion
- MLGH: Sewer network
- World Bank: Technical Assistance
- Beneficiaries: Toilet construction</td></tr>
<tr><td>Start Date</td><td colspan="2"></td></tr>
<tr><td>Completion Date</td><td colspan="2">Phase 1: Completed
Phase 2: Commencing in March 2015 (planned date)
Phase 3: Commencing after 2016 (planned date)</td></tr>
<tr><td rowspan="3">Scope of Work</td><td>Phase 1</td><td>Water and sewer network extension, sanitation marketing:
- 3.2 km of sewer network
- 4.5 km of water supply network (90 new HHs connected)
- Construction of 156 toilets (target): Only 45 toilets were built and connected to sewer network</td></tr>
<tr><td>Phase 2</td><td>Planned Activities: Water and sewer network extension, sanitation marketing
- About 12 km of sewer network to be built (to include truck main)
- About 9 km of water supply network to be installed
- Sanitation marketing: Toilet construction by beneficiaries - X target toilets to be built (TBD)</td></tr>
<tr><td>Phase 3</td><td>Planned Activities: Water and sewer network extension, sanitation marketing
- About 20 km of sewer network to be built
- About 15 km of water supply network to be installed
Sanitation marketing: Toilet construction by beneficiaries - X target toilets to be built (TBD)</td></tr>
<tr><td>Target Population</td><td colspan="2">156 households</td></tr>
<tr><td>Intervention Location</td><td colspan="2">Geographic (street) and/or GIS boundaries</td></tr>
</table>

KABANANA	
Funding	Devolution Trust Fund (Zambia)
Start Date	Starting in early 2015
Completion Date	
Scope of Work	- **13.3km** Water network - About **305 m^3** water supply overhead reservoir tank - Software component: - Selection of community based Project Task team - Community sensitization on project objectives and hygiene promotion
Target Population	**~ 22,000** people to benefit
Intervention Location	*Geographic (street) and/or GIS boundaries*

Appendix 7: Sample Size Considerations – Household Survey

Water and Sanitation Interventions

Crude sample size estimates for differences in proportions and means are computed with the following varied assumptions: 1) prevalence of disease outcome; 2) intended power of 80% and 90% to detect effect; and 3) a minimum design effect of 2 to account for cluster sampling. We will aim to select at least half the SEAs in an intervention area to minimize cluster effects. Assumptions specific to this evaluation are below, and sample size estimates given varying levels of power are included in Table 1, below.

- Water supply intervention, children under five years old: At baseline it is estimated that a diarrhea prevalence of 15% will be seen among children under five years of age. Water supply interventions are expected to reduce this to 12% while remaining unchanged in the comparison group for a 20% reduction overall (Waddington et al., 2009; Fewtrell et al., 2005).
- Water supply intervention, children 6-24 months: For children aged 6-24 months the baseline diarrhea prevalence is expected to reduce from 25% to 20% in the water supply intervention group. The prevalence in the control group is expected to remain constant at 25%. Thus, a 20% reduction in diarrheal prevalence is also expected among children aged 6-24 months living in areas receiving water supply interventions.
- Sanitation intervention: Sanitation interventions are expected to reduce the prevalence of diarrheal illness from 25% at baseline to 16.25% at follow-up (while remaining unchanged in control areas) for an overall reduction of 35%. (Waddington et al., 2009; Fewtrell et al., 2005). The sample size estimates given these assumptions and varying the power are displayed in Table 1.

Table 1: Sample Size Calculations

Power	Intervention Sample Size	Comparison group sample size	Sample Size Grp 1 N1	Sample Size Grp 2 N2	Prop|H1 Grp 1 or Trtmnt P1	Prop Grp 2 or Control P2	Diff if H0 D0	Diff if H1 D1	%reduction
0.9	4114	8228	2057	4114	0.12	0.15	0	-0.03	20
0.8001	**3092**	**6184**	**1546**	**3092**	**0.12**	**0.15**	**0**	**-0.03**	**20**
0.9001	2208		1104	2208	0.2	0.25	0	-0.05	20
0.8001	1658		829	1658	0.2	0.25	0	-0.05	20
0.9005	678		339		0.1625	0.25	0	-0.0875	35
0.8006	512		256		0.1625	0.25	0	-0.0875	35

The primary health outcomes that will be evaluated require large sample sizes to detect significant intervention impacts, and therefore, if used, will adequately power all other study objectives. For comparison, the sample size calculated to detect a reduction in minutes to collect water from 180 to 120 minutes would require only 112 to 224 households (depending on a design effect of 2 or 4) per each group to be 90% powered. To detect a reduction in time to collect water from 180 to 60 minutes would only require a sample size of 30 households per group (assuming a design effect of 2).

These preliminary sample size calculations assume best case scenarios in which there are not major differences occurring in both the intervention and comparison groups at baseline and follow-up periods. For example, activities such as rotavirus vaccine campaigns occurring or other NGO activities might provide additional noise to be controlled for in the data and thus require a larger sample size. In particular, sample size estimates assume that baseline proportions will be the same in both intervention and comparison groups. In addition, for modeling purposes (e.g., adjusting for covariates), we may require additional observations to retain adequate power to report adjusted estimates.

Cluster Sampling, Design Effect, and ICC

A cluster is usually defined as a pre-organized group of respondents which may be organized for other purposes such as health care facilities or geographic areas. In this study, SEAs serve as predefined areas from which to sample and serve as our clusters. Data from cluster surveys tend to be correlated because of the similarity in respondents within a cluster. The *intraclass correlation coefficient* (ICC) is used to quantify the degree to which individuals within a cluster resemble each other in terms of a quantitative trait. The intraclass correlation coefficient is a measure of the homogeneity of elements within clusters and has an upper limit of 1 (which would indicate complete homogeneity within clusters) (Kish, 1965). The ICC can vary greatly depending on the quantitative attribute being measured.

When planning a complex survey sample, the sample size should account for potential correlation in the data. A common approach is to estimate a sample size, *n*, with a formula that does not account for correlation, and then to calculate a final sample size by multiplying *n* by an estimate of the design effect (Rowe et al., 2002). For study design and sample size calculations, this approach requires deciding, *a priori,* what number to use for the design effect, which will serve as the multiplier to increase the sample size to account for the within cluster correlation. A minimum design effect of 2 is frequently assumed. Previous complex surveys conducted in Lusaka, although using a different sampling design, have suggested that the design effect for diarrhea measures in children under 5 is as low as 1.2 (CSO, 2009).

The design effect is defined as 'the ratio of the actual variance of a sample to the variance of a simple random sample of the same number of elements' (Kish, 1965). The formula for the design effect is $\rho(m - 1) + 1$, where ρ is the intraclass correlation coefficient and m is the average number of consultations per cluster (Kish, 1965). Using this formula, it is evident that the design effect increases as the cluster size increases (and if using a fixed design effect, you must assume a lower ICC as the cluster size increases). Therefore, this study will aim to use the determined sample size to maximize the number of clusters sampled and thus reduce the average cluster size (m) to account for larger ICCs. Table 2, below, reflects the calculated ICC, assuming a fixed design effect of 2 and an average cluster size of 30 and 60.

Table 2: ICC Calculations

Average cluster size (m)	Design Effect	ICC (ρ)
30	2	0.03
60	2	0.02

Equation:
DEFF = $1 + \rho (m - 1)$, where
DEFF is the design effect,
ρ is the intraclass correlation for the statistic in question, and,
m is the average size of the cluster

Appendix 8: Water Quality Monitoring Protocol

Protocol Number: XXXXX

Protocol Sponsors and Collaborators
Ministry of Health (MOH), Lusaka, Zambia
Lusaka Water and Sewerage Company (LWSC), Lusaka, Zambia
Zambia Bureau of Standards (ZABS), Lusaka, Zambia
Centers for Disease Control and Prevention (CDC-Z), Lusaka, Zambia
Centers for Disease Control and Prevention (CDC-A), Atlanta, GA, USA

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Andrew Thornton, Epidemiologist, WDPB (CDC-A)

Date: November 12, 2014

Executive Summary

Context

Diarrheal diseases, the second leading cause of death in children under five, are often associated with a lack of access to safe water and adequate sanitation. The Millennium Challenge Corporation (MCC) is partnering with the Government of Zambia (GRZ) under the Millennium Challenge Account - Zambia (MCA Zambia) to improve the water, sanitation, and drainage systems in Lusaka. CDC will evaluate the health and economic impact of these interventions. As part of this evaluation, microbial, chemical, and physicochemical measures at various points from source to stored water will be used to assess water quality before, during, and after interventions are complete.

Project Objectives

As part of the larger project goal to evaluate the impact of the water, sanitation, and drainage interventions on the incidence of diarrheal disease, we will use water quality measures to assess improvements in water and sanitation interventions in peri-urban areas (PUAs) in Lusaka. To achieve these goals we have the following objectives:

1. To measure select microbial, chemical, and physicochemical water quality parameters in a random selection of stored household drinking water, point-of-consumption (POC) drinking water, and corresponding source water in intervention and control PUA households prior to

interventions (baseline) and after interventions are complete (follow-up), as part of CDC's health impact evaluation.

2. To routinely measure select microbial, chemical, and physicochemical water quality parameters at various points within the distribution system, including the Iolanda Treatment Plant, boreholes, the Chilanga Booster Station, ten main booster stations within the city, public kiosks and tap stands, and household connections in intervention and control areas throughout the intervention time period. The World Health Organization advises that ongoing water quality assessment is an essential component of a well-managed distribution system.

3. To routinely measure select chemical and physicochemical water quality parameters of influent and effluent streams at the Kaunda Square Stabilization Ponds throughout the intervention time period in order to assess effects of sanitation upgrades in Lusaka.

Table of Contents

Abbreviations

CDC-A	Centers for Disease Control and Prevention – Atlanta
CDC-Z	Centers for Disease Control and Prevention – Zambia
COD	Chemical oxygen demand
FCR	Free chlorine residual
GRZ	Government of Zambia
HPC	Heterotrophic plate count
LWSC	Lusaka Water and Sewerage Company
MCA Zambia	Millennium Challenge Account – Zambia
MCC	Millennium Challenge Corporation
MOH	Ministry of Health
POC	Point-of-consumption
ppm	Parts per million (equivalent to mg/L)
PUA	Peri-urban area
QA/QC	Quality assurance/quality control
SOP	Standard operating procedures
TSS	Total suspended solids
WASH	Water, sanitation, and hygiene
WHO	World Health Organization
ZABS	Zambia Bureau of Standards

Acknowledgements

The authors wish to thank Tracy Ayers and Xin (Lucy) Lu for their assistance with sample size analysis and Dr. Daniele Lantagne for her assistance with study design.

Introduction

Global Water and Sanitation Crisis

Diarrheal disease is the second leading cause of death in children under five years of age. Safe drinking-water and adequate sanitation and hygiene can help prevent or reduce diarrheal disease.[1] Drinking water is considered safe if it meets World Health Organization (WHO) guidelines or national standards for drinking water quality; the proportion of people using improved drinking water sources is used as a proxy measure to access to safe drinking water. Likewise, the proportion of people using improved sanitation facilities, such as flush toilets and piped wastewater systems, serves as a proxy to access to basic sanitation. In 2010, 89% of the global population had access to an improved drinking water source; most of this growth was from gained access to a piped drinking water supply on premises. In addition, 64% of the global population had access to improved sanitation in 2010, an increase of 1.8 billion people from 1990. However, while access to improved water and adequate sanitation has seen improvements in recent years, almost 750 million people still lacked access to improved water sources and 2.5 billion people still lacked improved sanitation in 2010.[3]

Water and Sanitation Infrastructure in Lusaka, Zambia

Lusaka is the capital of Zambia, with a population of over 1.8 million. It is a fast-growing city, with substantial growth in peri-urban areas (PUAs). Due to the nature of unplanned settlement growth in PUAs, water and sanitation utilities encounter great challenges in providing adequate services. As a result, populations in these types of areas can often experience a high risk of water- and sanitation-related disease.

Water Sources and Treatment Processes

The Lusaka Water and Sewerage Company (LWSC) is the commercial utility responsible for the provision of water and sanitation in the greater Lusaka area. Lusaka's water and sanitation systems were built in the 1960s and 1970s; due to the rapid increase in need for these services, much of the infrastructure is unable to provide optimal services.

Kafue River and Iolanda Treatment Plant

The Kafue River serves as a main drinking water source for Lusaka. Water is treated at the Iolanda Water Treatment Plant, nearly 40 km outside of Lusaka city limits. The treatment plant consists of coagulation/flocculation, up-flow sedimentation, rapid gravity filtration, disinfection by chlorine gas, and pH correction with lime. The Iolanda Treatment Plant supplies Lusaka with approximately 98,000 m^3 of water per day.

Boreholes

Water from approximately 100 boreholes located throughout the city is chlorinated and fed into the distribution system directly or first through reservoirs. Groundwater supplies Lusaka with approximately 130,000 m^3 of water per day.

Water Distribution System

Transmission Mains

There is one treated water transmission main from Iolanda Treatment Plant to Lusaka. The first section runs from Iolanda to the Chilanga Booster Station; the second section runs from Chilanga Booster Station to Stuart Park Reservoirs in Lusaka. The Chilanga Booster Station and Stuart Park Reservoirs are chlorinated.

Distribution Centers

Treated water is fed into the Lusaka distribution system from four main points: 1) transmission main terminal reservoirs at Stuart Park; 2) offtake from Kafue transmission main at Lusaka Water Works to Lumumba Reservoirs; 3) offtake from the Kafue transmission main at Lusaka Water Works to Woodlands and High Court Reservoirs; and 4) various boreholes within the distribution system which feed the system either directly or to reservoirs first before distribution.

Booster Stations

There are ten main booster stations situated at the following storage reservoir locations: Stuart Park, Lusaka Water Works, Lumumba, High Court, Woodlands, Mass Media, 7C (Mtendere), Quarry, Chleston, and Chawama. Distribution lines extend from these ten main booster stations and feed into select areas of the city.

Kiosks and Public Taps

More than 600 kiosks and public taps are located in various peri-urban areas and are fed by the distribution system. They are generally functional only at select times in the day. A number of kiosks are currently non-functional.

Household connections

Low, medium, and high income households throughout the city have household connections. A household connection is generally supplied to the edge of the property and the land owner is responsible for piping it into the household. Many households utilize one single standpipe located within the household lot. Household connections provide either metered or flat rate water service.

Sanitation Systems

Currently, approximately only 65% of Lusaka residents have access to piped sewerage; most of these residents live outside of PUAs. Sanitation services in Lusaka consist of two wastewater treatment plants and the Kaunda Square Treatment Ponds. None of the waste treatment systems in Lusaka are at optimal operation.

Kaunda Square Ponds

The Kaunda Square Stabilization Ponds were commissioned in 1970 and have received very limited maintenance since then. Banks that originally separated the three separate ponds have been damaged and the pond is now one single body of water. In the last 40 years, the service area has been developed extensively and the pond is beyond treatment capacity. Furthermore, as the sewer systems have declined, they now serve as combined storms and sanitary sewers; the ponds are not designed to handle the increased hydraulic loads and introduction of inorganic grit from these sewers, especially during the rainy season. Pond effluent is not disinfected prior to its discharge into a small, seasonal stream and it is often used by the downstream community for food and non-food crop irrigation. Lusaka residents that are without sanitation access typically rely on pit latrines, which are often improperly designed and lead to groundwater contamination.

MCC Interventions Covered under the CDC Evaluation

MCC interventions chosen for the Zambia Compact were selected to support the continued growth of LWSC's ability to better manage water and sanitation in select PUAs. Water interventions include rehabilitation of Iolanda Treatment Plant, transmission mains, and distribution centers; strengthening of the primary distribution system by adding and repairing pipelines; and increasing water supply and water quality through expansion of household connections, addition of boreholes, and rehabilitation of infrastructure such as reservoirs and kiosks. Sanitation interventions include sewer network expansion; and repair and upgrading of pumping stations and interceptors; and upgrade and expansion of Kaunda Square Stabilization Ponds.

CDC Evaluation

CDC's role is to independently evaluate select Compact activities by conducting monitoring and evaluation activities to assess the project's impact on health outcomes; economic indicators; water, sanitation, and hygiene (WASH) characteristics; behavior change; and flood risk reduction. As part of this evaluation, CDC will measure select microbiological, chemical, and physicochemical water quality parameters before, during, and after interventions are complete. Areas considered eligible but do not receive intervention services will be considered as control areas for the evaluation.

Measurement Parameters

In order to assess water quality, select microbiological, chemical, and physicochemical parameters will be measured in water and wastewater.

Water Parameters

Microbial Concentration

Due to complexity, sensitivity, cost, and time required, testing for specific waterborne pathogens is not routinely performed in water treatment or distribution systems. Instead, use of *Escherichia coli* (*E. coli*) as an indicator of fecal pollution in water is well-established.[4] *E. coli* are present in high numbers in the gut of warm-blooded animals, including humans, therefore their presence in water is indicative of the presence of fecal contamination and predictive of the presence of pathogens. The WHO Guidelines for Drinking Water Quality state that there must be no detectable *E. coli* in any 100 mL sample of treated water entering or within the distribution system or in water directly intended for drinking.[5] WHO's recommended minimum sample numbers per year for *E. coli* testing in piped distribution systems are presented below and in Appendix C. Total coliforms and heterotrophic plate count (HPC) bacteria, while not indicators of human-specific fecal contamination, are also used as indicators for the effectiveness of disinfection processes and the integrity of distribution systems. WHO does not provide guideline values for these microbial indicators.[5-6]

Free Chlorine Residual

The most common chemical type monitored in water treatment and distribution systems is disinfectant residual.[5-6] LWSC's Iolanda Water Treatment Plant and most of its booster stations situated throughout the network utilize chlorine gas for disinfection. Free chlorine residual (FCR) is the amount of chlorine present in the water that is available for disinfection. For effective disinfection, WHO states that there should be a FCR of ≥0.5 mg/L (or parts per million [ppm]) for at least 30 minutes at pH <8.0; that a chlorine residual should be maintained throughout the distribution system; and that there should be a minimum FCR of 0.2 mg/L (maximum 5.0 mg/L) at the point of delivery.[5] WHO suggests weekly to monthly FCR testing from individual taps.[6]

Nitrates

Elevated levels of nitrates detected in water may be related to fecal contamination from inadequate sanitation. Routine monitoring of nitrate levels in distribution system water is necessary due to their acute negative health effects, especially in bottle-fed infants.[5]

Process Parameters

There are a number of physicochemical parameter measurements that should be performed routinely at the water treatment plant, throughout the distribution system, and at the point of delivery. These measures include: pH to assess efficacy of chlorine disinfection (optimally 7.0-7.5); turbidity to assess efficiency of treatment processes (optimally <5 NTU); conductivity to assess the presence of inorganic dissolved solids (i.e., increased concentration in the presence of sewage); temperature to assess potential for growth of microbes and/or reduced efficacy of disinfectant (i.e., warmer temperatures facilitate growth); and pressure to assess fluctuations that may lead to dislodgment of biofilms or ingress of contaminants.[5-6]

Wastewater Parameters

Process Parameters

Chemical oxygen demand (COD) is used as a measurement of pollutants and is often used to assess treatment efficacy in wastewater.[7] Additionally, high levels of total suspended solids (TSS) can indicate high concentrations of bacteria, nutrients, pesticides, and metals are present. Other wastewater treatment physicochemical measures include pH, temperature, total nitrogen, and total phosphorous.

Objectives

As part of the larger project goal to evaluate the impact of the water, sanitation, and drainage interventions on the incidence of diarrheal disease, we will use water quality measures to assess improvements in water and sanitation interventions in peri-urban areas (PUAs) in Lusaka. To achieve these goals we have the following objectives:

1. To measure select microbial, chemical, and physicochemical water quality parameters in a random selection of stored household drinking water, POC water, and corresponding source water in intervention and control PUA households prior to interventions (baseline) and after interventions are complete (follow-up), as part of CDC's health impact evaluation.

2. To routinely measure select microbial, chemical, and physicochemical water quality parameters at various points within the distribution system, including the Iolanda Treatment Plant, boreholes, the Chilanga Booster Station, ten main booster stations within the city, public kiosks and tap stands, and household connections in intervention and control areas throughout the intervention time period. The World Health Organization advises that ongoing water quality assessment is an essential component of a well-managed distribution system.

3. To routinely measure select chemical and physicochemical water quality parameters of influent and effluent streams at the Kaunda Square Stabilization Ponds throughout the intervention time period in order to assess effects of sanitation upgrades in Lusaka.

For Objectives 1 and 2, comparisons will be made between measurements taken before, during, and after interventions are complete, as well as between control and intervention areas. Furthermore, as part of Objective 1, comparisons will be made between measurements taken from a subset of stored household drinking water and corresponding POC water. These latter data may provide information on water storage and handling practices. For the Kaunda Square treatment pond (Objective 3), comparisons will be made between measurements taken before, during, and after interventions are complete, as well as between influent and effluent streams. The extent of improvement will be based on frequency of outcomes (e.g., fewer *E. coli* positive water samples; increase in number of households with FCR concentration ≥0.2 mg/L; decrease in BOD in effluent samples).

Methodology

Objective 1: Household and Source Water Quality Testing

Overview

The health impact study will consist of three arms: 1) PUAs receiving water supply interventions; 2) PUAs receiving both water supply and sanitation interventions; and 3) control PUAs. There will be 1:2 matching between treatment and control groups. Water quality testing will be performed in the field for intervention and control PUA households both before interventions (baseline) and after interventions are complete (follow-up). Stored household drinking water samples will be collected from a randomly-selected subset of these households for microbiological analysis. Within this subset, a random selection of POC water samples will be collected for microbiological analysis. Finally, water samples will be collected from source waters corresponding to the household drinking water.

Field Testing and Sample Collection

Following each interview, a field technician will measure FCR, pH, turbidity, conductivity, and temperature of stored drinking water on-site using field-portable digital probes and colorimeters. Stored household drinking water samples will then be collected from 1516 randomly-selected intervention households (758 from each of the two treatment arms) and 1516 control households (see Appendix A for sample size calculations).An additional sample of POC drinking water (e.g., water transferred by a household member to a drinking glass) will be collected from 25% of study households (379 randomly-selected invention and 379 randomly-selected control households). Each sample will be collected into a sterile sample collection bottle containing sodium thiosulfate to neutralize any chlorine present. The source of that stored drinking water will be located and water testing will be performed as described above to provide assessment of distribution system upgrades as well as to provide information on the impact of household drinking water storage. For the baseline study, we assume that there will be one source for every four households; for the follow-up study, we assume that there will be one source for every two households. An ethanol wipe will then be used to clean the inside and outside surfaces of the tap and a water sample will be collected as described above. Pressure of the tap will also be measured at the source using a pressure gauge.

Laboratory Analyses

Sample bottles will be stored and transported back to the laboratory on ice and will be analyzed the same day (within 4-6 hours of collection) by a standard membrane filtration method[7] (see additional details in Appendix B). In the laboratory, a 100 mL volume of each sample will be membrane-filtered (0.45 µM, 47 mm) and the filter placed on Petri dishes containing MI agar, a medium that is selective for total coliforms and *E. coli*. Plates will be incubated at 35-37 °C for 22-24 hours. Colonies exhibiting select characteristics will be enumerated to provide bacterial concentrations. In cases of highly turbid water (e.g., treatment plant source water), a tenfold dilution of a sample may need to be performed prior to analysis. Additionally, samples will be analyzed in the laboratory for nitrate concentration using a spectrophotometric method.

Objective 2: Routine Distribution Water Quality Monitoring

Overview

Various types of network water samples will be collected in intervention and control PUAs on a quarterly basis (every three months) throughout the four-year intervention time period. Network components to be tested include: influent (source water) and effluent (treated water) from the Iolanda Water Treatment Plant, boreholes, the Chilanga Booster Station, ten main booster stations located within the city, public kiosks and tap stands, and household connections (see Appendix C for additional details). WHO guidance for yearly *E. coli* testing in piped distribution systems will be followed (i.e., for a population >500,000, 12 samples per 50,000 population plus an additional 600 samples.[5]; for Lusaka this equates to 1032 samples per year). The same sample locations will be used for the duration of the study for consistency in temporal assessment.

Field Testing and Sample Collection

A field technician will measure FCR, pH, turbidity, conductivity, and temperature on-site using field-portable digital probes and colorimeters; pressure will be measured using a pressure gauge. Then an ethanol wipe will then be used to clean the inside and outside surfaces of the tap. A water sample will be collected into a sterile sample collection bottle containing sodium thiosulfate (to neutralize any chlorine present).

Laboratory Analyses

The sample bottle will be stored and transported back to the laboratory on ice and will be analyzed the same day (within 4-6 hours of collection) by a standard membrane filtration method.[7] In the laboratory, a 100 mL volume of the sample will be membrane-filtered (0.45 µM, 47 mm) and the filter placed on Petri dishes containing MI agar, a medium that is selective *E. coli* and total coliforms. Plates will be incubated at 35-37 °C for 24 hours. Colonies exhibiting select characteristics will be enumerated to provide bacterial concentrations. In cases of highly turbid water (e.g., treatment plant source water), tenfold dilutions of samples may needed. Additionally, HPC bacteria will be quantified in distribution system samples in the laboratory using membrane filtration and R2A agar.[7] Samples will also be analyzed for nitrate concentration using a spectrophotometric method. Lead testing will be conducted annually using atomic absorption spectroscopy.

Objective 3: Routine Wastewater Stabilization Pond Testing

Overview

Influent and effluent streams at the Kaunda Square Treatment Ponds will be analyzed on a quarterly basis to assess changes that might be due to sanitation interventions made upstream and at the ponds.

Field Testing and Sample Collection

Each quarter, influent stream samples and final effluent stream samples will be tested on-site for pH and temperature. One-liter samples will be collect and acidified on-site and shipped to CDC-A within 30 days for laboratory testing.

Laboratory Analyses

Due to logistical concerns and the production of hazardous wastes in COD analysis, samples will be shipped to CDC-A for COD, TSS, total phosphorous, and total nitrogen analyses.

Quality Assurance/Quality Control

In order to ensure quality sample analysis, the following measures will be undertaken:

- Field and laboratory staff will undergo training by CDC staff and be tested on proficiency.
- Equipment will be calibrated and monitored on a routine basis; all calibration and monitoring will be documented.
- Each day of analysis, microbiological assays will include parallel analysis of positive and negative controls.
- Ten percent (10%) of samples will be analyzed in duplicate for each water quality parameter.
- Two laboratory staff will be tasked with reviewing and signing off on Chain of Custody forms, laboratory data sheets, and data entry into the electronic database.
- CDC staff will review electronic copies of Chain of Custody forms, laboratory data sheets, and data entry into an electronic database.
- A senior member from the laboratory organization will be briefed on the project progress and will be available for consult if laboratory problems arise.

Waste Management

It is the laboratory's responsibility to comply with all regulations governing waste management, particularly the biohazard and hazardous waste identification rules and land disposal restrictions, and to protect the air, water, and land by minimizing and controlling all releases from fume hoods and bench operations. Samples, reference materials, and equipment known or suspected to have viable microbes must be disinfected prior to disposal or reuse.

Data

Data Management

Hard copies of Chain of Custody forms and laboratory data sheets will scanned for storage as electronic documents and will also be stored onsite at the laboratory (hard copy filing strategy to be determined). An online database will be created so that data collected in the field and in the laboratory can be entered directly following analysis and can then be monitored in real-time by CDC staff.

Data Analysis

Analysis of the results will be done in using Microsoft Office 2013 (Redmond, WA, USA) and SAS software version 9.3 (Cary, NC, USA), or similar software. Comparisons will be made between measurements taken before, during, and after interventions are complete, as well as between control and intervention areas. The extent of improvement will be based on frequency of outcomes.

References

1. WHO. (2013). Diarrhoeal Disease. from http://www.who.int/mediacentre/factsheets/fs330/en/

2. WHO and UNICEF. (2006). Core Questions on Drinking Water and Sanitation for Household Surveys. Geneva, Switzerland.

3. WHO and UNICEF. (2012). Progress on Drinking Water and Sanitation: 2012 Update.

4. WHO. (2011). Guidelines for Drinking-Water Quality (4th ed.). Geneva, Switzerland.

5. WHO. (1997). Guidelines for Drinking-Water Quality (2nd ed., Vol. 3 Surveillance and Control of Community Supplies). Geneva, Switzerland.

6. WHO. (2014). Water Safety in Distribution Systems. Geneva, Switzerland.

7. APHA. (2005). *Standard Methods for the Examination of Water and Wastewater* (21st ed.). Washington, DC

Appendices

Appendix A: Intervention Study Sample Size Analysis

- *E. coli* concentration and free chlorine residual are considered the two most important parameters for assessment of water quality improvement.
- Free chlorine residual will be measured in each household interviewed, so this parameter is not necessary for sample size calculation.
- LWSC performs ongoing distribution system testing throughout Lusaka each quarter. LWSC 2013 water quality monitoring reports were analyzed to aid in sample size calculation.
    - LWSC does not test for *E. coli*, the WHO-recommended microbial standard assessing distribution systems. Instead, they test for a less-specific fecal indicator (fecal coliforms). For sample size calculation purposes, we use LWSC's fecal coliform results (83% of samples were <1 CFU [colony forming unit]/100 mL) as a conservative proxy for *E. coli*.

Indicator	**Standard**	**2013 Compliance**
fecal coliform concentration	<1 CFU/100 mL	82.6%

Per Tx Arm SS	Control Arm SS	Follow-up proportion	Baseline Proportion	Detectable difference
1832	3664	0.85	0.8	0.05
1576	3152	0.88	0.83	0.05
894	1788	0.87	0.8	0.07
758	1516	0.90	0.83	0.07
514	1028	0.89	0.8	0.09
430	860	0.92	0.83	0.09

(758 per arm * 2 arms) + 1516 controls = 3032 samples

- Sample size calculation designates improvement to 90%, or an overall 7% detectable difference; power=90%

Appendix B: Intervention Study Sampling Details

Baseline	# samples
Stored household water	3100
POC water	775
Source water (assume 4 hh: 1 source)	775
QA/QC 10% duplicates	465
Total samples needed	**5115**
Total samples to collect per day	**25**
Samples to collect per day per team	**6-7**
Stored household water	*4*
POC water	*1*
Source water	*1*
QA/QC 10% duplicates	*0-1*
Daily positive and negative controls	408
Total samples to analyze (incl. controls)	**5523**
Samples to analyze per day (incl. controls)	**~27**

Follow-up	# samples
Stored household water	3100
POC water	775
Source water (assume 2 hh: 1 source)	1550
QA/QC 10% duplicates	543
Total samples to collect	**5968**
Total samples to collect per day	**29**
Samples to collect per day per team	**7-8**
Stored household water	*4*
POC water	*1*
Source water	*2*
QA/QC 10% duplicates	*0-1*
Laboratory controls	408
Total samples to analyze (incl. controls)	**6376**
Samples to analyze per day (incl. controls)	**~31**

Sampling logistics

- Samples will be collected and transported to the laboratory for *E. coli* and nitrates analyses.
- Samples must be collected from Monday through Thursday, resulting in approximately 17 sampling days per month and 204 sampling days per year. The laboratory cannot analyze samples on Fridays unless Saturday work days for reading results are included in the budget. If Saturday work days are possible, there will be approximately 4 fewer samples to collect and analyze on M-R.
- Samples must be collected by 1:30 pm (including 30 minutes for lunch) in order to be transported to the laboratory and analyzed by 5:00 pm that day.

- We estimate that each field team can visit 8 collection sites per day:
    - Complete 1 interview, test water on-site, and collect samples in approximately 1 hr (1 hr/household * 4 households = 4 hrs); note: 10% of samples will be collected in duplicate
    - Test and collect 1 (baseline) or 2 (follow-up) source water samples for households visited in approximately 0.5-1 hr
- Assuming four field teams:
    - A total of 16 stored household water samples can be collected and analyzed per day. A total of 272 stored household water samples can be collected and analyzed per month (approximately 17 work days).
    - A total of 3264 stored household water samples can be collected and analyzed at both Baseline and Follow-up, which meets our sample size requirement.

Laboratory logistics

- Samples must be analyzed from Monday through Thursday.
- Samples must arrive to the lab by 2:00 pm in order to be processed by 5:00 pm that day.
- We estimate that the lab can process 24-32 samples per day for total coliforms/*E. coli* and nitrates: 16 stored household water samples, 4 POC samples, 4-8 source water samples, 0-4 duplicate samples (10% of samples in duplicate for QA/QC purposes), 1 positive control, 1 negative control
- We estimate that membrane filtration can be performed by 1 microbiologist in ~2.5 hrs; nitrates analysis can be performed by 1 chemist in ~2 hrs; clean-up will take ~0.5 hr.
- Microbiological results can be read the day following analysis (after 22-24 hrs incubation).
- ~2 hours of data entry from the previous day and ~1-2 hrs of prep work must be completed prior to samples arriving each day.
- It is recommended that LWSC does not perform the laboratory analyses for the following reasons: 1) LWSC does not routinely perform *E. coli* analysis, and 2) water quality tests should be performed by an independent laboratory.

Summary

The above sample size calculation and sampling details are the minimum level approach for the Intervention Study in order to be 1) powered to see an increase in the proportion of *E. coli* non-detect samples [83% (estimate based on available data) to 90%], and 2) considered realistic for field and laboratory teams to manage on a daily basis. We propose offering ZABS $20 per sample for total coliforms/*E. coli* analysis (we will provide the microbiological media) and $10 per sample for nitrates analysis, for a total of $30 per sample. Please note: this price includes the costs of consumables (including, but not limited to, pipets, membrane filters, Petri dishes, positive microbiological controls, and nitrate standards), labor, and costs associated with performing equipment calibrations and running daily positive and negative microbiological control analyses. ZABS will not be responsible for collecting samples in the field for the Intervention Study.

A "gold standard" approach would involve increasing the sample size in order to see an even greater increase in proportion of *E. coli* non-detect samples (i.e., 83% to 95%). A sample size increase will require:

- An increase in the number of field teams collecting samples each day

- Additional field testing equipment (~$3600 per team)
- An additional microbiologist to assist with sample analysis

Appendix C: Ongoing Monitoring Sampling Details (Distribution System and Kaunda Square Ponds)

	No. samples/quarter	No. samples/year	No. samples/ 4 years
Iolanda Plant influent	1	4	16
Iolanda Plant effluent	1	4	16
10 booster stations	10	40	160
New boreholes*	14	56	224
25% of existing boreholes	25	100	400
Renovated kiosks*	36	144	576
Existing kiosks in intervention	36	144	576
Existing kiosks in control	72	288	1152
New hh connections*	40	160	640
Existing hh connections in intervention	40	160	640
Existing hh connections in control	80	320	1280
(Kaunda Square Pond influent and effluent)†	*2*	*8*	*32*
Subtotal	357	1428	5712
QA/QC 10% duplicates	36	143	571
Total	**393**	**1571**	**6283**
Samples to collect per day	**7-8**		
Controls	102	408	1632
Samples to analyze per day (incl. controls)	**~10**		

hh: households

*Total sample number per year prior to these interventions is 1060, which is still above WHO's minimum recommended sample number (n=1032) for a city of this size

†To assess sanitation improvements, pH and temperature testing will be performed onsite, followed by sample collection and shipment to CDC Atlanta; no ZABS laboratory tests are required for these samples

Sampling logistics

- Distribution system water will be tested onsite and samples will be collected and transported to the laboratory for total coliforms, *E. coli*, HPC, and nitrates analyses. Kaunda Square Ponds wastewater will be tested onsite and samples will be collected and shipped to CDC Atlanta; these samples do not require ZABS laboratory analysis.
- Samples must be collected from Monday through Thursday, resulting in approximately 17 sampling days per month and 204 sampling days per year. The laboratory cannot analyze samples on Fridays unless Saturday work days for reading results are included in the budget. If Saturday work days are possible, there will be approximately 1 less sample to collect and analyze on M-R.
- Samples must be collected by 2:00 pm (including 30 minutes for lunch) in order to be transported to the laboratory and analyzed by 5:00 pm that day.
- We estimate that the ZABS field technician can collect 7 distribution system samples per day:

    - Travel to a distribution system site, perform on-site testing, and collect 1 distribution sample in approximately 45 mins (0.75 hr/site * 7 sites = 5.25 hrs) per day; note: 10% of samples will be tested and collected in duplicate. *Note: 1 day per quarter, Kaunda Square Ponds (influent and effluent) will be tested on-site, collected and acidified, and shipped to CDC-A.
- Assuming one field technician:
    - A total of 355 distribution system water samples can be collected and analyzed (not including 10% duplicates) and 2 Kaunda Square Ponds samples can be collected and tested onsite per quarter.
    - A total of 1420 distribution system water samples can be collected and analyzed (not including 10% duplicates) and 8 Kaunda Square Ponds samples can be collected and tested onsite per year.
    - Excluding any new/renovated boreholes, kiosks, or household connections (as these will be added to the existing system over 4 years), a total of 1060 distribution system water samples (not including 10% duplicates) can be collected and analyzed per year. Therefore, this will still meet WHO's recommendation of testing 1032 distribution samples per year for a city of this size. Sample size will increase as construction or renovations are completed over 4 years therefore ensuring that WHO recommendations will be met.

Laboratory logistics

- Distribution system water samples must be analyzed from Monday through Thursday.
- Samples must arrive to the lab by 2:30 pm in order to be processed by 5:00 pm that day.
- We estimate that the lab can process 10 samples per day for total coliforms/*E. coli*, HPC, and nitrates: 7 distribution system water samples, 1 duplicate sample (10% of samples in duplicate for QA/QC purposes), 1 positive control, 1 negative control
- We estimate that membrane filtration can be performed by 1 microbiologist in ~2 hrs; nitrates analysis can be performed by 1 chemist in ~1 hr; clean-up will take ~0.5 hr; note: lead analysis will take ~1 hr per day for 3 months of the year.
- Microbiological results can be read the day following analysis (after 22-24 hrs incubation).
- ~2 hours of data entry from the previous day and ~1-2 hrs of prep work must be completed prior to samples arriving each day.

Summary

Throughout the four-year intervention period, a ZABS field staff member will travel to each water distribution system field site quarterly, for which we propose offering $30 per sample for water quality testing and sample collection. For the water distribution system, the above sample numbers and sampling details are adequate for ongoing monitoring of the distribution system based on recommendations provided by WHO. *E. coli* and nitrates testing provide water quality data that are relevant to health, while HPC testing provides water quality data that are relevant to efficacy of distribution system upgrades. We propose offering ZABS $20 per sample for total coliforms/*E. coli* analysis (we will provide the microbiological media), $15 per sample for HPC analysis (ZABS will provide the media), and $10 per sample for nitrates analysis. This results in a total cost of $75 per water distribution sample. Lastly, we also propose offering ZABS $10 per sample for lead analysis, which will be completed once annually on each of the water distribution samples. Please note: this price includes the costs of consumables (including, but not limited to, pipets, membrane filters, Petri dishes, positive microbiological controls, and nitrate and lead standards), labor, and costs associated with performing equipment calibrations and running daily positive and negative microbiological control analyses.

Throughout the four-year intervention period, a ZABS field staff member will travel to Kaunda Square Ponds field sites once quarterly to collect influent and effluent pond samples, for which we propose offering $20 per sample for water quality testing, sample collection and acidification (acid to be procured by ZABS), and packaging and shipment to CDC-A.

A minimum approach would eliminate HPC analysis (reducing laboratory analysis costs by $15 per sample) and/or lowering the frequency of nitrates testing to annually (reducing costs by $30 per sample per year). This is not recommended because we see value added in the inclusion of these two tests as described above. Furthermore, lead analysis could be eliminated, reducing costs $10 per sample per year).

A "gold standard" approach would involve increasing the sample number of the following: existing and new boreholes, existing and renovated kiosks, and existing and new household connections. A sample size increase will require:

- An increase in the number of field samplers collecting samples each day
- Additional field testing equipment (~$3600 per team)

Appendix D: ZABS and MCA-C/CDC Roles and Responsibilities

ZABS

Ongoing Monitoring sample collection; lab analyses for Intervention Study and Ongoing Monitoring

Staffing

1 microbiologist full-time for 4 years
1 microbiologist half-time for 2 years (Years 1 and 4), to assist full-time microbiologist
1 sample collector half-time for 4 years
1 chemist half-time for 4 years

Equipment

Membrane filtration manifold, pump, and related-equipment
Incubators (2; for TC/EC and HPC incubation)
Atomic Absorption Spectroscopy instrument
UV-1800 Spectrophotometer

Consumables

PPE
pipets
Sterile bottles for dilutions
Petri dishes (TC/EC and HPC)
0.45 µm, 47 mm membrane filters (TC/EC and HPC)
m-HPC or equivalent agar for HPC analysis
Microbiological reference materials
Lead analysis-related reagents
Nitrates analysis-related reagents
Phosphate buffered saline
Distilled water

Transportation

Vehicle and fuel for sample collection for 4 years

MCAZ/CDC

*Intervention Study Sample Collection; WW pond analyses

Staffing

Interviewers/sample collectors

1 CDC-A microbiologist 4 weeks/year for 4 years (in-kind)

Equipment

Field coolers and ice packs

All field equipment and calibration standards

Sample bottles

Reusable membrane filtration filter cups

Long-wave ultraviolet light

COD/TSS/total phosphorous/total nitrogen equipment

Consumables

MI agar

COD/TSS/total phosphorous/total nitrogen reagents

Shipping

Equipment and consumables to Zambia

WW pond samples to CDC-A (quarterly)

Transportation

Vehicles and fuel for sample collection

Appendix E: Proposed Budget

1. Supplies and Equipment to be purchased by MCA Zambia/CDC

FIELD SUPPLIES		Intervention Study	Ongoing Monitoring
One-Time Purchases	**Each**	**4 field teams (MCA Zambia)**	**1 field team (ZABS)**
Colorimeter for FCR	$450	$1,800	$450
pH/conductivity/temp meter	$700	$2,800	$700
Turbidimeter	$1,100	$4,400	$1,100
Sample bottles (400)	$1,200	$1,200	$1,200
Pressure gauges	$50	$200	$50
Coolers and ice packs	$50	$200	$50
Shipping	$1,000.00		
Subtotal	**$14,650.00**		
Annual Purchases	**Each**	**2 years (MCA Zambia) @ ~14,000 samples/year**	**4 years (ZABS) @ ~2000 samples/year**
FCR standards	$150	$300	$600
pH/conductivity standards	$50	$100	$200
Turbidimeter standards	$160	$320	$640
DPD 1 sachets (1000)	$200	$5,600	$1,600
Sodium thiosulfate	$50	$100	$200
Shipping	$1,000		
Subtotal	**$10,660**		
Field Supplies Total	**$25,310**		

LABORATORY SUPPLIES			
One-Time Purchases			
Membrane filtration filter cups (35)	($220 * 35)	$7,700	
Long-wave ultraviolet light		$200	
Annual Purchases		**2 years (MCA Zambia) @ ~6000 samples/year**	**4 years (ZABS) @ ~2000 samples/year**
MI agar (500 g = 2600 tests)	$1,500	$6,923	$4,615
COD/TSS/total N/total P reagents (CDC-A)	$600	-	$2,400
Shipping - reagents	$1,000		
Shipping - samples to CDC-A	$8,000		
Laboratory Supplies Total	**$30,838**		

Field and Laboratory Supplies Subtotal	$56,148
10% Misc. Expenses	$5,615
TOTAL	**$61,763**

2. Overall Proposed Budget for Water Quality Testing

Field and Laboratory Supplies	$62,000.00
Year 1	
Intervention Study - Baseline	(5115 samples * $30/sample) = $153,450
Ongoing Monitoring	(1562 samples * $75/sample) + (391 samples * $10/sample†) + (8 samples * $20/sample‡) = $121,220
Year 2	
Ongoing Monitoring	(1562 samples * $75/sample) + (391 samples * $10/sample†) + (8 samples * $20/sample‡) = $121,220
Year 3	
Ongoing Monitoring	(1562 samples * $75/sample) + (391 samples * $10/sample†) + (8 samples * $20/sample‡) = $121,220
Year 4	
Intervention Study - Follow-up	(5968 samples * $30/sample) = $179,040
Ongoing Monitoring	(1562 samples * $75/sample) + (391 samples * $10/sample†) + (8 samples * $20/sample‡) = $121,220
GRAND TOTAL	**$879,370**

†Lead analysis to be completed once per year on each of the 391 water distribution system samples
‡Influent and effluent streams at the Kaunda Square Treatment Ponds will be analyzed on a quarterly basis

Appendix 9: Business Questionnaire

Impact Evaluation of Lusaka Water Supply, Sanitation, and Drainage Project

Survey Instrument

Business Survey to Assess Flood Impact

04/22/15 Version

Draft: Please, do not copy or circulate!!

Evaluation by CDC for Millennium Challenge Corporation

Business Identifiers

Business Unique Identifier: ________________ **Township:** _________________________

Business Address: ____

Name of Business Owner: ____

Interviewer Visits		
	First Visit	**Final Visit**
Date (DD/MM/YYYY):		
Interviewer's Name:		
Result*:		
Next Visit Date: **Time:**	_______________ _______________	_______________ _______________
***Result Codes** **1** Completed **2** No business employee member at address or no competent respondent at time of visit **3** Business closed down **4** Postponed **5** Refused **6** Other (Specify):		

Total Number of Visits: ________________

A. Business Background

ENUMERATOR: Ask to speak to the business owner. If the business owner is not there, arrange to come back when he or she is present.

1) **First I would like to ask you some general questions about your business. What is your current role with this business?**
   ____ Owner (1)
   ____ Partner/co-owner (2)
   ____ Manager (3) **End Survey**. **Arrange for a follow-up visit to speak to the owner**
   ____ Employee (4) **End Survey**. **Arrange for a follow-up visit to speak to the owner**
   ____ Part time worker (5) **End Survey**. **Arrange for a follow-up visit to speak to the owner**
   ____ Client/customer (6) **End Survey**. **Arrange for a follow-up visit to speak to the owner**
   ____ Other, specify (88): ___________________ **End Survey**. **Arrange for a follow-up visit to speak to the owner**

2) **What type of business is this?**
   ____ Wholesaler (1)
   ____ Retailer (2)
   ____ Manufacturing (3)
   ____ Service Industry (4)
   ____ Restaurant/Canteen (5)
   ____ Other, specify (88): ___________________

3) **What does this business primarily sell?** ***(Select the best answer)***
   ____ Clothing (1)
   ____ Shoes (2)
   ____ Household Items (3)
   ____ Services (e.g., repair, tailoring) (4)
   ____ Restaurant/Catering (5)
   ____ Grocery (6)
   ____ Other, specify (88): ___________________

4) **How many people work at this business?**
   ____ Number of workers ____ Don't Know (99)

5) **How many years has this business been going/operating?**
   ____ Years ____ Don't Know (99)

6) **How long have you been working at this business?**
   ____ Years ***OR*** ____ Months

7) **If answer to Question 6 is less than 6 months (i.e., they have not worked at the shop during the rainy season, then stop, and ask to speak to somebody else)**

8) **During the dry season, without any floods, how many customers/clients do you serve on a typical day?**

____ Customers ____ Don't Know (99)

9) **During the dry season, without any floods, how many delivery vehicles of any type (trucks, cars, taxis, etc.) *unload* goods at your business in a typical week?**

____ Number of delivery vehicles
____ Don't Know (99)
____ Not applicable (95)

10) **During the dry season, without any floods, how many delivery vehicles of any type (trucks, cars, taxis, etc.) *load up* goods from your business to be taken elsewhere in a typical week?**

____ Number of delivery vehicles
____ Don't Know (99)
____ Not applicable (95)

11) **What is your average income/sales revenue in a month? Please tell me the amount in rebased Kwacha, and before any expenses, taxes, or other deductions.**

____ ZMW (1)
____ Don't Know (99)
____ Refused (77)

B. Flooding

1) **Now I would like to ask you some questions about how flooding has affected your business. Have you experienced flooding in or around this business in the past year?**
____ Yes (1)
____ No (0) **Go to Section C**

2) **How many days, on average, was there flooding by/around your business in the month of ….?**

Month	**Days of Flooding: Enter the number of days OR 99 if don't know**
December	
January	
February	
March	
Other, specify:____________	

3) **How many days, on average, was the business shut down because of the flooding in ….?**

Month	**Days business shut down due to flooding: Enter the number of days OR 99 if don't know**
December	
January	
February	
March	
Other, specify:____________	

4) **Did the flooding destroy any property?**
____ Yes (1)
____ No (0) **Go to Q10**

5) **What type of property did it destroy?** ***(Select all that apply)***
____ Building (1)
____ Sales goods (2)
____ Equipment (3)
____ Raw materials (4)
____ Vehicles (1)
____ Other, specify (88): ____________________

6) **Can you give an estimate of the cost of all the property that was destroyed during flooding? (*If no, probe: What would be the loss for vehicles, what would be the loss for the building/walls, etc. and then add up all the cost estimates)***

____ ZMW (1)
____ Don't Know (99)
____ Refused (77)

7) **How did you pay for the repairs or replacements due to the flood damage? (*Select all that apply)***

____ Special reserve fund (1)
____ Business savings (2
____ Personal savings (3)
____ Cash flow (4)
____ Other, specify (88): ___________________

8) **Did you get any help or compensation from the government or other entity to help pay for the flood damage? (*Select all that apply)***

____ Yes (1)
____ No (0) **Go to Q10**

9) **What was the total amount of compensation you received from the government? (*Select all that apply)***

____ ZMW (1)
____ Don't Know (99)
____ Refused (77)

10) **Did you hire any extra employees to help make repairs or manage issues caused by flooding?**

____ Yes (1)
____ No (0) **Go to Q12**

11) **How much money did you spend to hire these extra workers? This includes any money you spent on piece workers, such as wheel barrow haulers.**

____ ZMW (1)
____ Don't Know (99)
____ Refused (77)

12) **When compared to dry season, did your revenue decrease because of the flooding?**

____ Yes (1)
____ No (0) **Go to Q14**

13) **By what amount or percentage did your revenue decrease as a result of the flooding?**

____ ZMW ***OR*** ____ Percentage
____ Don't Know (99)
____ Refused (77)

14) As a result of the floods, did you have to lay off any workers (either during or after the flooding)?

____ Yes (1)
____ No (0) **Go to Q16**

15) How many workers were laid off due to the flooding?

____ Number of workers
____ Don't Know (99)
____ Refused (77)

16) Did you have to reduce the amount you paid your employees or yourself as a result of the flooding?

____ Yes (1)
____ No (0) **Go to Q18**
____ Don't Know (99) **Go to Q18**
____ Refused (77) **Go to Q18**

17) If you had to reduce pay, what was the total amount that it was reduced by (total, for all workers, summed)?

____ ZMW
____ Don't Know (99)
____ Refused (77)

18) Did flooding affect employees' ability to get to work on time?

____ Yes (1)
____ No (0) **Go to Q21**

19) On average, how many workers were late for work during flooding?

____ Number of workers
____ Don't Know (99)

20) On average, how many minutes were they late?

____ Number of minutes
____ Don't Know (99)

21) During flooding, how many delivery vehicles of any type (trucks, cars, taxis, etc.) *unloaded* goods at your business in a typical week?

____ Number of minutes
____ Don't Know (99)
____ Not applicable (95)

22) During flooding, how many delivery vehicles of any type (trucks, cars, taxis, etc.) *loaded up* goods from your business to be taken elsewhere in a typical week?

____ Number of minutes
____ Don't Know (99)
____ Not applicable (95)

23) After the flooding, how many business days did it take until your business returned to normal? That is, the way it was before flooding?

____ Number of business days before return to normal (1)
____ Still not back to normal (2)
____ Don’t Know (99)

C. Mitigation Efforts Against Flooding

1) Did you make any new investments to protect against flooding in the future, like buying sand bags or water-proof equipment?

____ Yes (1)
____ No (0) **Go to Section D**

2) How much did you pay for these investments?

____ ZMW
____ Don't Know (99)
____ Refused (77)

D. Other Businesses and Opinions

1) **Now I would like to ask you about how flooding may have affected other business and people in your community. During the past rainy season, do you know of any other businesses that were affected by flooding?**
   ____ Yes (1)
   ____ No (0) **Go to Q3**

2) **Were these business affected more than you, less than you, or to a similar degree as you were?**
   ____ Similar to mine (1)
   ____ Worse than mine (2)
   ____ Not as much as mine (3)
   ____ Don't know (99)

3) **Do you think that you have been sick because of the flooding?**
   ____ Yes (1)
   ____ No (0) **Go to Q5**

4) **What were you sick with?**
   ____ Diarrhea (1)
   ____ Cough (2)
   ____ Other, specify (88): ___________________
   ____ Don't know (99)

5) **Do you know of other people that have been sick because of the flooding?**
   ____ Yes (1)
   ____ No (0) **Go to Q7**

6) **What were they sick with?**
   ____ Diarrhea (1)
   ____ Cough (2)
   ____ Other, specify (88): ___________________
   ____ Don't know (99)

7) **Would you like to share your opinion about the flooding and its impacts on your business and the community?**
   ____ Yes (1) **Record response below, as exactly as possible.**
   ____ No (0) **End Survey. Thank the respondent for their time.**

   ____
   ____
   ____

Appendix 10: Sentinel Surveillance Protocol

Syndromic Diarrheal Surveillance with Sentinel Laboratory Surveillance as part of Lusaka's Water and Sanitation Improvements

Protocol Sponsors and Collaborators
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1.0 Background and Introduction

1.1 Rationale for study

Diarrheal diseases, the second leading cause of death in children under five, are often associated with a lack of access to safe water and adequate sanitation. The Millennium Challenge Corporation (MCC) is partnering with the Government of Zambia (GRZ) under the Millennium Challenge Account - Zambia (MCA-Z) to improve the water, sanitation, and drainage systems in Lusaka. CDC will evaluate the health and economic impact of the water, sanitation, and drainage system interventions. As part of the evaluation activities, CDC seeks to collaborate with the Zambia Ministry of Health to strengthen the existing syndromic surveillance for diarrheal diseases and add laboratory-enhanced sentinel surveillance to selected health facilities in intervention and control areas in Lusaka.

1.2 Significance

Although diarrhea remains a major public health issue in Lusaka and throughout much of sub-Saharan Africa, the proportion of diarrheal illness attributable to specific pathogens, and the proportion attributable to different transmission pathways (waterborne, foodborne, person-to-person) remains poorly characterized. Furthermore, the degree to which investments in urban water supply, sanitation, and drainage may reduce diarrheal infections in general and by specific pathogens is not clearly defined. A thorough evaluation of the MCC-supported activities in Lusaka is an opportunity to address these major questions and to inform future investments in water, sanitation, and hygiene (WASH) infrastructure and diarrheal disease prevention and control.

1.3 Aim

This project is part of a large evaluation of the impact of the water, sanitation, and drainage improvements funded by the United States Government (USG) under the MCA-Z in Lusaka. Integrated into the existing diarrheal disease surveillance, this project aims to inform disease management and public health priorities. Eventually, the hope is that this project will serve as a pilot for laboratory-enhanced sentinel diarrheal disease surveillance that the Zambia Ministry of Health (MOH) can scale up during and following the evaluation period.

1.4 Specific objectives

For this project, the primary goal is to evaluate the impact of the water, sanitation, and drainage interventions on the incidence of diarrheal disease. However, we also hope this project will support and strengthen surveillance and diagnostic laboratory capacity for diarrheal diseases. Laboratory testing will help us to gain a better understanding of the proportion of diarrheal illness attributable to specific pathogens. To achieve these goals we have the following objectives:

> **Objective 1**: Strengthen and track clinical syndromic surveillance for diarrheal disease using existing case definitions in specified health facilities within Lusaka.
>
> **Objective 2**: Carry out laboratory-enhanced sentinel surveillance for selected parasitic, viral, and bacterial pathogens for a subset of cases of diarrheal disease presenting to selected health facilities in intervention and control areas in Lusaka.

2.0 Literature Review

Diarrheal diseases are the second leading cause of death in children under five, causing an estimated 760,000 deaths globally each year (WHO 2013). Nearly 800 million people do not have access to improved sources of water and 2.5 billion people lack adequate sanitation (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012). Lack of access to safe water and adequate sanitation are primary causes of diarrhea, particularly in countries without universal access to water supply and sanitation systems. Inadequate water and sanitation infrastructure impacts populations in many cities in the developing world that are experiencing rapid population growth without equivalent expansion of water and sanitation capacity to meet the increased demand for these services. The Millennium Challenge Corporation (MCC) is partnering with the Government of Zambia under the Millennium Challenge Account- Zambia (MCA-Z) to improve the water, sanitation, and drainage systems in the capital, Lusaka.

Lusaka, the capital of Zambia, is one of the fastest growing cities on the continent. Lusaka's water and sanitation system was built in the 1960s and 1970s when the population was one sixth of that in the 2010 census (Central Statistics Office, 2011). MCC-supported activities will focus on strengthening and upgrading the main water treatment plant for Lusaka, and on selected neighborhood-specific projects within the city – extending household water connections to approximately 100,000 residents in one area, providing a sewerage network and flush toilets to approximately 100,000 residents in another area, building 60 new water kiosks where residents without household water connections can purchase water, and improving the drainage network (~30 km) for the primary business district along the Bombay drain and surrounding residential communities. Only some of the areas eligible for the intervention will receive water, sanitation, and/or drainage improvements. The areas that were considered eligible without intervention services will be considered as control areas.

As part of this investment, CDC will evaluate the health and economic impact of the water, sanitation, and drainage system interventions. To conduct this evaluation, CDC seeks to collaborate with the Ministry of Health to strengthen laboratory surveillance for diarrheal diseases at several sentinel health facilities in intervention and control areas in Lusaka. As part of this project, after providing informed consent, selected patients who present to the health facilities with acute watery or bloody diarrhea will be asked to answer a few questions about their illness and to submit a stool specimen for laboratory testing for diarrheal pathogens. Laboratory results will be reported back to health providers when available at the health facility and will be compared with existing routine clinical surveillance for diarrhea to better characterize the distribution of diarrheal etiologies within Lusaka's population. The laboratory surveillance system created by this activity will be integrated with the current syndromic surveillance that MOH already conducts for diarrhea, dysentery, and cholera based on Integrated Disease Surveillance and Response (IDSR) guidelines (Kasolo 2010), and will strengthen existing laboratory diagnostic capacity.

Infants, children under 5 years old, and persons with HIV/AIDS are at greatest risk for diarrheal infections and poor outcomes. Pathogen-specific burdens of diarrheal disease in children under 5 years old were recently characterized in four African sites (Mali, Kenya, Mozambique and the Gambia) by the Global Enteric Multicenter Study (GEMS), a large prospective case-control study that tested stool samples from children under 5 years old with moderate to severe diarrhea for a wide range of enteric pathogens (Kotloff 2013). GEMS found that rotavirus, *Shigella*, ST-ETEC, and *Cryptosporidium* were the most common pathogens, with rotavirus affecting infants in the highest proportion, but continuing to remain an important pathogen throughout toddlerhood (Kotloff 2013). Bamako, Mali, the only African GEMS site, is in a very different geographical region from Lusaka. In addition, rotavirus vaccine was not available in any of the GEMS sites whereas, Zambia piloted a national rotavirus vaccine campaign starting in Lusaka District in 2013 (Stringer 2012). While the efficacy of the rotavirus vaccine in Zambia is still being assessed, it has proven effective in reducing rotavirus diarrhea in children in other

African sites (Madhi 2010). Because of the proportionally large burden of this single pathogen, we expect the vaccination campaign will result in a significant reduction in diarrhea cases due to rotavirus in children under 5 years old in both the MCC intervention and control areas. To validate the extent to which reductions in diarrheal cases seen in health facilities and reported through syndromic surveillance is attributable to rotavirus vaccination, rotavirus will be included among the agents tested for in the laboratory-enhanced sentinel surveillance system.

We expect the impact of the MCC-supported interventions to be greatest on pathogens that are primarily waterborne or a combination of water, poor hygiene and sanitation. Rotavirus is the most common cause of diarrheal illness in children without vaccine. However, with introduction of rotavirus vaccine and because water, sanitation, and drainage are not thought to impact rotavirus as much as other pathogens, the interventions of this project we predict will have less impact on rotavirus incidence than on other causes of diarrhea. The MCC interventions could have a more dramatic impact on diarrheal pathogens that are more closely related to WASH including *Vibrio cholerae*, *Cryptosporidium, Giardia*, *Campylobacter* spp, *Salmonella typhi*, *Shigella* spp, which are considered here and which affect people of all ages. Also considered are *Salmonella* spp, and *E. coli* spp, which have more complex transmissions patterns but consistently increase in prevalence in settings with poor hygiene conditions.

3.0 Methodology
3.1 Objectives
The primary objective is to measure the impact of the water, sewer, and drainage interventions on the number of cases of diarrhea presenting to health facilities in the intervention areas, and to characterize the impact on cases of diarrhea attributable to specific pathogens. The hypothesis is that populations residing in areas receiving water, sewer, and drainage interventions will experience a greater reduction in clinical cases of diarrheal disease than populations residing in similar areas not receiving these interventions. The secondary hypothesis is that there will be a greater reduction in diarrheal disease caused by pathogens thought to be primarily waterborne or hygiene-related (i.e., *Cryptosporidium, Giardia*, *Campylobacter* spp, *V. cholerae*, *Shigella* spp*,* and *S. typhi*, and *Salmonella* spp and *E. coli* spp*)*, than diarrheal disease caused by pathogens that are not thought to be waterborne or hygiene related (i.e., rotavirus). The null hypothesis is that there would be no difference in clinically detected diarrheal disease, or diarrheal disease attributable to specific pathogens thought to be waterborne or hygiene-related between the intervention and control areas.
To help measure the health impact of the water, sewer, and drainage intervention, this project will:

1. Strengthen and track clinical syndromic surveillance for diarrheal disease using existing case definitions in specified health facilities in intervention and control areas within Lusaka city
2. Carry out laboratory-enhanced sentinel surveillance for selected parasitic, viral, and bacterial pathogens in a subset of cases of diarrheal disease presenting to selected health facilities in intervention and control areas

This project aims to support system strengthening that can be transitioned during approximately the third year of the project (Calendar Outline and Gantt Chart). Data collection will need to be through the end of 2018 to assess the impact of the interventions.

3.2 Evaluation Design
The sentinel surveillance project will serve as part of a larger evaluation of the health and economic impact of Lusaka's water, sewer, and drainage interventions. The health facility surveillance component will track incident cases of diarrhea among patients presenting to participating health facilities and characterize the etiology of diarrheal pathogens in a subset of these patients.

Project surveillance will be integrated into existing diarrheal disease surveillance in MOH health facilities based on currently available data, capturing the total number of outpatient visits for all illness, number of outpatient visits, admissions, and death for diarrhea, dysentery, cholera-like diarrhea, and severe diarrhea with dehydration, and the age category (<5 vs ≥5 years old) for patients with diarrheal disease, and when possible treatment provided in these cases. Population rates of diarrheal disease will be based on updated population estimates of the catchment area of the health facility. Additionally, the proportion of diarrhea cases will be compared to a consistent selection of acute illness cases to ensure that any changes in the number of diarrhea cases are not accidentally attributed to the interventions when actually they just reflect changes in the number of people using the health facility.

In addition to the clinical information already collected about diarrheal disease, this project will include laboratory-enhanced diarrheal disease surveillance. A subset of patients presenting with acute diarrhea to participating health facilities will be consented to have stool specimens collected and tested for major diarrheal pathogens. Additional clinical information will be collected from these patients. Stool specimens will be collected between one and four days per week from four (two intervention and two control) area health facilities. The specimens will either be tested on site or transported to laboratory(ies) for processing. A portion of fresh stool specimens as well as isolates will be stored over the course of the week for quality assurance testing.

Neither the syndromic surveillance nor the sentinel laboratory based surveillance will directly impact individual patient management. Management and treatment will continue based on existing practices and protocols performed by current health facility staff. Results will be returned to health facilities when available. Additionally, periodic reports will be written and reviewed with all parties involved from health facility staff through the MOH.

3.3 Sample size and population

Syndromic surveillance data are already being collected city-wide. We plan to use these available data for all intervention areas. Areas that were deemed eligible for interventions, i.e., ones that share similar water, sanitation, and socioeconomic characteristics based on census data, will be used as control areas. There will be up to a total of four (two intervention and two control) areas selected for the enhanced laboratory-enhanced sentinel surveillance activities. The intervention areas were selected by Lusaka Water and Sewerage Company (LWSC) and are largely based on geographically defined townships, with one cluster of townships (Chipata, SOS East, Ng'ombe, Kamanga) receiving new household water supply and another township (Mtendere) receiving both household water supply and sanitation. Two similarly sized, geographically distinct (without overlap in catchment area), areas with similar water, sanitation, and socioeconomic characteristics based on census data will be chosen as control area health facilities. We anticipate Kanyama and Chelstone to be primary testing sites with quality assurance and possibly more complex techniques for *Campylobacter* and/or *E. coli* done at UTH and possibly Levy Mwanawasa General Hospital (LMGH). Samples will maybe collected from Kanyama, Mtendere, Ng'ombe, Chainda, and Kalingalinga though this could change based on patient load and clinic and laboratory capacity.

A rough estimate of up to 40 samples per week is proposed (20 from intervention area health facilities and 20 from control area health facilities, approximately 2,000 samples per year). This is based on potential facility collection and laboratory capacity. This project is for surveillance and so sample size is based on the number of health facility outpatient visits for the syndromic surveillance and is based on capacity for the sentinel laboratory-enhanced surveillance. Detecting a 1% change in a single pathogen, with 80% power and 5% type I error would require 4,200 samples per year positive for that particular pathogen. Taking a rough estimate of pathogen recovery of 5% from all samples it would require a total of 84,000 samples per year or 1,600 samples per week. Therefore the anticipated sample sizes required to detect significant effect size differences are beyond the scope and budget of this project.

3.4 Enrolment Procedures for specimen collection and testing

Patients, of any age, presenting to the outpatient health facilities with a primary complaint of diarrhea (>3 looser than normal stools in 24 hours) with or without bloody stools that began no more than 7 days ago, and who reside in the defined intervention or control areas will be eligible for inclusion in laboratory-enhanced surveillance. Inclusion criteria will capture the already accounted for cases of acute diarrhea and dysentery in the existing surveillance system as well as other diarrheal definitions such as cholera-like diarrhea and diarrhea with dehydration. All eligible individuals on selected collection days at the health facility will be offered the opportunity to consent to participate in the laboratory-enhanced surveillance. An attempt to collect a minimum of 2-3 samples per day will be made based on patient volume and willingness to participate. A proposed maximum is 20 specimens (up to 10 specimens from patients greater than 5 years and up to 10 specimens from patients 5 years or younger) per facility per week. Consent will be sought either from the individual or guardian. Adults defined as individuals ≥18 years old will consent for themselves. Minors, defined as 13-17 year olds, may sign their own consent if emancipated which is defined as mature and living either with a consensual sexual partner or a female adolescent who is pregnant or a mother. Non-emancipated minors and children, defined as individuals <13 years old, will need parental or guardian consent. If an individual is too sick to consent, they will be excluded.

3.5 Laboratory Testing

Specimen Flow:

At least 3g or 3ml and up to 10g or 10ml will be collected from the patient at the time of the health facility visit. If there is a fresh stool available within 1 hour it can be collected from a diaper/nappie. Containers of whole stool will be swabbed and the swab placed in Cary Blair transport medium. Both whole stool and Cary Blair swab will then be sealed, labelled with a single unique number, placed in a plastic bag, and kept on ice in a cooler or refrigerator at 4 C until the end of the day when they will be transported to the lab for processing. Lab Collection Form will be completed by the HF staff at the time of stool collection. Clinical Information Form will be kept with locked area that is only accessible where all other clinical information is housed for the HF. Lab Collection Form will be kept in duplicate, one in the lab and the other with clinical records. A laboratory log will used to track specimens by ID that can be decoded as necessary by verifying the Clinical Information Form.

When the specimen arrives in the laboratory it will be accessioned using standard operating procedures. Lab Processing Form will be completed at this time. When possible, microbiology testing will start at the time of accession. If not specimens will be held in the 4 C refrigerator for up to 24 hours. Specimens for virology and/or parasitology testing will be kept at recommended conditions and analyzed within two weeks. A portion of specimens will be split and stored within this two week time frame for additional testing and quality assurance. Initially all isolates will be stored in a -20 C freezer for quality assurance testing at University Teaching Hospital (the only identified MOH laboratory in Lusaka that has external quality assurance at this time). At this time there is no plan for archiving specimens or testing past this initial time frame, although a provision for this option may be included in the protocol if MOH and CDC Zambia see a potential future benefit.

Positive and negative lab results will be compiled in the laboratory and returned to clinical staff as soon as available in HF where laboratory testing is being done and to the HF where the specimens came from but where laboratory testing is not being done when available as part of routine specimen transport. Regular reports summarizing syndromic and laboratory-enhanced sentinel surveillance data will be provided to partners and providers involved in the project.

Test results will be recorded in the standard database as part of routine lab processing using only the unique ID. Results will also be recorded on the Lab Results Form. These forms will be entered once a week without any personal identifiers into an electronic database that will be made available to all partners, including lab(s), MOH, and CDC by electronic transfer either through email, direct transfer, or on a shared network. A copy of the Lab Results Form will be returned to the health facility when available on the same schedule as specimens are collected. Follow up and treatment will be based on current practice, not on surveillance laboratory testing. Regular reports summarizing syndromic and laboratory-enhanced sentinel surveillance data will be provided to partners and providers involved in the project.

Specific Pathogen Testing:

The following pathogens are listed because in country laboratory scientists have discussed their significance, they have been studied in country or in similar settings and found to be significant diarrheal etiologies, or they cause periodic waterborne outbreaks.

Protozoa/Parasites:

The parasites specifically targeted are *Cryptosporidium*, *Giardia, Ascaris* and Hookworms (*Ancylostoma duodenale* and *Necator americanus*). A combination of Enzyme Immunoassay (EIA) and microscopy will be used to identify *Cryptosporidium* and *Giardia* and microscopy with a preservative method such as Fecal Parasite Concentrator (FPC) for *Ascaris* and Hookworms. Since microscopy is general other pathogens may be identified and will be recorded as well. These tests will be performed on whole stool that is collected from symptomatic patients. Immunofluorescense has been used in the past as a quality control measure and may still be implemented for a portion of samples as part of quality control checks in this project.

Rotavirus:

Laboratory testing for rotavirus will be done by Enzyme Immunoassay (EIA) following standard operating procedures outlined by the manufacturer with a manufacturer-provided positive and negative control to be run with each batch/plates of tests.

Bacteria:

The bacteria targeted are *Shigella* spp, *E. coli* spp. Under consideration is a multiplex Polymerase Chain Reaction (PCR) panel for diarrheagenic *E. coli* [EPEC (*eae, bfpa*), EHEC (*eae*), EaggEC (*aatA*), ST-ETEC (*estA)]*, *Salmonella* spp with a particular focus on *S. typhi*, *V. cholerae,* and *Campylobacter*. A variety of methods including culture, antisera reaction, PCR, and EIA will be used to identify pathogens and specific serotypes. Selective antimicrobial susceptibility testing will be performed on cultured isolates.

3.6 Results Reporting and Treatment

Positive laboratory results will be returned to health facilities when available (Lab Results Form) by the same courier service collecting specimens. Current standard of care should be undertaken before laboratory results are returned (i.e., vitamin A, zinc, Oral Rehydration Solution, intravenous fluids antibiotics, etc. will be prescribed as currently indicated). Treatment will be provided by the clinical staff based on existing algorithms and available medications. Follow up assessment will be provided by health facility staff per routine.

3.7 Quality Review

Prior to starting data and specimen collection all clinic and laboratory staff will be trained in general principles of surveillance, currently used data collection tool and project specific forms, safety, and ethics. Quality review (QR) will be continuous as the project starts. Initially, the CDC project staff will perform QR, but responsibilities will transitions to the nurses in charge, lead laboratory scientists with oversight from MOH staff primarily at the district level with support from the provincial and national MOH, but backed up by CDC personnel, as needed. This transition is in an effort to promote sustainability of quality within the system. QR is scheduled for every other month, but may increase in intensity during the initial project phase, with any changes to the project protocol, or if issues are identified. A draft schedule is outlined in Calendar Outline and Gantt Chart.

QR will include a review of at least 10% of all data collection forms during a specified time period (e.g., previous two weeks), repeat laboratory testing on at least 10% of specimens collected during the QR time period, and shadowing during health facility visits with feedback to health facility staff during the QR time period. At the time of review, the number of clinical cases will be compared to those from whom specimens were collected to review eligibility and the reason for exclusions. These cases will be drawn from the preceding two week period as well.

3.8 Data
3.81 Data Management
As mentioned paper forms will be kept in a secure office and filing cabinet. Laboratorie(s) will maintain a copy of lab processing forms and a separate database (electronic or paper depending on the facility). De-identified clinical data and lab results will be entered into a database by other project staff or MOH staff.

3.82 Data Security
Every effort will be made to maintain the confidentiality of all data collected. Paper forms with personal and clinical information will be kept in a secure location. All of the electronic data will be recorded by the unique number. The only link between an individual's name on the Consent Form and clinic information will be on the Clinical Information Form. The Consent Form and Clinical Information Form will be kept in separate locked filing cabinets in a separate office such as the sister-in-charge's office or the data room. Laboratory processing forms will have a separate unique ID that can be traced back to the Clinical Information Form, but not the consent form.

It is with the unique number that laboratory specimens will be tracked from the time of leaving the health facility to results returning to the health facility. The project and/or health facility staff will decode the unique ID on the lab forms before returning the results to the clinic.

De-identified data will be aggregated for analysis. This will be done on an electronic database on a password protected computer in a secure office location. However, the database will be freely shared with all partners involved including laboratory, MOH, CDC, etc.

3.83 Data Analysis
Analysis of the results will be done in aggregate using SAS software version 9.3 (Cary, NC) or similar statistical software. Data analysis will be primarily descriptive in nature comparing differences between intervention and control areas and over time in the number of clinically recognized diarrheal cases seen in the health facility as compared to total number of acutely ill patients. In addition to the proportion of diarrheal cases over time identified, we will look at the proportions of cases that have evidence of specific pathogens.

3.9 Ethical Considerations
This project study involves collection of minimal personal health information, collection of clinical specimens, enhancement of laboratory testing for diarrheal disease, and provision of appropriate clinical diagnosis and treatment. However, we do not plan to extend any aspect of this data collection beyond the current standard of care except the laboratory diagnostic techniques component. While the information will not be used by any individual patients, overall the information the laboratory-enhanced surveillance provides should improve the accuracy of clinical diagnosis and treatment. This project should pose minimal risk since it should be well integrated with routine care and surveillance activities. The level of services will not change before, during, or after the study since the addition of laboratory testing is for surveillance solely.

The personal health information collected is minimal. A unique coded number will link the clinical and health information to the specimen and laboratory testing. A log of this unique number with the patient's name will be kept in the health facility, separately from the specimens. A master back up list will be kept by project staff and MOH for back up and quality control checks. This separation is to help keep identifiable information (the patient's name) separate from all other information collected in this study. Only the unique identification numbers from clinical and lab forms will be entered in lab logs and electronic databases.

Informed consent in whatever language is most comfortable for the participant will be obtained from eligible patients18 years or older or a guardian if they are less than 18 years, and consent and assent for children between 7-17 years old. Emancipated minors (as defined above in Enrolment Procedures) between 13-17 years old will be able to consent for themselves. The Informtion Sheet, Consent, and where applicable Assent Forms will be read to participants by HF staff. Signature or thumb print will be used as verification. If the participant or guardian cannot read or cannot write, an impartial third party will witness the entire consent process and sign the consent document. The participant or guardian will be asked to sign his/her name (or place an "x" or a fingerprint if unable to sign his/her name) on the consent form. The original signed/imprinted form will be retained in the study files, and the participant or guardian will be given a copy to keep. Consent forms with signatures, or other potentially identifiable information will be kept maintained by MOH.

Participants will be specifically asked if they permit to have their biological specimens tested, stored and shipped for future laboratory tests relevant to diarrheal disease. This is not part of the planned project, but the provision will be made in case further testing is warranted, an outbreak of an unusual pathogen is detected, or it is deemed necessary for quality control. Specimens will be stored with unique patient and specimen IDs, but no personal information.

The purpose of the project, and the risks and benefits will be explained to study participants in a language they can understand. The voluntary nature of this study will be emphasized and participants will be free to refuse to answer any question(s) and to end their participation at any time. There are no direct benefits from this project to participants, but in general the hope is through surveillance there will be better diarrheal disease detection and that with better disease detection target therapies, interventions, and early warning of outbreaks might occur. Overall, it is the community that stands to benefit the most from this project through early detection of possible outbreaks, understanding what pathogens are causing diarrhea and what their antibiotic resistance patters are, and assessing the impact of water and sanitation infrastructure projects. No time compensation will be provided as part of this study. There will be no monetary or non-monetary payment provided for participation. This project does not involved and drug or devices.

Before starting this project, the protocol will be reviewed the University of Zambia Biomedical Research Ethics Committee (UNZABREC) if determined to be warranted by MOH ethics review board. The CDC Human Research Protection Office (HRPO) has provided the paper work for a reliance request if determined to be acceptable by UNZABREC.

3.10 Expected Application of Results

This project is part of a larger evaluation of Lusaka's planned water, sewer, and drainage intervention's impact. The foci here are on the number of cases of diarrheal disease presenting to health facilities in the intervention and control areas and the etiology of diarrhea among these patients. The gain in understanding about the distribution and frequency of circulating pathogens is important both for the rigor of the evaluation as well as capacity building for laboratory surveillance and testing of diarrhea in Zambia. The project in this way aims to be a meaningful pilot for continued lab based diarrheal disease surveillance.

Regular reports will be prepared to give feedback to stakeholders, primarily MOH, MCDMCH, UTH, MCC/MCA-Z, CDC Zambia, and involved clinicians and laboratory scientists as part of the surveillance enhancement process. These reports will be in addition to protocols already in place for timely clinical and laboratory reporting of potential outbreak pathogens such as *S. typhi* and *V. cholerae*. Results from the surveillance system will be used to establish public health program priorities and may be presented at scientific conferences or summarized in peer-reviewed journals.

4.0 Budget

Description of the budget

Testing Equipment and Supplies

The project funds will provide needed equipment not already available within the MOH system. For example, -20^{0}C freezers needed to store isolates for quality assurance are not available and can be provided through the project. Such equipment will become the property of MOH. MOH will also assume responsibility for ongoing maintenance. Other equipment such as centrifuges, incubators, distillers, autoclaves, etc. will be provided by MOH. Ongoing supplies needed for testing will be purchased by the project budget. The project will pay for the supplies for surveillance testing. Other testing that these same supplies could be used for such as clinical specimen testing will not be covered.

Staffing

Staffing to perform laboratory testing will be provided by MOH, i.e., personnel already assigned to the facilities will be involved in the project. Qualifications are to meet those usually used for trained lab staff within the MOH system. Short term leave and vacation would be expected. However, for extended leave periods a replacement laboratorian will be provided by MOH.

Training, Technical Assistance, and Quality Assurance

CDC-Zambia will provide laboratory technical assistance. This will include microbiology training workshops given by trainers from both CDC-Zambia and MOH staff assigned to the Bacteriology Unit at University Teaching Hospital (UTH). The trainers will also serve as mentors to laboratories to help them overcome implementation challenges and build functional testing capacity.

CDC-WDPB will provide ongoing technical assistance to in regard to surveillance. This will include ongoing monitoring and evaluation, quality review, data analysis, recommendations for system improvements, and materials and support in any trainings regarding diarrheal disease surveillance that MOH and CDC agree upon.

Logistics

Office supplies and services will be supported by the project budget. Transportation will be provided by Lusaka District Health Office with financial support initially from the project with the plan to transition to a district wide courier service by two years into the project.

Clinical Testing

Capacity built within laboratories could be used for routine clinical testing as clinicians and laboratory personnel see fit. However, this would be separate from the scope of surveillance work and will not be covered by this MOU. Likewise supplies and materials agreed upon in this MOU could not be used for testing outside of the scope of the surveillance activities agreed upon here and detailed in the project protocol.

Budget figures

Startup Costs

	Cost per unit (USD)	At laboratories with the capacity that UTH, LMGH, Kanyama, and Chelstone have currently
Training	~5,000	~10,000
Laptop	349	349
Incubator	2,000	6,000
Refrigerator	1,000	3,000
Distiller	5,000	10,000
Miscellaneous lab supplies (i.e., thermometer)	100	600
Total	**13,249**	**29,549**

Ongoing Costs

Pathogen	**Price per test**
Diarrheagenic *E. coli*	15 USD
V. cholera, Salmonella, Shigella	Combined 30 USD
Rotavirus	2 USD
Cryptosporidium, Giardia	2 USD
***Campylobacter* 1**	100 USD
Ascaris	1 USD
Hookworm	1 USD

Test combinations	**Cost/sample**	**40 sample/wk cost/year**
All tests	151	314,080
All tests except Campy	51	106,080

Miscellaneous ongoing costs

	Hours per week	**Cost per hour**	**Total per year**
Transportation	16	100	1,600
Office supplies			400

5.0 Time Frame

5.1 Gantt Chart

Activity	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec 2014
Submit protocol for ethics review (IRB/BREC)									X			
Sign memorandum of understanding (MOU)											X	
Purchase supplies										X	X	
Establish data collection standard operating procedures (SOP)										X	X	
Laboratory procedure SOPs										X	X	
Design database										X		
Train clinic staff											X	
Train laboratory staff								X	X	X	X	
Start data collection												X
	Jan 2015	**Feb 2015**	**Mar 2015**	**Apr 2015**	**May 2015**	**Jun 2015**	**Jul 2015**	**Aug 2015**	**Sep 2015**	**Oct 2015**	**Nov 2015**	**Dec 2015**
Quality review (QR)	X	X		X		X		X		X		X
Ongoing training and quality improvement		X		X		X		X		X		X
Write preliminary report					X	X						
Stakeholder meeting to assess initial project implementation			X									
Refresher training for clinical and laboratory staff				X								
	Jan 2016	**Feb 2016**	**Mar 2016**	**Apr 2016**	**May 2016**	**Jun 2016**	**Jul 2016**	**Aug 2016**	**Sep 2016**	**Oct 2016**	**Nov 2016**	**Dec 2016**
QR		X		X		X		X		X		X
Ongoing training and quality improvement		X		X		X		X		X		X
Write interim report					X	X						
Present interim report findings to stakeholders						X						
	Jan 2017	**Feb 2017**	**Mar 2017**	**Apr 2017**	**May 2017**	**Jun 2017**	**Jul 2017**	**Aug 2017**	**Sep 2017**	**Oct 2017**	**Nov 2017**	**Dec 2017**
QR		X		X		X		X		X		X
Ongoing training and quality improvement		X		X		X		X		X		X
Write interim report					X	X						
Present interim report findings to stakeholders						X						
Transition data entry and analysis from CDC to MOH	X	X	X									
Transition QR from CDC to MOH								X	X			
	Jan 2018	**Feb 2018**	**Mar 2018**	**Apr 2018**	**May 2018**	**Jun 2018**	**Jul 2018**	**Aug 2018**	**Sep 2018**	**Oct 2018**	**Nov 2018**	**Dec 2018**
QR		X		X		X		X		X		X
Ongoing training and quality improvement		X		X		X		X		X		X
Drafting of final report										X	X	X
Transition supply chain and procurement to from CDC to MOH									X	X	X	
	Jan 2019	**Feb 2019**	**Mar 2019**	**Apr 2019**	**May 2019**	**Jun 2019**	**Jul 2019**	**Aug 2019**	**Sep 2019**	**Oct 2019**	**Nov 2019**	**Dec 2019**
Give final report and presentation		X	X									

5.2 Calendar Outline

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	Draft Protocol							ERB/IRB Review, procurement, MOUs			Establish SOPs, complete trainings	
					Establish Lab Capacity							
2015	Start specimen collection →	QR/evaluate process		QR	Write preliminary report	QR		QR		QR		QR
2016		QR		QR		QR		QR		QR		QR
2017		Transition data entry and analysis from CDC to MOH→		QR		QR		Transition QR from CDC to MOH→			QR	
2018									Transition supply chain and procurement to from CDC to MOH →			

6.0 References

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6.1 Abbreviations

ABA	Ampicillin Blood Agar
APW	Alkaline Peptone Water
CDC	Centers for Disease Control and Prevention
EIA	Enzyme Immunoassay
GEMS	The Global Enteric Multicenter Study
GRZ	Government of Zambia
HF	Health Facility
IDSR	Integrated Disease Surveillance and Response
LWSC	Lusaka Water and Sewerage Company
MAC	MacConkey Agar
MCA-Z	Millennium Challenge Account - Zambia
MCC	Millenium Challenge Corporation
MOH	Zambian Ministry of Health
MOU	Memorandum of Understanding
MSA	Mannitol Salt Agar
PCR	Polymerase Chain Reaction
QR	Quality Review
SEA	Standard Enumeration Area
SFB	Selenite-F Broth
SOP	Standard Operating Proceedure
TCBS	Thiosulfate Citrate Bile Salts Sucrose Agar
TTGA	Taurocholate Tellurite Gelatin Agar
USG	United States Government
UTH	University Teaching Hospital
WASH	Water Sanitation and Hygiene
XDL	Xylose Lysine Agar