GREEN CITY KIGALI

GREEN CITY KIGALI: A NEW MODEL FOR URBAN DEVELOPMENT IN RWANDA

ANNEX 2: FEASIBILITY STUDY

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ABBREVIATIONS

BMZ	German Ministry for Economic Cooperation and Development
BRD	Development Bank of Rwanda
CBC	Community Benefit Company
CoK	City of Kigali
CSO	Civil Society Organization
EDPRS2	Second Economic Development and Poverty Reduction Strategy (Later replaced by NST1)
EMIP	Environmental Management and Implementation Plan
ESIA	Environmental and Social Impact Assessment
ESMF	Environmental and Social Management Framework
ESMP	Environmental and Social Management Plan
EU	The European Union
FONERWA	Rwanda Environment and Climate Change Fund / Rwanda Green Fund
FS	Feasibility Study
GAP	Gender Action Plan
GCF	Green Climate Fund
GCK	Green City Kigali
GGGI	Global Green Growth Institute
GoR	Government of Rwanda
HH	Household
HtO	Help to Own Mortgage Assistance Programme
IFC	International Finance Corporation
JV	Joint Venture
KfW	Kreditanstalt für Wiederaufbau/German Development Bank
LDP	Land Development Plan
LGI	Local Government Institute
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MININFRA	Ministry of Infrastructure

MoE	Ministry of Environment
MoU	Memorandum of Understanding
NDC Nationally	Determined Contribution
NST 1	National Strategy for Transformation (2017-2024)
PAP	Project Affected Person
PAH	Project Affected Household
PPF	GCF's Project Preparation Facility
RAP	Resettlement Action Plan
RFP	Request for Proposal
RPF	Resettlement Policy Framework
REMA	Rwanda Environment Management Authority
RIBA	Royal Institute of British Architects
RHA	Rwanda Housing Authority
RSSB	Rwanda Social Security Board
RwaGBO	Rwanda Green Building Organization
RWH	Rainwater Harvesting
SACCOs	Savings and Credit Cooperative Organisations
SESA	Strategic Environmental and Social Assessment
SPV	Special Purpose Vehicle
SWM	Solid Waste Management
ToR	Terms of Reference
UADC	Urban and Architectural Design Consultant
UNFCCC	United Nations Framework Convention on Climate Change
UN-Habitat	United Nations Human Settlement Programme
WB	The World Bank
WUF	UN-Habitat's World Urban Forum

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GREEN CITY KIGALI

1 INTRODUCTION

1.1 Purpose of this Report

This Feasibility Study has been undertaken as part of preparing a Green Climate Fund application that will seek financial support for the upgrade of an informal settlement at Ngaruyinka in Kigali. It provides an assessment of context, strategy, recommendations, measurable outcomes and climate impacts of investment.

The Study sets out:

- the location and situation of Ngaruyinka,
- the climate profile of the settlement and region,
- Ngaruyinka as an exemplar of a country-wide climate induced problem,
- the assets in the settlment that the project is targeting,
- a range of possible interventions to address the problem and the reasons for selecting specific technological solutions over a '*Business As Usual*' (BAU) approach,
- the rationale for investment, upscaling, and wider, longer-term impact, and
- the potential mitigation and adaptation impacts of proposed interventions.

The Study first explains the current situation in Ngaruyinka, its physical condition and context, and deficiencies and vulnerabilities in terms of a sustainable urban community. It sets out the current and future climate risks that threaten Ngaruyinka and makes clear that Ngaruyinka is an exemplar of a country-wide climate induced problem which disproportionally affects vulnerable groups.

It describes the assets that will be targeted by GCF investment, and the impact these upgrade investments will have on the settlment in terms of resilience to and mitigation of climate change, as well as non-climate related benefits of sustainability; economically, socially and environmentally.

It outlines relevant policy documentation related to urban planning and settlement upgrades in Rwanda and Kigali including the Green City Kigali sustainable urban development project which the settlment lies within, and adopts the methodology established by the Green City Kigali project to quantify the planned densification in the settlment.

The Study adopts a Multi Criteria Analysis methodology to arrive at a 'Climate Responsive' approach (CR) and recommendations that meet the objectives of Green Climate Fund requirements. These recommendations act as the Basis of Design in support of the Land Development Plan (LDP) for the upgrade, which can be shown to provide significant benefits in terms of climate adaptation and mitigation when compared to a 'Business As Usual' approach (BAU).

The study analyses the potential impact of the proposed project, including the rationale for achieving economies of scale through investing in a toolkit approach that can be upscaled to achieve wider long-term climate benefits to tackle a country-wide issue. A transparent GHG emission measurement, reporting and verification methodology is proposed and presented, including a GHG emission reduction calculation sheet for the upgrade project.

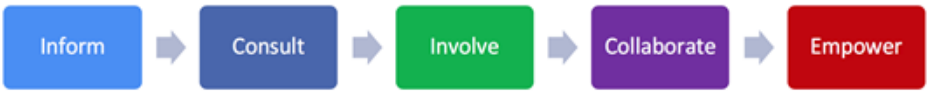
This study has been carried out by a multidisciplinary team of experts led by Sweco and based in Rwanda, Sweden, Germany and the UK.

1.2 Description of the Consultation Process

A Stakeholder Engagement Framework (SEF) has been prepared for the Project, where the overall framework and strategy for stakeholder engagement, grievance mechanism, and information disclosure are described. The following subchapters summarize the stakeholder engagement requirements to be followed during the Project and its future components.

The purpose of stakeholder consultation and information disclosure mechanism is to:

- *Inform*: by promoting stakeholder understanding of issues, problems, alternatives, opportunities and solutions through balanced and objective information sharing;
- *Consult*: by obtaining feedback and acknowledging concerns and aspirations of stakeholders on analysis, alternatives, and decisions regarding development projects;
- *Involve*: Work directly with stakeholders during the process to ensure that their concerns and desired outcomes are fully understood and taken into account;
- *Engage*: by working directly with stakeholders to ensure that their concerns and aspirations are understood and considered and to assure them that their concerns / aspirations would be directly reflected in the developed alternatives; and that feedback will be provided on how their input influenced the final decisions;
- *Empower*: by making stakeholders partners in each aspect of the decisions, including development of alternatives and identification of preferred solutions.



In order to clearly develop a systematic and effective means of engagement, stakeholders are identified in relation to the projects to be undertaken and mapped out to understand their interests in these development activities, as described in the Project's Stakeholder Engagement Plan (SEP).

Stakeholder's identification and mapping for inclusion in engagement activities can be divided into 2 groups:

- have an interest in the various parts of the Project or could provide commentary on issues and concerns related to the Project (interested parties);
- would potentially be affected by or have a positive or negative influence on the various parts of the Project (affected parties)

Timely and transparent disclosure of information about the Project is essential to guide the process of stakeholders in understanding and evaluating the risks, impacts and opportunities and positive impacts of the Project. In line with international best practices stipulated by the WB ESS10[1], the Project shall provide affected communities with Project information on an ongoing basis throughout Project planning, development and implementation. Where feedback demands changes and / or adaptations to Project plans, these updates will be communicated to affected communities.

When selecting an appropriate consultation technique, culturally appropriate consultation methods and the purpose for engaging with a stakeholder group will be considered.

Prior to any engagement event, the following steps will be followed:

i. Preparation of standard 'question and answer' sheets tailored for specific stakeholder types
ii. Planning/design of engagement action (s) with Project Implementation Units
iii. Agree on the roles of parties during stakeholder engagement activities;
iv. Selection of individual/group stakeholders with whom engagement will occur;

1 WB ESS10: Stakeholder Engagement and Information Disclosure

v. Selection of methods for engaging and disclosure of information (including such topics as format, language, and timing);
vi. Selection of location and timing for engagement activities, for PAPs, avoiding busy work times when special activities may be occurring);
vii. Agreeing mechanisms for ensuring stakeholder attendance at engagement activities (s) (if required);
viii. Identification and implementation of feedback mechanisms to be employed.

2 CLIMATE PROFILE: CLIMATE RISK AND VULNERABILITY ASSESSMENT

2.1 Current and Future Climate Risks

Rwanda is one of the most vulnerable countries in the world to climate change[2]. Rwanda experiences high levels of climatic variability and natural hazards due to the current climate and the influence of El Niño – Southern Oscillation (ENSO) events. It is particularly affected by heavy rainfall, and combined with the hilly terrain, this leads to frequent floods and landslides.

The climate in Kigali is characterized by two rainy seasons and stable temperatures throughout the year with average temperatures ranging from 15 to 28 degrees Celsius. The mean annual rainfall for Kigali is around 1000mm a year. The highest rainfall is in April with 154mm while the driest month is July with 11mm.

Notwithstanding historic weather patterns, Kigali is facing a changing climate with increasing average temperatures of 1.4-2.3 degrees Celsius coupled with an increasing frequency of heatwaves by 7 days to 22 days per annum. Rainfall patterns are predicted to become more extreme with increased frequency of heavy rainfall and intensity contrasting with a likely increase in the duration of dry spells.

The consequences of these changing weather patterns for Kigali are likely to include periods of water shortage, decreasing water quality, an increasing risk of vector borne disease and impact on biodiversity together with the risk of flooding and landslides.

Droughts are a recurring disaster in Rwanda, often leading to famines, loss of animals, depletion of water resources and increased rates of disease. The figure below shows the number of people affected by different types of natural hazards in recent decades.

[2] Ranked no. 8 according to the Climate Risk Index 2020: https://germanwatch.org/sites/default/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_14.pdf

Key Natural Hazard Statistics for Rwanda.[3]

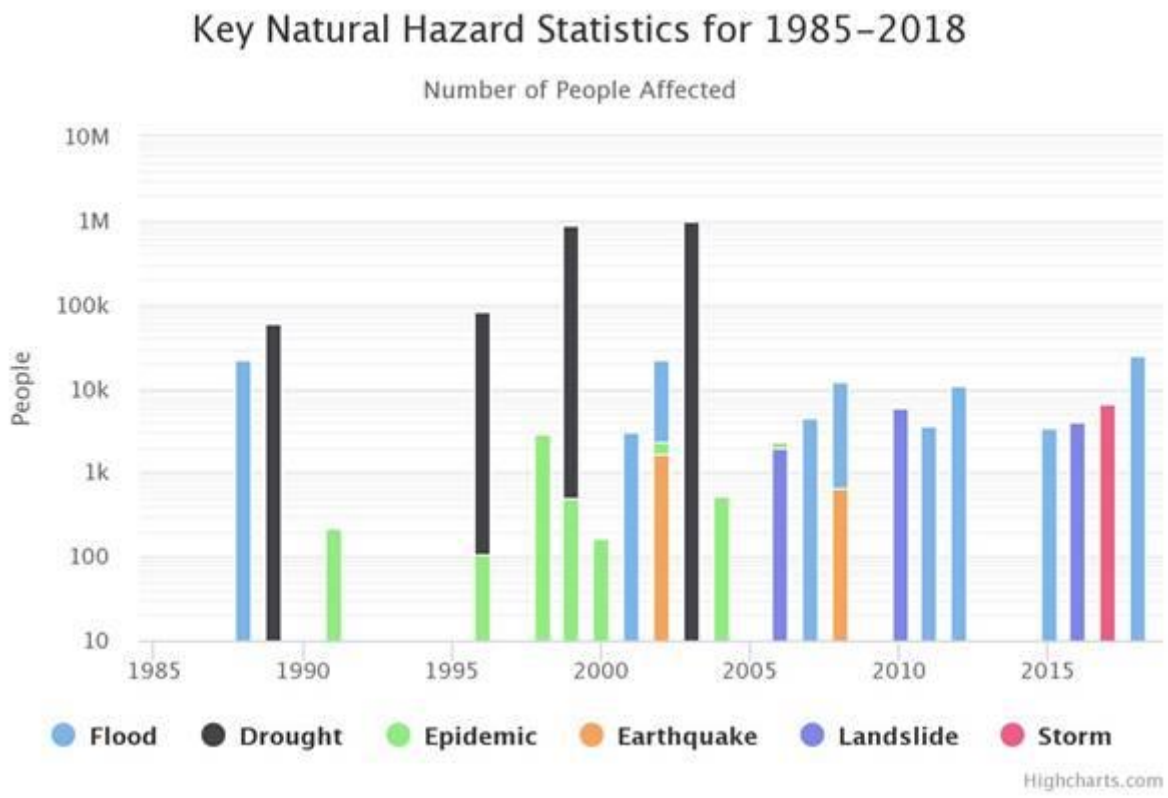


Figure 2-1: Key Natural Hazard Statistics for Rwanda (World Bank Climate Knowledge Portal, 2020).

The climate of Rwanda is already changing, and impacts are increasing. Meteorological observations show that the temperature of Rwanda has increased strongly over recent decades, with around 1.4°C of warming. There is increased rainfall intensity, which is increasing flood and landslide risk. Analysis of the global climate models project that there will be further increases in temperatures and increases in the number of hot days in the future, as well as increases in the intensity of heavy rainfall. The average temperature is projected to rise as high as 2.5 to 3.3℃ by the end of the century (World Bank, 2020). Models also predict that the average annual rainfall will change between -100mm and +400mm in the next 30 years, with short and more intense rainfalls during the rainy seasons and longer and drier periods during the dry seasons. Windstorms are also expected to increase in intensity and frequency due to climate change. Currently 2.8 million people in Rwanda are exposed to windstorms at moderate to strong intensity. Approximately 42 percent of the land is moderately or severely susceptible to landslides.

Several graphs below show the projections by the Couple Model Intercomparison Project, Phase 5 (CMIP5) included in the IPCC's Fifth Assessment Report (AR5), using the RCP8.5 (high emission scenario).

[3] https://climateknowledgeportal.worldbank.org/country/rwanda/vulnerability

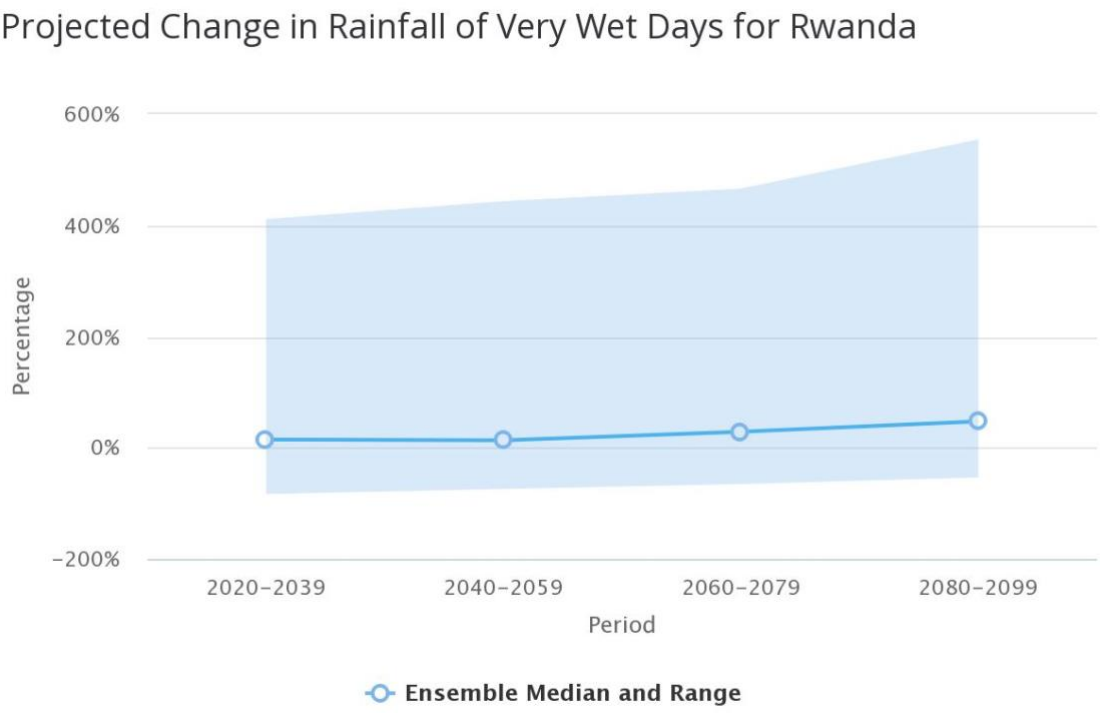


Figure 2-2: Projected change in rainfall of very wet days for Rwanda (World Bank Climate Change Portal, 2020)

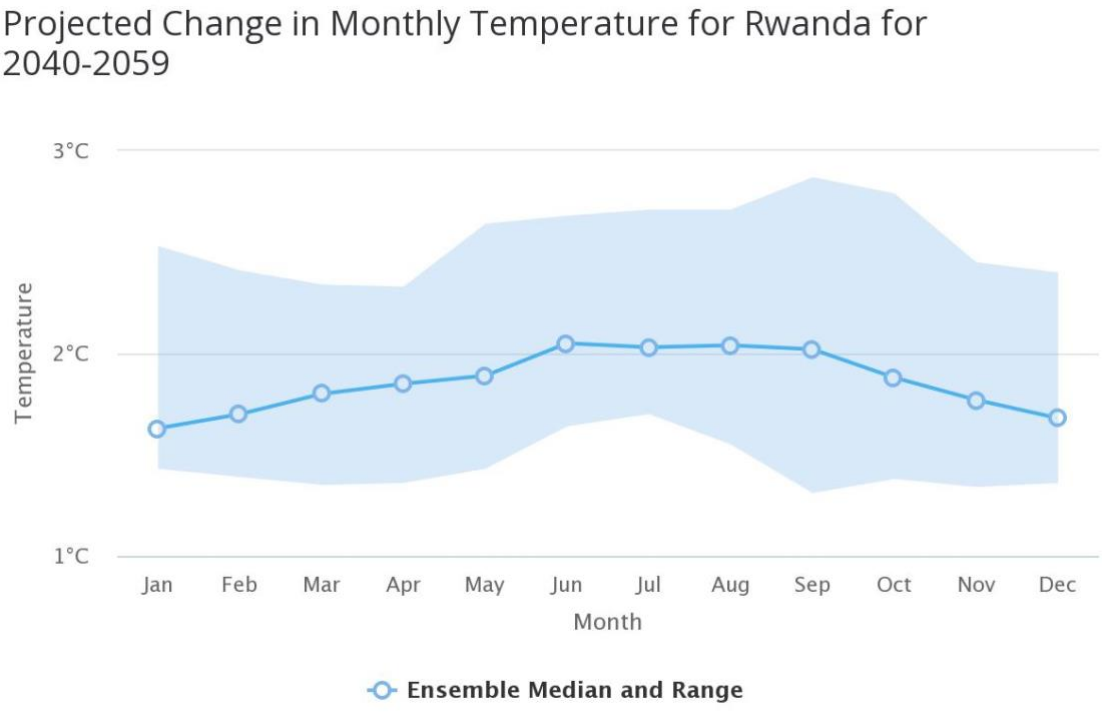


Figure 2-3: Projected change in monthly temperature for Rwanda for 2049-2059 (World Bank Climate Change Portal, 2020)

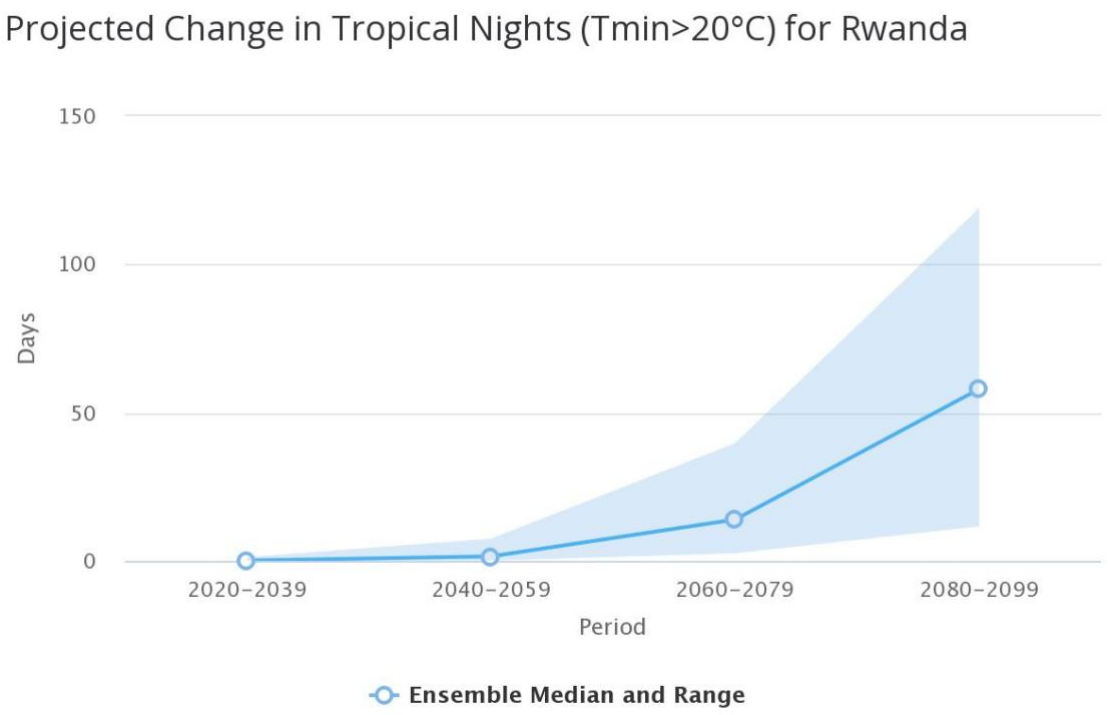


Figure 2-4: Projected change in tropical nights for Rwanda (World Bank Climate Change Portal, 2020)

All of these changes will exacerbate the impacts of current climate variability in Rwanda in urban areas, as well as lead to new risks. Rwanda is already susceptible to many diseases that are influenced by climatic factors, including malaria, meningitis and cholera. Malaria affects the largest share of the population and is second in mortality (following AIDS), causing 23% of all deaths.

Changes in rainfall patterns will pose challenges to water resource management and will require increased water supply and efficiency. It will also be necessary to reduce disaster risks by mitigating floods and landslides. Rwanda has high sensitivity to climate change and low adaptive capacity.

Summary of Climate Risks for Gasabo District / Ngaruyinka

Unplanned settlements like Ngaruyinka are particularly vulnerable to flood risks, land degradation and biodiversity loss. Kigali's wetlands have shrunken from 100 sq. km in 2013 to 72 sq km due to activities such as industry and urban agriculture. The Nyabugogo sub-catchment has also been degraded due to deforestation and unplanned settlements on the hillsides of Kigali. These changes have led to higher pollution and negative impacts to biodiversity, including native plant species and migratory birds. The loss of wetlands reduces the ability of the natural systems to help reduce flood risks, and contributes to surface water, groundwater, soil and land contamination. This results in damage to infrastructure, including roads and structures (World Bank, 2020).

A summary of the expected climate changes and associated implications for Ngaruyinka are presented in the table below.

Table 2-1: Climate change impacts[4]

Aspect	Change by 2050	Impacts for Kinyinya Hill
Temperature	Increase average annual temperature of 1.4 – 2.3 degrees Celsius.	Decreasing water quality, increase vector borne diseases, impact on biodiversity, heat stress and increasing electricity demand due to increased demand to cool buildings.
	Increased duration of heat waves by 7-22 days.	
Rainfall patterns	Increase in average rainfall (range -3 to +9 percent).	Flooding, landslides, damage to houses, roads and other infrastructure, water shortages, power cuts, pollution of water resources.
	Increased heavy rainfall event frequency (7-40 percent) and intensity (2-11 percent).	
Droughts	Likely increase in the duration of dry spells with a range of 0 to +7 days.	Water shortages, habitat degradation, decreased air quality.

The ThinkHazard! analysis tool identifies natural hazards and provides recommendations for reducing their impact. Results from the tool indicate that the Gasabo district (where Ngaruyinka is located) has the following main risks:

Table 2-2: Information from the ThinkHazard! Risk assessment for Gasabo District, Kigali, Rwanda.

Risk	Risk Level	Climate Change Impacts	Recommendations
Wildfire	High: there is a greater than 50% chance of encountering weather that could support a significant wildfire that is likely to result in both life and property loss in any given year.	Modelled projections of future climate identify a likely increase in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. In areas already affected by wildfire hazard, the fire season is likely to increase in duration, and include a greater number of days with weather that could support fire spread because of longer periods without rain during fire seasons. Climate projections indicate that there could also be an increase in the severity of fire.	Design projects in this area to be robust to increases in the severity and frequency of wildfire hazard. Areas of very low or low wildfire hazard could see an increase in hazard, as climate projections indicate an expansion of the wildfire hazard zone. Consider local studies on the impacts of climate change on wildfire trends, before deciding whether to design projects to withstand fire of greater intensity than those previously experienced in this region.
Landslide	Medium: this area has rainfall patterns, terrain slope, geology, soil, land cover and (potentially)	Climate change is likely to alter slope and bedrock stability through changes in precipitation and/or temperature.	Planning decisions such as project siting, project design, and construction methods, should take into account the potential for landslides.

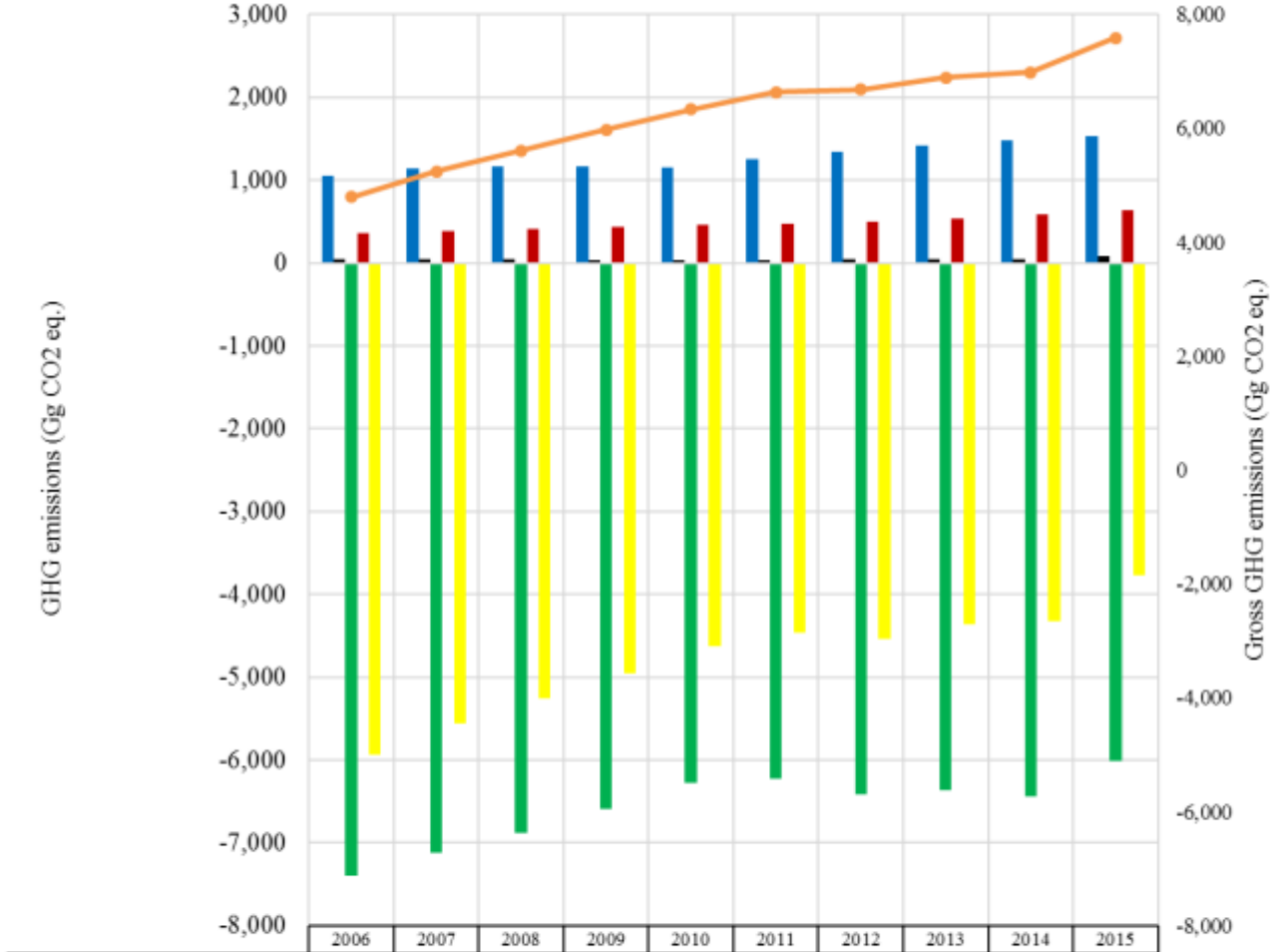
[4] USAID (2019). Climate change fact sheet

	earthquakes that make localized landslides an infrequent hazard phenomenon		
Water Scarcity	Medium: there is up to a 20% chance that droughts will occur in the coming 10 years	As noted in the previous table, dry spells are likely to increase in duration due to climate change.	Design projects in this area to be robust to increased drought hazard and water scarcity in the long-term.
Earthquakes / Volcanoes	Medium There is a 10% chance of potentially-damaging earthquake in the next 50 years Gasabo is less than 50 km from a volcano that had a potentially damaging eruption in the past, and future damaging eruptions are possible.	N/A	The potential impact of earthquake and volcanic eruption should be considered in all phases of the project.

It is critical that infrastructure in Ngaruyinka is adapted to the risks posed by climate change and that smart choices are made to mitigate future emissions. The choices of spatial planning, building material use and design, as well as energy, water, wastewater and transport systems, will affect the future emissions from the area as well as its level of resilience in the face of these threats.

2.2 GHG Emission Profile

According to the Third National Communication under the United Nations Framework Convention on Climate Change (UNFCC, 2018), Rwanda's greenhouse gas emissions with and without forestry and other land use (FOLU) had an increasing trend with annual average increases of 4.54% and 4.8%, respectively, during the period between 2006 and 2015. The increases in GHG are attributed to the growing economy, changes in lifestyle and modernization of the agricultural sector. The figure below summarises the GHG emissions from various sectors between 2006 and 2015.

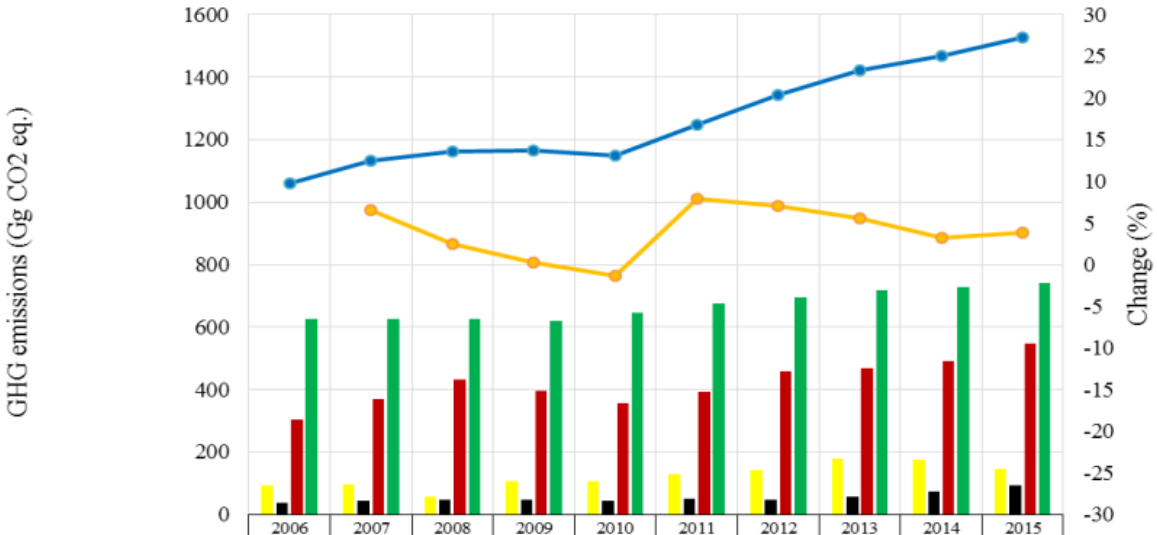


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy	1,058.79	1,139.11	1,164.18	1,164.65	1,150.14	1,248.41	1,343.16	1,421.46	1,475.12	1,526.37
IPPU	40.26	39.60	39.76	34.94	36.54	38.29	39.47	43.32	49.15	81.68
AFOLU	-7,394.51	-7,125.08	-6,879.36	-6,594.30	-6,276.83	-6,224.55	-6,416.59	-6,364.98	-6,443.97	-6,014.41
Waste	362.26	390.14	415.38	437.22	457.89	477.22	497.26	542.33	589.17	637.27
Total emissions with FOLU	-5,933.19	-5,556.22	-5,260.04	-4,957.49	-4,632.26	-4,460.63	-4,536.70	-4,357.87	-4,330.53	-3,769.09
Total emissions without FOLU	4,795.45	5,242.10	5,608.45	5,981.33	6,337.19	6,640.50	6,682.44	6,897.63	6,987.43	7,590.76

Figure 2-5: Summary of GHG emissions between 2006 and 2015. AFOLU is agriculture, forestry and other land use and IPPU is industrial processes and product use.[5]

Additional details are available for each of these input categories. The figure below shows a breakdown of the energy emissions category, including energy industries, manufacturing industries and construction, transport, and other energy-related sectors.

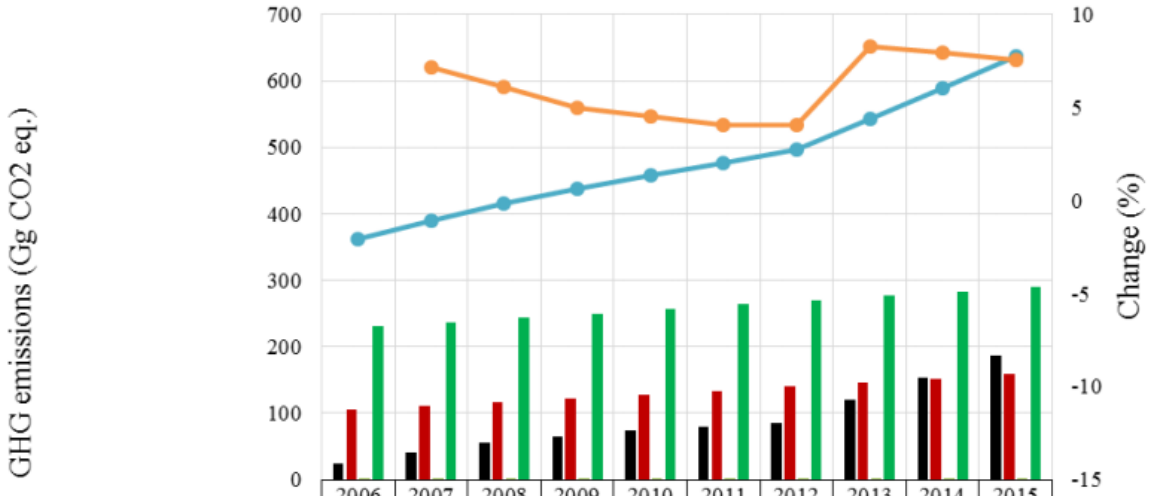
[5] https://unfccc.int/sites/default/files/resource/nc3_Republic_of_Rwanda.pdf



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy industries	91.73	95.94	58.03	104.99	105.67	130.36	143.78	179.54	176.84	144.99
Manufacturing industries and construction	38.34	42.48	46.05	46.55	43.08	48.85	47.33	56.29	73.25	92.59
Transport	301.94	369.4	432.87	394.17	355.5	393.54	458.29	468.53	489.56	547.35
Other sectors	626.77	624.92	624.62	618.94	645.43	675.68	693.78	717.1	728.56	741.44
Total	1,058.78	1,132.74	1,161.57	1,164.65	1,149.68	1,248.43	1,343.18	1,421.46	1,468.21	1,526.37
Change		6.53	2.48	0.26	-1.30	7.91	7.05	5.51	3.18	3.81

Figure 2-6: Summary of GHG emissions from the energy sector in Rwanda between 2006 and 2015 (UNFCC, 2018).

The figure below shoes the emissions associated with the waste category, including solid waste disposal, biological treatment of solid waste, and wastewater treatment and discharge.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Solid Waste Disposal	24.04	41.51	54.68	64.93	73.04	79.82	85.7	119.22	152.82	186.99
Biological Treatment of Solid Waste	105.5	110.44	115.62	121.04	126.71	132.65	140.36	145.38	152.19	159.33
Incineration and Open Burning of Waste	1.06	1.08	1.12	1.14	1.17	1.2	1.23	1.26	1.29	1.32
Wastewater Treatment and Discharge	231.67	237.11	243.97	250.11	256.97	263.54	269.98	276.47	282.88	289.63
Total	362.27	390.14	415.39	437.22	457.89	477.21	497.27	542.33	589.18	637.27
Change		7.14	6.08	4.99	4.51	4.05	4.03	8.31	7.95	7.55

Figure 2-7: Summary of emissions from the waste sector in Rwanda between 2006 and 2015 (UNFCC, 2018).

Looking forward to 2050, GHG emissions are expected to continue to rise under a business as usual scenario. The following graph shows the increases over time for energy, waste, IPPU, crops, and livestock.

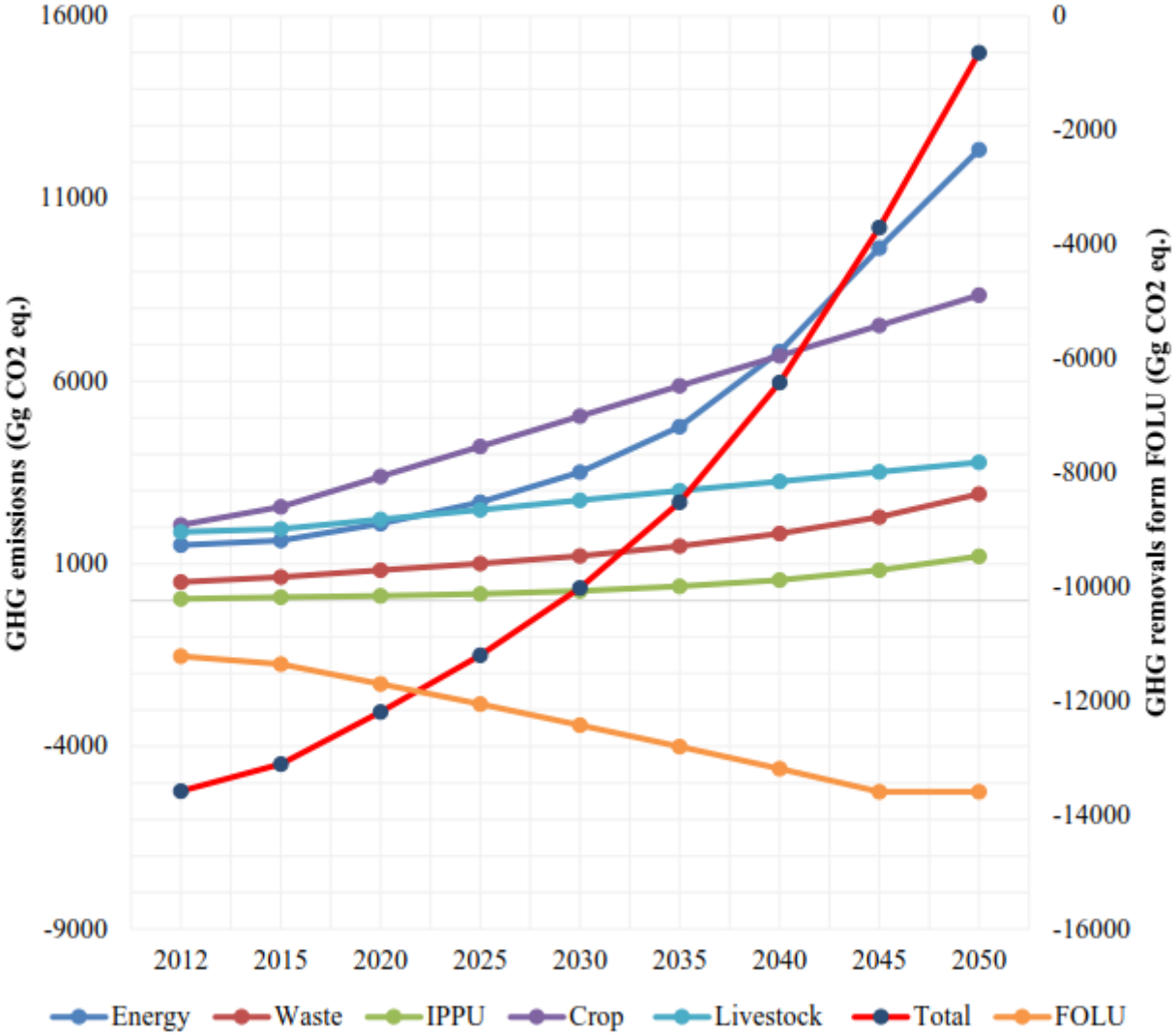


Figure 2-8: GHG simulation trends for a BAU scenario (UNFCCC, 2018).

The GHG inventory data reported in the Third National Communication covers emissions up to the year 2015. This year is also adopted as the baseline year of Rwanda's nationally determined contribution (NDC). In 2015, total emissions excluding forestry were estimated at 5.33 million tCO2e. The agriculture sector accounted for the largest share of the total (2.94 million tCO2e, 55% of total), followed by energy (1.68 million tCO2e, 31% of total) and waste (0.64 million tCO2e, 12% of total). Emissions from industrial processes and product use (IPPU) represented just 0.08 million tCO2e, equivalent to around 2% of total emissions in 2015 and mainly associated with calcination CO2 emissions from clinker production.

Under a BAU projection, Rwanda's total emissions are forecast to more than double over the 2015-2030 period, rising from 5.3 million tCO2e in the base year to 12.1 million tCO2e in 2030 (excluding removals from the forest and land use sectors). The forecast indicates the growing contribution from fossil

fuels to national emissions, arising from increasing demand for power generation, road transport and other modern energy uses.

A detailed assessment of identified GHG mitigation options for Rwanda estimates a total emissions reduction potential of around 4.6 million tCO2e in 2030 against the BAU emissions in the same year of 12.1 million tCO2e. Rwanda's NDC includes an:

- Unconditional contribution: A reduction of 16 per cent relative to BAU in the year 2030; equivalent to an estimated mitigation level of 1.9 million tonnes of carbon dioxide equivalent (tCO_2e) in that year. This is an unconditional target, based on domestically supported and implemented mitigation measures and policies.

- Conditional contribution: An additional reduction of 22 per cent relative to BAU in the year 2030; equivalent to an estimated mitigation level of 2.7 million tCO_2e in that year. This represents an additional targeted contribution, based on the provision of international support and funding.

Following the agricultural sources, major sources for 2015 included CO_2 emissions from fuel combustion for heating and cooking in buildings (LPG, kerosene), which accounted for 14% of the total, and CO_2 emissions from liquid fuel use in road transport (diesel, gasoline), which accounted for 13% of the total.

Emissions from Ngaruyinka are expected to follow similar trends under a BAU scenario with increasing levels of energy consumption for cooking, lighting and operating electrical appliances is expected to increase. Emissions from transport would also increase, with increased use of cars and motorcycles. In the solid waste sector, the BAU scenario includes increased emissions from solid waste disposal and wastewater.

Within energy use, increased use of renewables to meet increasing energy demand dominates the mitigation potential. Significant emissions reduction potential exists across each of the main sub-sectors. Hydropower, covering large- and small-scale new generation, represents the largest share of the identified GHG reduction potential, followed by the use of solar energy for water heating, pumping for agricultural irrigation and off-grid electricity which together account for around a quarter of all mitigation.

The project supports activities under the conditional NDC target, Solar mini-grids, Off-grid and rooftop solar electrification, Solar water heater (SWH) programme.

2.3 Climate Change Induced Problem

A helpful way to illustrate and explain the climate induced problem that is being tackled is through the use of a Problem Tree Analysis. It explains through the metaphor of a tree relationships between a problem (trunk), its causes (roots), and its effects (canopy). The Problem Tree Analysis for Ngaruyinka is explained in Figure 2-9.

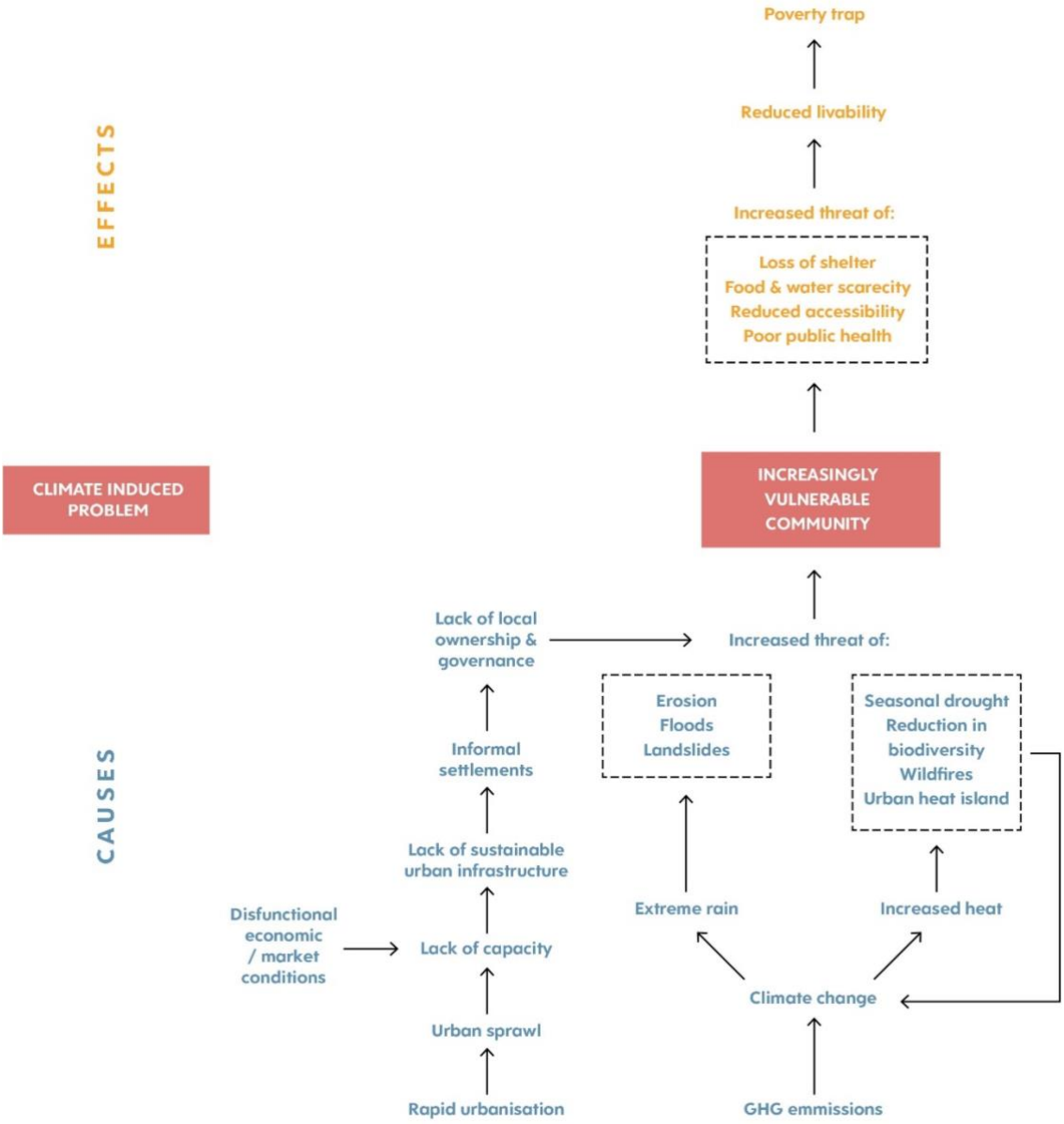


Figure 2-9: Problem Tree Analysis

2.4 Identification of Potential Interventions

A Solution Tree helps understand the solutions available to resolve the core problem which is illustrated in the Problem Tree. A Solution Tree for Ngaruyinka has been created by mapping solutions onto the Problem Tree framework. It is explained in Figure 2-10.

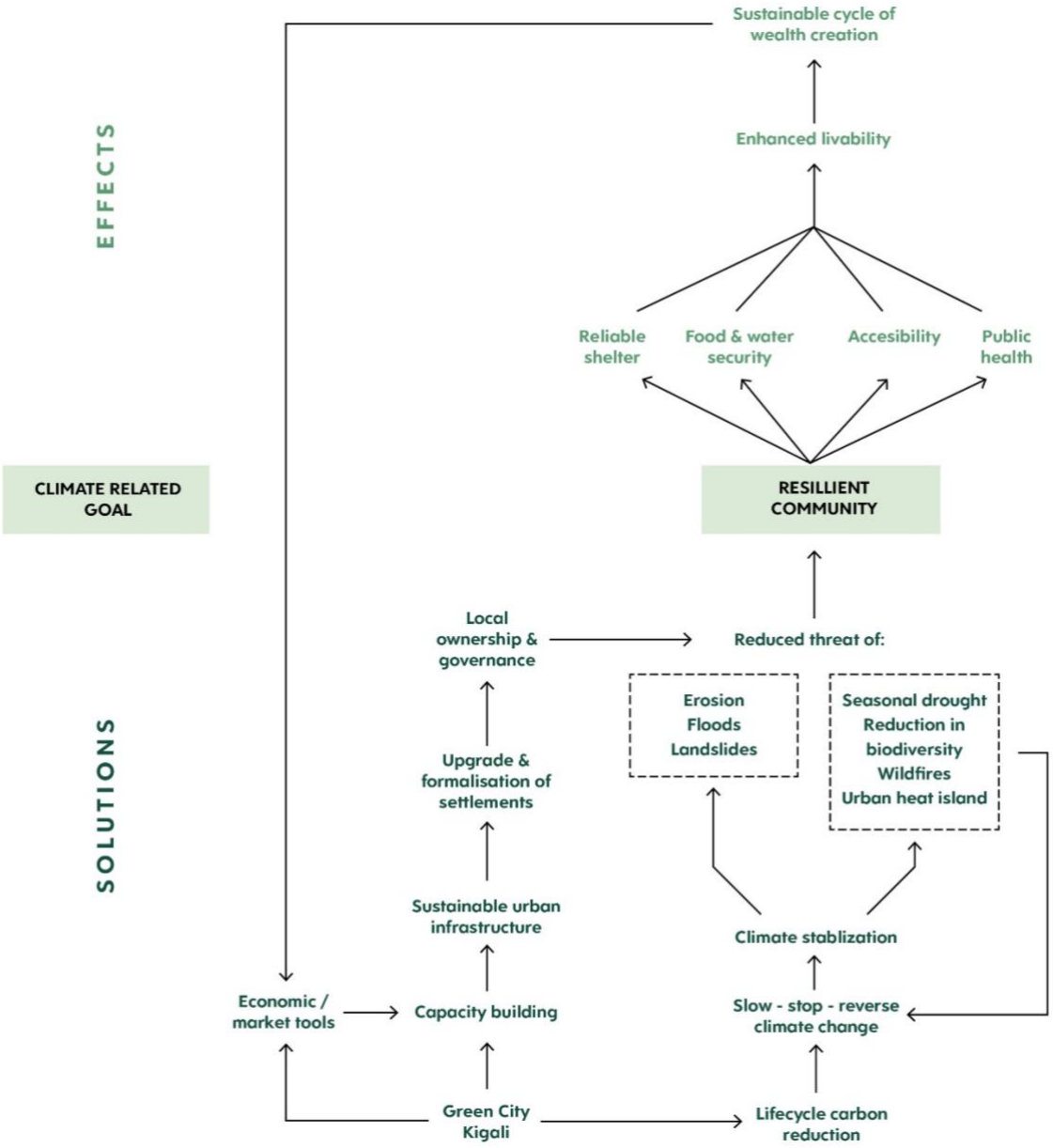


Figure 2-10: Solution Tree Analysis

3 OBJECTIVES OF THE PROJECT

3.1 Green City Kigali

Rwanda is a forward-looking country which seeks to increase the prosperity of its people while safeguarding its natural environment and strengthening communities socially and culturally. As is the case in much of sub-Sharan Africa, Rwanda's cities are predicted to grow substantially in line with the country's growing economic prosperity. It is recognised by leaders in Rwanda that a model for sustainable urban growth is required to manage the process of urbanisation in line with its vision for green economic growth.

Kinyinya Hill, located in the north-eastern area of Kigali (in Murama Sector, Gasabo District), has been identified as the subject area for *Green City Kigali (GCK)*, a project which will act as a model for climate-responsive and affordable urbanisation which can be upscaled and applied to multiple situations in Kigali and Rwanda's secondary cities. The GCK project forms part of a broader strategy for achieving sustainable, climate responsive urban growth in the country, including the development of a national spatial masterplan together with an updated masterplan for the capital Kigali.

Figure 3-1: View of Kinyinya Hill

GCK rests on four pillars of sustainable development which derive from a combination of global sustainability goals - for example the UN's Sustainable Development Goals and the New Urban Agenda - along with the specific social, environmental and economic needs in Kigali and more widely throughout Rwanda.

These four pillars are:

I. **Climate Change Adaptation & Mitigation**: Significantly lowering carbon footprint in comparison to 'Business As Usual' (BAU), through integrated and synthesized development planning which mitigates and adapts to the effects of climate change – especially atmospheric temperature increase and extreme weather events such as rainstorms and flooding.

II. **Affordable & Socially Equitable Development**: Tackling poverty and social & spatial inequalities through cost effective and efficient sustainable development; offering a diverse range of housing types and sizes to enable low to medium household income groups to invest and thrive in vibrant, socially equitable communities and sustainable local economies.

III. **Resource Efficiency**: Design, construction and strategies for long-term operation which makes highly efficient use of resources and creates circular economies in terms of land, water, energy sources and ecosystem services.

IV. **Culturally Sensitive Urban Development**: Sensitively combining a mix of Rwanda's modern, globally-oriented green economy and tradition-conscious spatial planning and design, thereby heightening urban livability and desirability through community cohesion, unity and interaction, access for all, social equality, public safety, health, wellness and learning throughout the urban environment.

The ambition for Green City Kigali is therefore to become a transformative project which will help drive systemic and sustainable change that will have a significant impact on the pattern of urban development within Kigali and throughout the country. It will contribute to the delivery of the UN 2030 Sustainable Development Goals and the New Urban Agenda together with the country's climate change and affordable housing commitments.

The funding framework for GCK derives from German Development Cooperation (BMZ) through KFW Development Bank and the Green Climate Fund (GCF). With regard to the Green Climate Fund, GCF has provided PPF funding through Rwanda's Ministry of Environment as accredited entity (AE) to facilitate necessary feasibility studies, E&S studies as well as for relevant design services for the project. The urban upgrade project has been identified as one sub-project of the Green City Kigali within this PPF framework.

The Green City Kigali Feasibility Study and related documentation provide comprehensive details of the GCK project.

3.2 Upgrade of Ngaruyinka Settlment

Two projects have been identified to be taken forward in the first phase of the implementation process for GCK. They are located close to each other, in the north-eastern corner of Kinyinya Hill creating opportunities for shared infrastructure and enabling works. Both projects are founded on the four pillars of sustainable development will deliver on the overall objectives of the GCK project. They are:

- A 16ha pilot new-build housing area along with associated commercial and community facilities on a greenfield site.
- An 18ha urban upgrade of an existing informal settlement (Ngaruyinka).

The Ngaruyinka project has been selected to provide a model for climate responsive upgrading of informal settlement in line with the Solution Tree Analysis in Figure 2.10. The objective is to create a model approach which can be upscaled and applied to multiple situations across Rwanda to maximize positive climate impacts in line with the GCK approach.

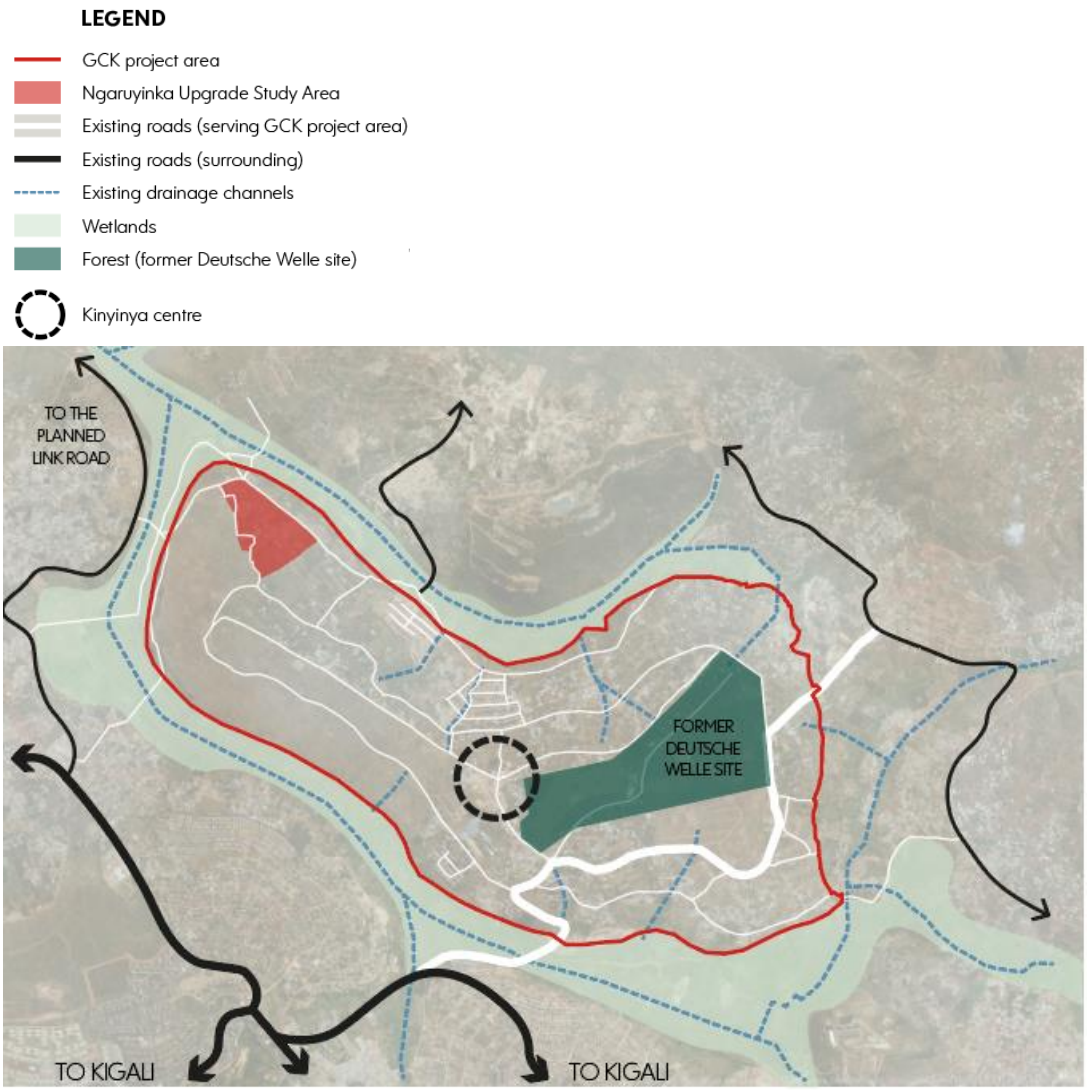


Figure 3-2: Ngaruyinka in the context of Kinyinya Hill and Green City Kigali (GCK)

3.3 Project Alignment with GCF Investment Criteria

The Ngaruyinka upgrade project will align with the GCF Investment Criteria. These criteria form a frame of reference for the Multi Criteria Analysis methodology, as set out below. The criteria are as follows:

- **Impact potential**
- **Paradigm shift**
- **Sustainable development**
- **Needs of recipients**
- **Country ownership**
- **Efficiency and effectiveness**

4 SECTORAL AND INSTITUTIONAL CONTEXT

4.1 Urban Challenges in Kigali & Rwanda

Kigali is a rapidly urbanizing city in the most rapidly urbanizing part of the world where the effects of climate change are felt acutely. Current urbanisation trends have been toward low-density informal sprawl on unsuitable land, creating vulnerable communities and threatening Rwanda's food security and the environment.

4.1.1 Population Growth & Urbanisation

Rwanda has the highest population density in mainland Africa, and the population is growing at 2.8% per year. It is predicted that the population will more than double from 11 million today to 26 million by 2050. The most acute trend within this overall projection will be seen in and around existing urban centres. This can be explained mainly by the increased pattern of rural to urban migration of persons in search of the perceived better economic opportunities. For example, the population of Kigali is estimated at 1.6m in 2020 and is projected to rise to 2.5m in 2032 - an average increase of 4.0% per annum.

If this urbanisation is properly managed and coupled with affordable, quality homes and access to jobs and services, it can be an instrument for sustainable wealth creation. Alternatively, there is a risk of an increase in sprawling and informal housing areas developing on unsuitable land in and around urban centres.

4.1.2 Systemic Constraints on Delivery of Sustainable Communities

In order to cater to a fast-growing city, Kigali will need to produce over 35,000 new dwelling units per year. Unfortunately, to date, the actual rate of production has fallen far short of this. The result is that the vast majority of Kigali's residents continue to inhabit informal housing, with the small amount of formal housing that does exist too expensive for the average resident. There are currently two major constraints within the housing sector: affordability and supply.

Housing Affordability

Rwanda has extremely high housing costs in relation to Gross National Income (GNI) per capita. This is due to the costs of development far outstripping income levels. Costs are high due to the scarcity of local materials, skills, labour and the high cost of financing. Conversely, around 80% of the population of Kigali receive less than $550 monthly income and around 18% live on less than $110.

This situation is compounded by the state of the capital and mortgage markets whereby banks are severely undercapitalized and household mortgage interest rates are exceptionally high (around 16% per annum), with typical down payments of 20% required and fees reaching 10% of purchase price. Consequently, Rwanda's penetration rate for mortgage loans of one-third of 1% of households is one of the lowest rates in Africa. Whilst households will willingly apportion 35% of household income to housing costs, at present good quality, affordable homes are generally out of reach at almost all levels of the income pyramid. This situation is made even worse by demand for affordable housing far outstripping supply.

Housing Supply

Kigali and Rwanda have a small construction sector with a low capacity which is currently unable to meet the current demands for housing construction. The country is landlocked; skills and materials are low in supply locally and expensive to import. Consequently, whilst Kigali will see a future demand for over 35,000 new homes to be built per annum, less than 3,000 homes are likely to be completed given current conditions. Most of these homes will be affordable for the top 30% of households only.

4.1.3 The Challenge of Informal Settlements in Kigali

The trend toward sprawling and informal housing areas developing on unsuitable land is resulting in communities that are highly vulnerable – to the increasing effects of climate change, to social and economic exclusion, and to wider environmental, public health and social impacts. Informal settlements in Kigali today often show varying degrees of housing quality and connectivity to public infrastructure. The most acute issues are stormwater erosion and flooding, the lack of adequate sanitation and inadequacy of social infrastructure as settlements are often located in inaccessible locations far from mainline public services. Coupled with this - and given the increasing population pressure in rural farming areas - is the associated threat of urban sprawl on the urban hinterland and Rwanda's ability to meet future food security needs.

In Kigali there has been an effort to relocate inner city informal settlement populations to new developments on the city periphery. However, once resettled there has been a trend for recipients to sell or rent out these units and return to central city informal settlements.

This is magnified by the trend that large areas of low-quality housing on small plots are more convenient and profitable to landowners compared to more permanent housing solutions based on relocation. This form of land usage creates a more competitive individualistic social context thus eroding the traditional social cohesion that is desirable to nurture within a community.

4.1.4 Densification & Formalisation

Densification and formalisation of urban growth in Rwanda's cities are therefore understood to be critical success factors to ensure inclusive, sustainable and economically active urban communities and is key to the green growth objectives of Rwanda as a whole.

High density walkable cities have been identified as one of the three 'big wins' of the National Urbanisation Policy (2015). High density development means a smaller built footprint; preserving more green space for valuable ecosystem services to help tackle climate change effects. If urbanisation is not achieved in a high-density manner, cities will face unprecedented levels of unplanned urban sprawl, often on unsuitable land which is highly vulnerable to the effects of climate change. This forces people to travel greater distances than necessary using motorised transport, resulting in unnecessary greenhouse gas emissions as well as air pollution. Planned densification can also create economies of scale to reduce costs, increase the viability and accessibility to public services, improve the affordability of sustainable and smart technologies and increase the quality of urban life while decreasing carbon footprint.

Culturally, Rwandans place a strong emphasis on privacy and prefer larger single-family homes with enclosed private outdoor spaces which runs counter to higher density urbanisation patterns. However, younger generations in Kigali are seeing the benefits of medium to high density ways of living, and anecdotal evidence gathered through consultation during the GCK feasibility stages has shown that even older Rwandans are positive about the future need for this transition.

4.2 Key policies and strategies

4.2.1 National Informal Urban Settlement Upgrading Strategy (2017)

The National Upgrading Strategy published by MININFRA is the key policy document relating to upgrading of urban settlements in Rwanda. It follows the provisions of the National Housing Policy (2015) which states that; *'existing informal housing units shall be upgraded and integrated into the formal housing stock to the highest degree feasible'*. The ultimate goal is that basic infrastructure will be available in all neighbourhoods, so that the efforts of formal housing development will also impact on the improvement of living conditions for low income groups, and to not drive low income groups out of serviced neighbourhoods as a result of market economic principles.

This strategy identifies five options of implementing an upgrading project and recommends where best each of the five options shall be adopted. They are:

Initiative of collaborating landowners who may form a cooperative, with intervention predominantly recommended in area where landowners are ready to invest in upgrading / development;

Investment, where a Real Estate Investor may either be acting on own proposal, or may have been identified by a group of landowners or government, with intervention recommended in areas under development pressure;

Initiative of the Central or Local Government, the intervention of which shall focus on areas requiring basic infrastructure provision following public investment plan, and in underserviced areas where the community alone is not capable to upgrade;

A scheme out of a Social Investment Trust, with intervention recommended in areas which are not matching Masterplan requirements;

Schemes developed with development partners, NGO/CSO's or lending institutions, whose support will be requested to focus on the most underserviced areas with low / very low income population.

The Strategy defines urban upgrading as per the definition of Cities Alliance (2003) as physical, social, economic, organizational, and environmental improvements undertaken cooperatively among citizens, community groups, businesses, and local authorities to ensure sustained improvements in the quality of live for individuals. Urban upgrading comprises measures intending to improve the living conditions of the urban population living in informal settlements by providing basic infrastructure and by supporting measures which facilitate non-governmental actors maintaining and increasing the urban housing stock.

The National Upgrading Strategy provides the key point of reference for the 'Business As Usual' approach set out in this Study.

4.2.2 2030 Agenda for Sustainable Development

Rwanda is a signatory to and has ratified the Paris Agreement under the United Nations Framework Convention on Climate Change and as such it follows the UN targets of reducing greenhouse gas emissions.

The 2030 Agenda for Sustainable Development published by the United Nations forms the global sustainable development framework and is a plan of action for people, planet and prosperity. The Agenda is anchored around 17 Sustainable Development Goals (SDGs). SDG 11 is a standalone goal on cities and human settlements namely *"Make cities and human settlements inclusive, safe, resilient and sustainable"*. The SDGs promise to address the growing challenges in the interlinked economic, social and environmental dimensions of sustainable development.

The GCK project seeks to deliver on SDG11 and it follows the general approach of interlinking the economic, social and environmental dimensions of sustainable development.

4.2.3 The New Urban Agenda

The New Urban Agenda (NUA) is the framework of the United Nations that that lays out how cities should be planned and managed to best promote sustainable urbanization to achieve the objectives of SDG11. It readdresses the way cities are planned, financed, developed, governed and managed, recognizing sustainable urban and territorial development as essential to the achievement of sustainable development and prosperity for all.

The New Urban Agenda now supports member states to implement the urban portions of their Nationally Determined Contributions (NDCs) into achieving of the long-term goals of the Paris Agreement on Climate Change.

4.2.4 UN Habitat PSUP

The UN's Participatory Slum Upgrading Programme was founded in 2008 as a tripartite initiative of the Secretariat of the Africa, Caribbean and Pacific Group of States (ACP), the European Commission and UN-Habitat. PSUP focuses on the most urgent deprivations for slum communities: the lack of adequate and safe housing conditions, clean water supply, sanitation and secure land tenure. The Programme focuses on solutions for waste management, gender equality and human rights, climate resilience and participation of the local communities in the slum upgrading process.

5 BASELINE – CONTEXT AND SITE ANALYSIS OF NGARUYINKA

5.1 Nagaruyinka in the Context of Kigali

Kinyinya Hill lies approximately 6km due north-east of the institutional and commercial centre of Kigali, on the northern periphery of the built-up area of the city within Gasabo sector. The general area is typically made up of formal and informal low-density housing and agriculture with some scattered industrial and commercial activity. The GCK project area is naturally defined by the topography of Kinyinya Hill and the surrounding wetland valleys, and measures 600 ha in area. Ngaruyinka lies in the north-western corner of Kinyinya Hill, on a north-facing hillside within the GCK area boundary.

Kinyinya Hill today is characteristic of the general surrounding area. It comprises areas of vacant developable land, the 70ha government-owned former Deutsche Welle site, some formal and informal agricultural land together with existing formal and informal housing communities and neighbourhood centers with commercial areas serving the communities. The Deutsche Welle site is currently subject to a parallel development planning process. There is some mining of clay with associated brick production occuring on the southern facing slope of Kinyinya Hill adjacent to the wetlands.

The forested Deutsche Welle site is the most biodiverse part of the Hill. Lying centrally at on the crest of the Hill, it comprises a large number of mature trees and is home to more than 50 species of birds and other small wild animals rarely seen in proximity to the capital. In addition, many of the surrounding wetlands provide important ecosystem services in terms of habitat, biodiversity and food production. Elsewhere though, Kinyinya Hill's natural flora has been depleted and is being progressively replaced with non-native species and crops, including eucalyptus trees. Little natural vegetation remains outside of the former Deutsche Welle site and uncultivated areas of the wetlands.

The primary existing access to the Hill from the city is from the south through the districts of Nyarutarama and Remera and west through Kagugu. In future, a regional link road will be built due west of the GCK area and provide better access from the primary network. The current modal split on Kinyinya Hill is divided approximately as follows: 71% walking, 20% public transport, 6% motorcycle taxi and 3% car, with a small proportion of bicycle use both for personal and commercial use. Car ownership is low due to low income levels and lack of affordability. The high proportion of walking reflects income levels but also indicates that daily activities are mostly undertaken locally or in close vicinity to the Hill. The road network serving the Hill is under-developed and comprises a mixture of paved and unpaved roads, many in poor condition. The community is served by a local bus terminus and the motorcycle taxi service which operates throughout Kigali.

The provision of public utilities and municipal services on Kinyinya Hill is limited and patchy, offering considerable scope for improvement. Mains electricity is generally available but not all houses are connected to the grid. Some households have a connection to the central water supply system, while other households purchase water from a kiosk. Wastewater is primarily managed via a mix of pit latrines and some septic tanks which create a risk of groundwater contamination. Solid waste is collected by the municipality but there is no provision for waste treatment or recycling. Cooking is still largely undertaken using charcoal, creating both environmental and health risks. Mobile telephone coverage is available but there is no cable provision for high speed internet access.

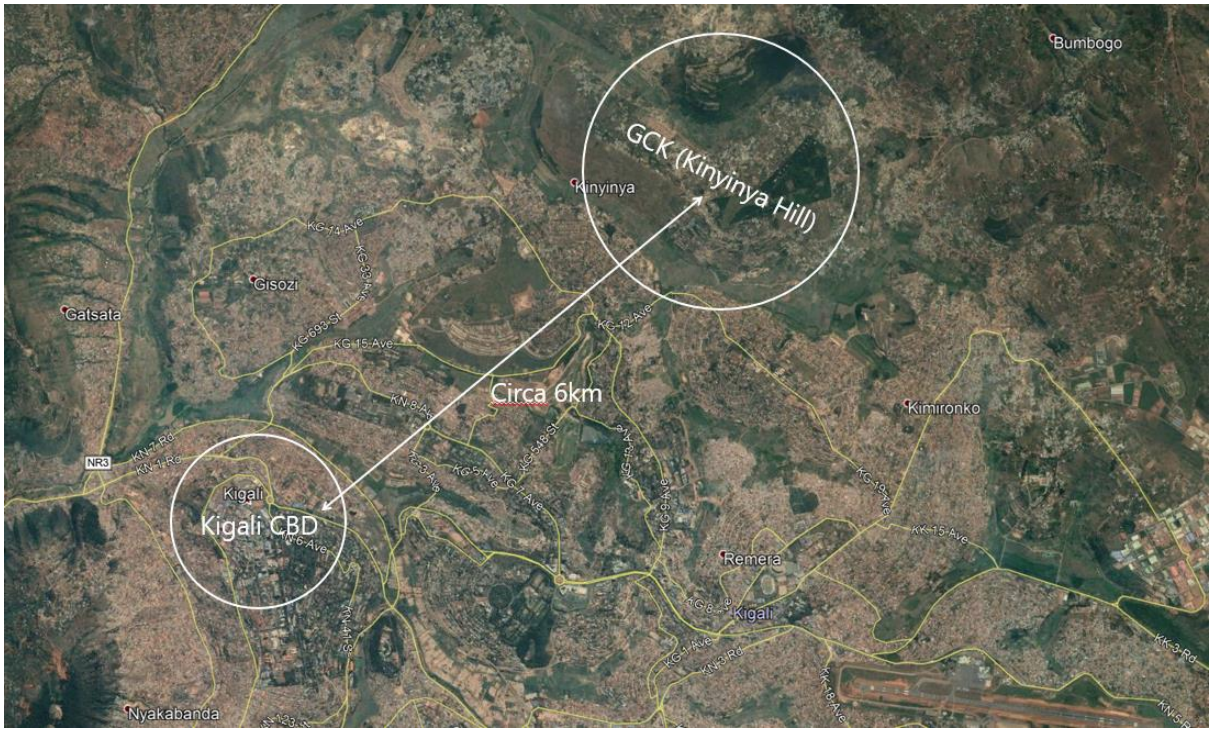


Figure 5-1: Location of Kinyinya Hill / GCK in relation to Kigali CBD

Figure 5-2: Location of the pilot project and Ngaruyinka in relation to Kinyinya Hill / GCK

5.2 Ngaruyinka Study Area

A topographic survey of Ngaruyinka was conducted in Spring 2020. This data has been converted into DWG and GIS data sets and provides the basis of the following condition survey. In addition to this several site visits have been carried out in the settlement to conduct interviews and additional physical survey work. Visits have been accompanied by local community leaders and representatives.

Figure 5-3: Ngaruyinka upgrade area defined

5.2.1 Topography

The settlement lies on a steep north-facing slope. For the most part the land falls to the north at a gradient of around 15%. The slope gets shallower at the southern and northern ends and is steepest in the central area.

Building foundations, roads and pathways have been manually levelled. Most buildings have poured concrete foundations, and some have concrete retaining walls. Roads and pathways are often shored up with sandbags as makeshift retaining structures.

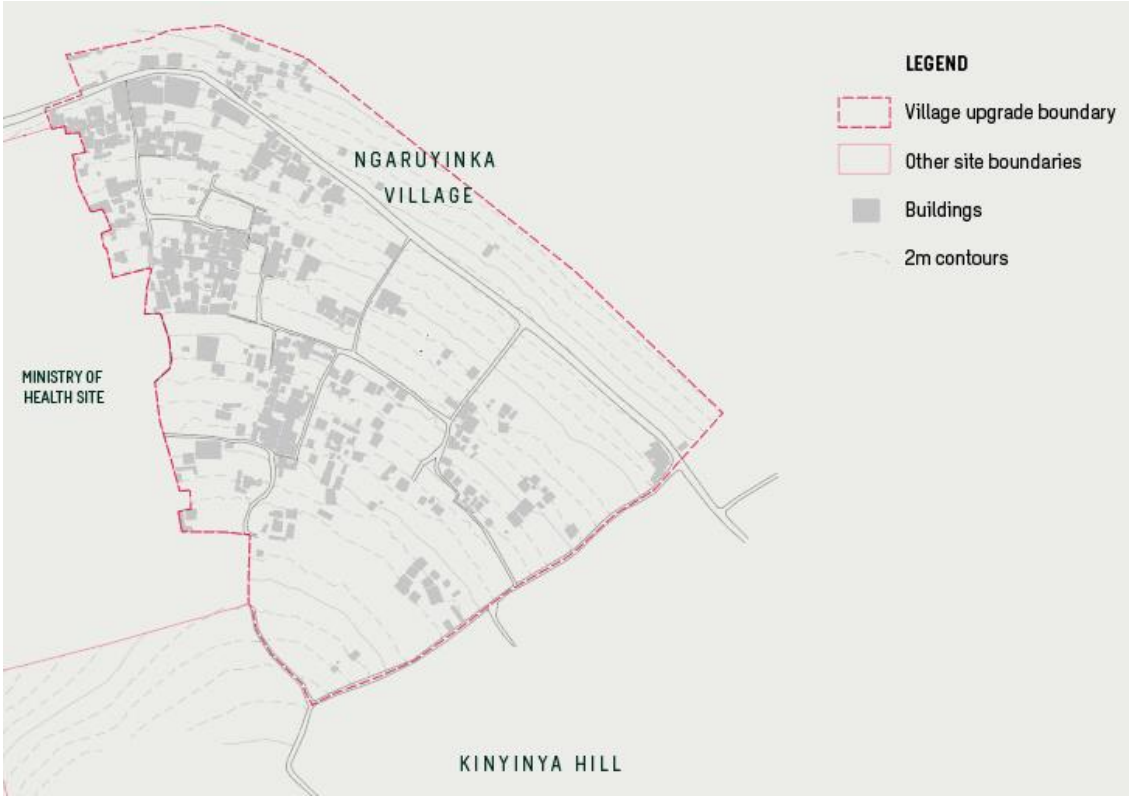


Figure 5-3: Topographic map of the study area

5.2.2 Population

The resident population of the Ngaruyinka settlement study area (as defined by figure 5-3) has been calculated at 1634. This has been calculated through a house by house count undertaken by local survey team with assistance from local community leaders and representatives. Average household size is 4-5 persons. The oldest living person in Ngaruyinka is 90 years old.

5.2.3 Land Uses & Activities

The built footprint of the settlement consists mainly of single family and multi family homes. Together they total 321. In addition to this there is one primary commercial area at the foot of the hill along the main access road and a secondary commercial area within the settlement itself.

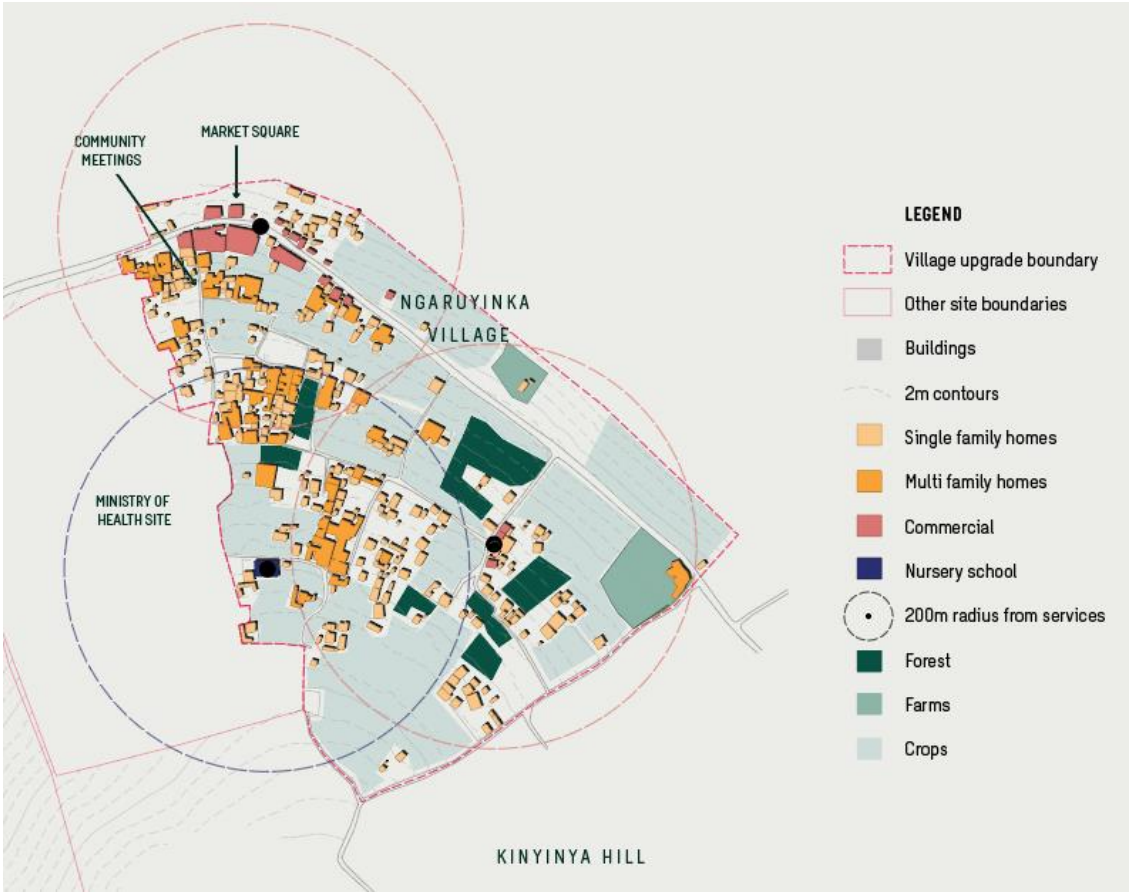


Figure 5-4: Ngaruyinka – land uses and services catchments

There is nursery school located halfway up the slope on the western boundary of the settlement adjacent to the Ministry of Health site. Primary and Secondary schools are located in Kinyinya centre. Murama sector has recently bought an ambulance that will service four communities in Kinyinya including Ngaruyinka. There are three community health workers in the community. The closest Primary Health Clinic is Kinyinya Health Centre about 40min walk away and there is a health post in Rwankuba around 20 minutes' walk away. The commercial area is supplied every morning by truck from Kinyinya center and consists of the following local shops and services:

- 2 x small restaurants serving local food, milk and tea
- A small market square selling locally harvested vegetables and charcoal
- A small canteen serving tea and bread
- A men's hair salon (there is no salon for women)
- Several small shops and kiosks selling vegetables, milk, grains
- Butcher shop (opening soon)

Local community meetings and events are held under trees in a clearing in the middle of the settlement which is also used as a market place. The New Life in Jesus church lies about 35min walk away from Ngaruyinka. Other religious buildings are located up the hill about 25min walk away toward Kinyinya Centre. Practically the entire 18ha study area is within a 200m catchment of either a commercial area or the school. The remainder of the area is a mix of grassland, formal farms and informal, domestic level farming. Further development in the settlement has been halted until infrastructure can be improved.

Figure 5-5: Market square in the settlement

Figure 5-6: A typical shop in the main commercial area

Figure 5-7: The community meeting place, also used as a market

Figure 5-8: Farming in the settlement

5.2.4 Buildings

Most of the buildings in the settlement are single story homes and/or commercial premises constructed of mud/clay bricks typically with corrugated steel roofs and steel framed doors and windows. Many buildings have concrete foundations and facing render. There are occasional concrete brick buildings. Many buildings are in a poor state of repair on facades and around foundations, particularly in high erosion risk spots (see below).

Figure 5-9: Typical part-rendered mud and clay brick facades with corrugated roofs

5.2.5 Public Spaces, Lighting & Furnishings

For the most part, all the streets and pathways in the settlement are very rarely trafficked and in effect they act as pedestrian controlled public space and play areas. There are a few specific places that are currently used for formally as 'public spaces', most significant of which is the market area. Every house located along the streets is required to have a light facing the street to act as public lighting although

coverage is very limited. There is no evidence of formal street furniture or public waste bins in the settlement.

Figure 5-10: Typical small streets in the settlement

Figure 5-11: Public space outside a cafe

5.2.6 Land Ownership

Approximately 60% of the population of the community rent their homes. It is typical that the landowners are also residents and that they might receive rent from around 10 households on their land.

5.2.7 Security

According to interviews with local residents at Ngaruyinka, most crimes in the area are petty thefts of phones, bags, etc. There is a community patrol in the settlement that is organised by a community member responsible for security. The least safe location in the community is apparently towards the top of the hill, near the Ministry of Health site and wasteland.

5.2.8 Socio Economic Conditions

The Integrated Household Living Conditions Survey EICV 3 (2012) survey results indicated that the Gasabo District's labour force (working population: persons above 16 years) is approximately 383,000 people. The working to population ratio for Gasabo is at 81 compared to a ratio of 77 in Kigali City.

In terms of the employment rate, a key indicator for enhancing economic growth and poverty reduction, the Gasabo district is well positioned, as evidenced in the following Figure 5-12 below.

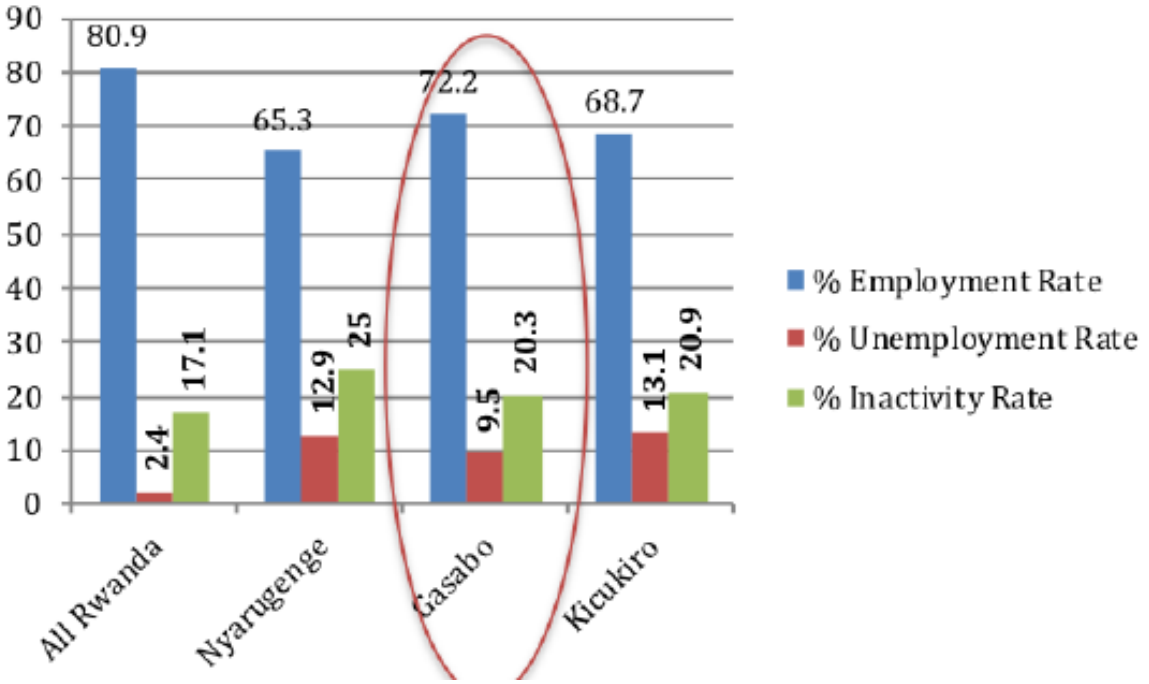


Figure 5-12: Employment Status for the Different Districts in Kigali City

The population of Kinyinya belongs to the medium and low-income class. Further assessment of the district's active population indicates that 5.1 % depend on farm wages and 47.9 % on non- farm wages.[6] Main sources of employment for the districts is shown in the following Table 5-1.

[6] https://gasabo.gov.rw/fileadmin/_migrated/content_uploads/Gasabo_DDP_2013-2018.pdf

Table 5-1: Main sources of Employment for the Districts and the National Average[7]

	Public	*Parastatals*	*Private, formal*	*Private, informal*	*Others*
National	*9.1*	*3.4*	*16.2*	*69.5*	*1.7*
Nyarugenge	*11.5*	*4.9*	*35.3*	*45.5*	*2.8*
Gasabo	*10.6*	*3.1*	*25.8*	*57.4*	*3.2*
Kicukiro	*8.6*	*6.4*	*27.9*	*53.5*	*3.6*

Important to note is that Gasabo District has a high number of labour force (16+ years) migrating for work compared to the other districts in Kigali City Province, both in terms of arrivals and departures. Gasabo registers approximately 41,000 arrivals and 30,000 departures compared to 37,000 and 28,000 arrivals realized in Kicukiro and Nyarugenge respectively (EICV3, 2012).

Although the Gasabo District's employment rate is at 72.2%, the District has the highest poverty rate of 15.8% compared to the sister provincial districts Kicukiro with 11.4% and Nyarugene with 11.8%. Extreme poverty rates are similar, with 3.5% extreme poverty in Kicukiro, 4.5% in Gasabo, and 4.6% in Nyarugenge.[8] Nevertheless, the Gasabo District's rates are better than the national rates of 39.3% and 16.5% for poverty and extreme poverty rates respectively and the revised target of 20% of extreme poverty by year 2020.

The majority of people in Kinyinya are self-employed.

Wages and salaries of households in Kinyinya have an average of 227,387Rwf. The national poverty line is 159,375 FRw[9] per adult equivalent per year.

5.2.9 Agriculture Activities

Gasabo District's agriculture sector is mostly based on cultivation of avocado (42.9%) and French beans (36.1%), as well as on cash crops like sugar cane (5%) and coffee (2.8%). On a national level, the majority of households are growing French beans (65.8%), avocado (37.4%), squash (26.2%), sugar cane (10.9%) and coffee (10.8%).

Table 5-2: Percentage of cultivating households producing fruit, vegetables and export crops

EICV3	No.of HHs cultivating land for crop production (000s)	% of HHs producing selected fruit and vegetables					% of HHs producing export crops			
		French beans	Avocado	Squash	Pepper	Papaya	Coffee	Tea	Cane sugar	Sunflower
Gasabo	68	36.1	42.9	24.9	26.2	21.1	2.8	0	5	1.4
Rwanda	2,095	65.8	37.4	26.2	19.4	16.8	10.8	0.9	10.9	6.8

Agro-business opportunities

Agriculture offers agro-business opportunities through the commercialization of crop production. These opportunities are measured by the share of harvest sold (including households selling zero crops) which is 19.6% in Gasabo District and below national level (20.9%). The mean share of harvest sold for fruits

[7] EICV3 Survey, 2012
[8] EICV5 Survey, 2017
[9] The Fifth Integrated Household living conditions survey, EICV5 (2016/17)

and vegetables is lower (16.3%) than that of staple crops (20.1%) in Gasabo District. Gasabo District is using improved seeds and chemical fertilizer in an insufficient way.

Livestock production and productivity

The main type of livestock raised by Gasabo District's households are hens, goats and cattle. Gasabo District counted only one milk collection centre with a capacity of 1,000 l (March 2013), but it is not currently operational. Since 45.3% of the District's households own cattle already, the expansion of milk commercialization and investment in milk collection centres could be profitable for the District's economic development.

5.2.10 Health

The leading causes of mortality in Gasabo District are malaria, respiratory diseases, AIDS, diarrheal diseases and diseases related to malnutrition. These various causes of mortality are often related to lack of hygiene or limited financial resources.

The diseases mostly affecting the people of Kinyinya are malaria and flu. The sexually transmitted diseases are rare (1.95% have been affected).

5.2.11 Education

There are currently three schools in the Kinyinya Hill area:

- Pefa Nursery School: primary level;
- GS Kinyinya: secondary A level; and
- College Amis Des Enfants: secondary A level.

In relation to education, the indicators such as gross primary enrolment rate (139.9%) and gross secondary enrolment rate (66.1%) positions the district below the national rates of 148.4 % (gross primary enrolment) and above the 40.9% national rate in gross secondary school enrolment. Also, in terms of literacy levels, the District's literacy levels persons of 15 years and older at 84.8 %, is above the national average rate of 69.7%, though, slightly below rates registered in Kicukiro and Nyarugenge at 89.5% and 86.7% respectively. The district level is below the country's target of 90% and 100%, as stipulated in the 7YGP and Vision 2020 respectively. The computer literacy rate for persons of 15 years and older stands at 17.4 %. The District recognizes the need to improve the literacy rates to boost up ICT innovations and private sector led economy.

According to the administrative data, the girl/boy attendance at primary level is equally balanced at 50% unlike the imbalance observed at a higher level.

In terms of student/classroom ratio at primary level is at 35.9, below the standard of 46 pupils per classroom while pupil/qualified teacher ratio is 54. However, it is also observed that the District has unqualified teachers, for example, in private, private-aided and public primary schools, at 5%, 4% and 8% respectively. Computer and internet usage in primary schools is through 4,641 computers and 28 schools have internet access.

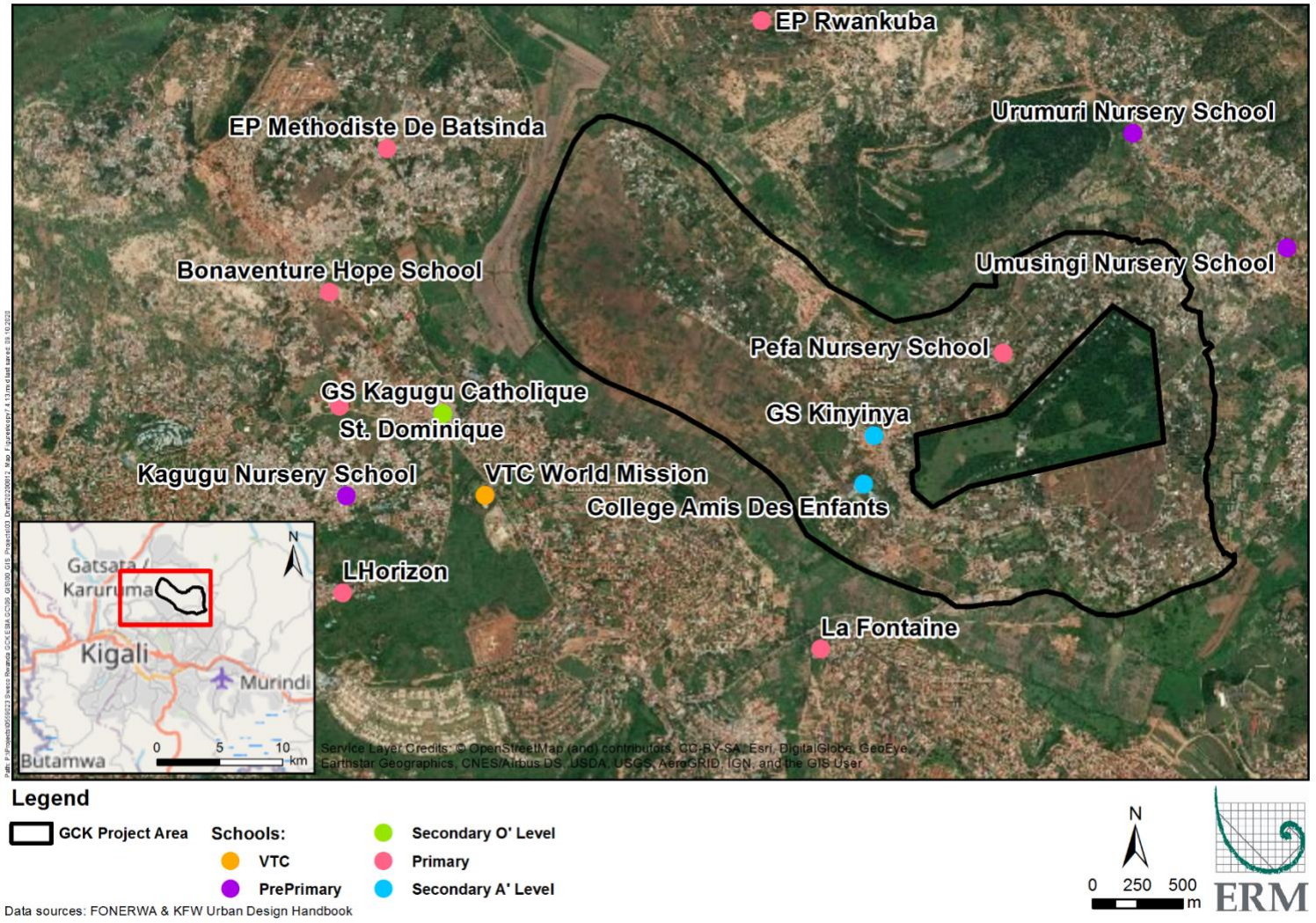


Figure 5-13 Schools in the proximity of Ngaruyinka

5.2.12 Existing Environmental & Social Risks

There are significant existing environmental and social risks at Ngaruyinka, as explained in the previous sections and chapters. The increase in informal neighbourhoods, a direct consequence of urbanisation, is largely due to market forces in the inner cities. Low-income earners are constantly being pushed out of Kigali's city centre due to the high cost of living. It has been estimated that more than 340,000 housing units will be needed by 2022 to supply the growing number of city dwellers. Meanwhile, the desire to survive in Kigali at all costs has driven the development of many informal enclaves where housing structures are of poor quality. In Ngaruyinka, the informal development is characterised by the lack of adequate waste and sanitation facilities and lack of stormwater drainage. These gaps lead to environmental degradation and social risks, such as poorer health and vulnerability to storm events. The High-Level Environmental and Social Impact Assessment Report prepared for the Green City Kigali Project contains additional information regarding environmental and social risks.

5.3 Status and Conditions of Existing Infrastructure

5.3.1 Transport & Mobility

Current transport infrastructure is underdeveloped with poor accessibility, reliability and resilience and posing threats to properties through erosion and flooding hazards. Roads are packed clay earth with erosion cracks and channels, and none are consistently wide enough for passing vehicles. Adjacent buildings and the slope constrain road widths for roads across the slope, and some roads are very steep (10-20% gradient). There are many footpaths between houses and some up the hill, and erosion channels are present as well as erosion and flooding controls such as sandbags. There are numerous slip hazards especially in wet conditions, and railings and safe stairways are often lacking. Conditions for cycling are very poor and unsafe especially due to uneven surfaces and gradients. Right of way lighting is present on buildings but is not continuous on thoroughfares. Some brick channels exist for open drains, and ditches are common. Elsewhere in Kigali there are paved roads and roads laid with stone.

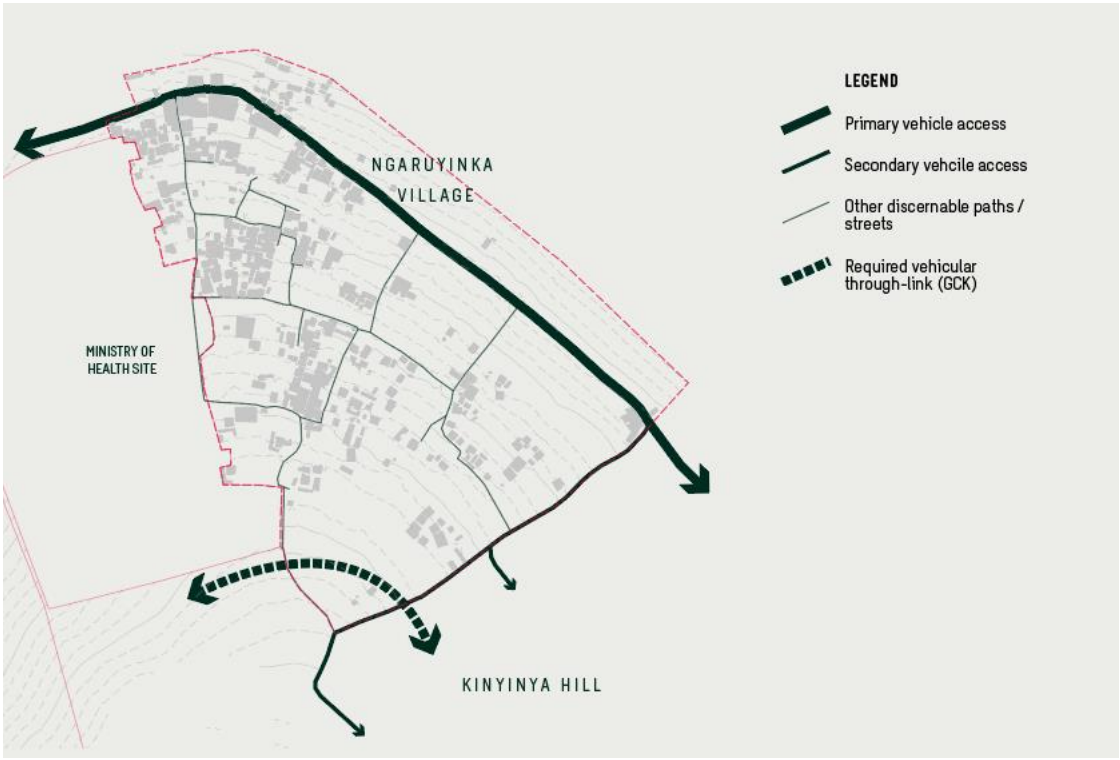


Figure 5-14: Ngaruyinka – existing accessibility and circulation

Figure 5-15: Primary vehicle access along the north boundary of the settlement, looking due north-west

Figure 5-16: Images showing the erosion channels and slip hazards that are present throughout the settlement.

The population is largely very poor or poor and from a rural background, with an average of 6-8 people per dwelling. The available household budget for transport, based on Kinyinya Hill information from 2019, is insufficient for regular motorized transport of any kind (daily bus commuting for example), even for one household member.

Residents' activities largely consist of schooling on Kinyinya Hill, farming, local food- and subsistence related trade, other work activities on Kinyinya Hill (mechanics, construction etc), water collection, household and neighbourhood maintenance, and social activities in the settlement and on the Hill.

Current travel behaviour is characterised by very local trips, a very high proportion of walking, and very small proportion of cycling, moto-taxi, bike-taxi and car use. Motorised transport in the settlement is mostly related to work, trade or construction-related activities (e.g. material deliveries).

The population increase planned in the settlement will lead to demand for more comprehensive, diverse and resilient transport infrastructure. Given the very local nature of travel now, the change in population and land use as well as economic growth will very likely also lead to more longer-distance travel. It will lead to demand for more cycling and motorised transport (including during construction) and require careful management to make affordable solutions and affordable travel possible.

The change on Kinyinya Hill external to the settlement will influence the settlement's transport context. The sustainable development strategy for Kinyinya Hill (MTFS 2019) plans to significantly limit through traffic for motorised vehicles through the Hill through settlements such as Ngaruyinka. Nonetheless demand for through-traffic brings challenges and opportunities to Ngaruyinka. Constraints such as existing narrow roads bounded by buildings, and the need to contain transport infrastructure expenditure, limit the degree to which car traffic in particular should pass through the community. However, significantly better walking and cycling links would considerably open up Ngaruyinka to passing travellers and benefit residents, as the settlement is near the proposed major road access point at the north west of the Hill. This location and likely through traffic can be a great socio-economic opportunity.

The transport infrastructure has multiple infrastructure and other interfaces and interdependencies to consider in planning, implementation and maintenance, such as:

- stormwater (a major interface)
- public domain and community space
- clean water system (including but not only pipes)
- grey and black water system (including but not only pipes)
- solid waste collection
- energy supply through the right of way
- lighting
- vegetation and ecocycle (through amenity and relating to stormwater)
- Skills, jobs, education/training, and community through accessibility, safety, construction, maintenance etc.

5.3.2 Stormwater Management

The general flowpaths (blue) of the area (marked in orange) is shown in Figure 5-17.

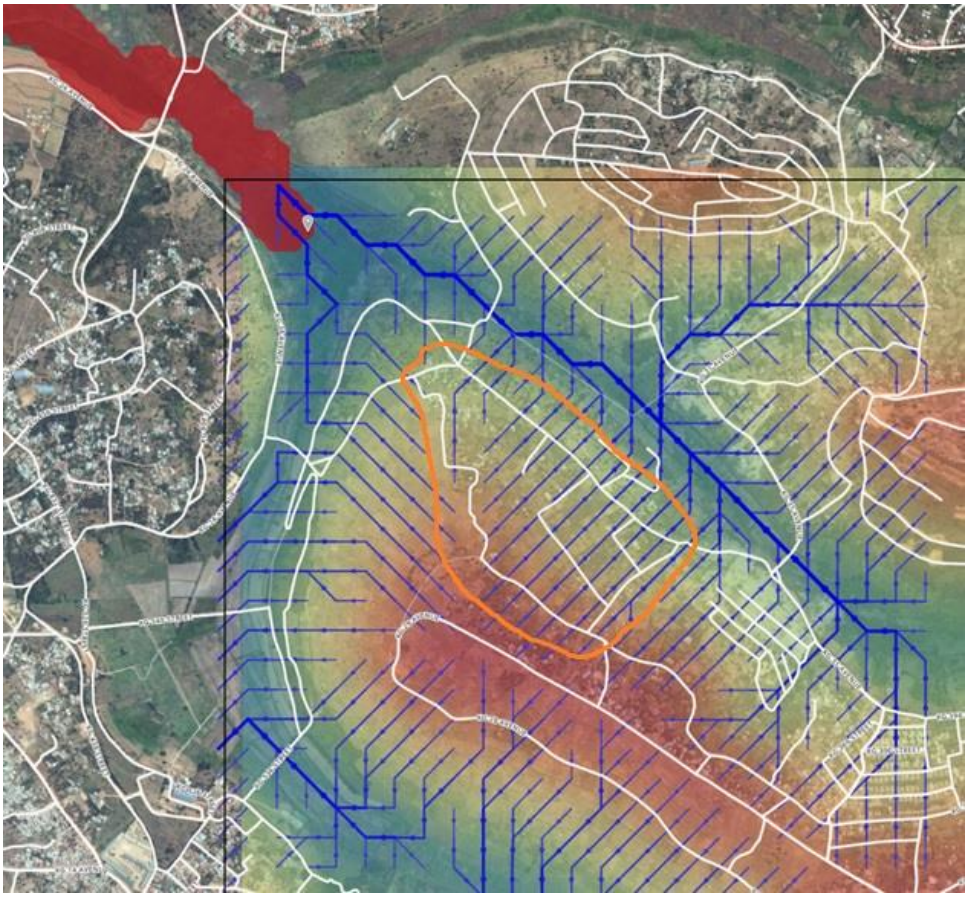


Figure 5-17: General flowpaths around the study area.

The site investigation has determined that erosion from storm water is a significant problem in the settlement. This is causing threats to undermine buildings, has potential to cause landslides and intermittently deteriorates roads and paths. The reason for these problems is mainly due to the sites inherent difficult condition being steep combined with lack of building + storm water planning and the lack of funding, probably also know how regarding sustainable measurements. The existing buildings are placed very dense and with small or no existing gardens mitigating the run off leading to accumulation of run off at many locations. There are no existing culverts, pipe system nor planned ditches in the area.

To establish the existing run off conditions the land survey of the settlement has been further elaborated and a detailed run off map with flow arrows, significant eroded gulleys, present storm water facilities and eco system services still provided (e.g green areas and stripes downstream the road and communities) has been created. The method used has been a combination of photos from the field visits and geodetic measurements.

It is noted from the field visits that the house entrances normally are elevated or protected from heavy flows by elevated thresholds. Around the houses, compacted soil from human activities and lack of trees makes the area look relatively ungreen. The widely spread compacted soil with no or very low permeability severely deteriorates the potential for recharge of the storm water into the ground water, vegetation uptake and evapotranspiration as well as interception end evaporation of the storm water. This leads to severe run off flows and therefore erosion.

However, It is noted from the field visits that the house entrances normally are protected by means of foundations being elevated or by elevated thresholds at the entrances.

Figure 5-18: Ngaruyinka – existing location of significant eroded gullies

The wettest months are April and November and June-August show almost dry conditions. According to the meteorological agency of Rwanda (http://maproom.meteorwanda.gov.rw/) the daily average precipitation intensity during wet days is moderate 8-12 mm/day. Severe rains with extremely high rainfall intensities with short duration can occur.

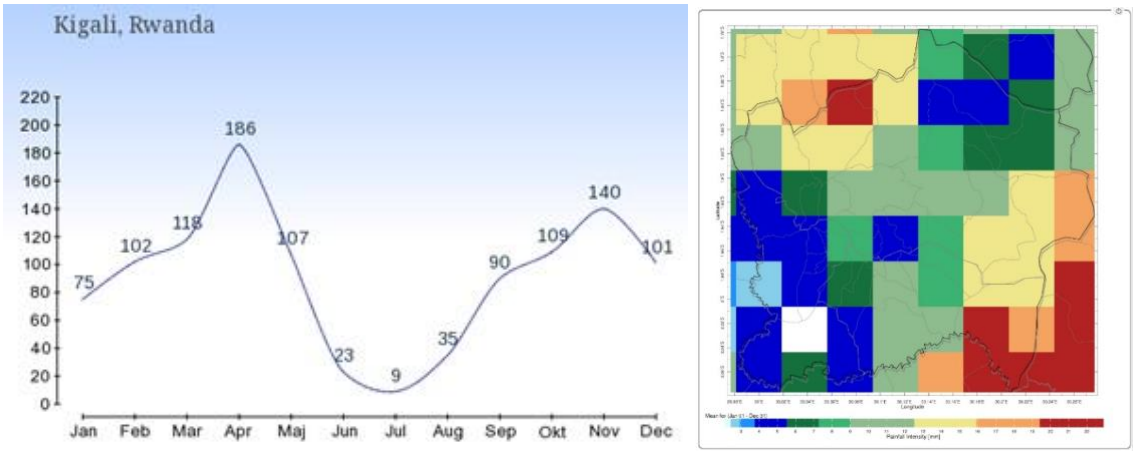


Figure 5-19: Average monthly mean precipitation (left) and rainfall intensity (right) showing the average daily precipitation over the season considering only wet days (Our area shows 8-12 mm/day 2000-2018). http://maproom.meteorwanda.gov.rw/

Figure 5-20: Images showing uncontrolled stormwater channels in the settlement, as well as stagnant water.

In order to cope with the erosion gullies sandbags are placed in the most severe locations and in at least one location a soil stabilising hedge has been planted.

Figure 55-21: Images showing the use of sandbags and soil stabilizing hedges

5.3.3 Water Supply

Ngaruyinka is connected to the Water and Sanitation Corporation's (WASAC) central water supply, which comes from a water treatment plant that uses surface water. WASAC provided the map below showing the location of the water distribution system in the settlement.

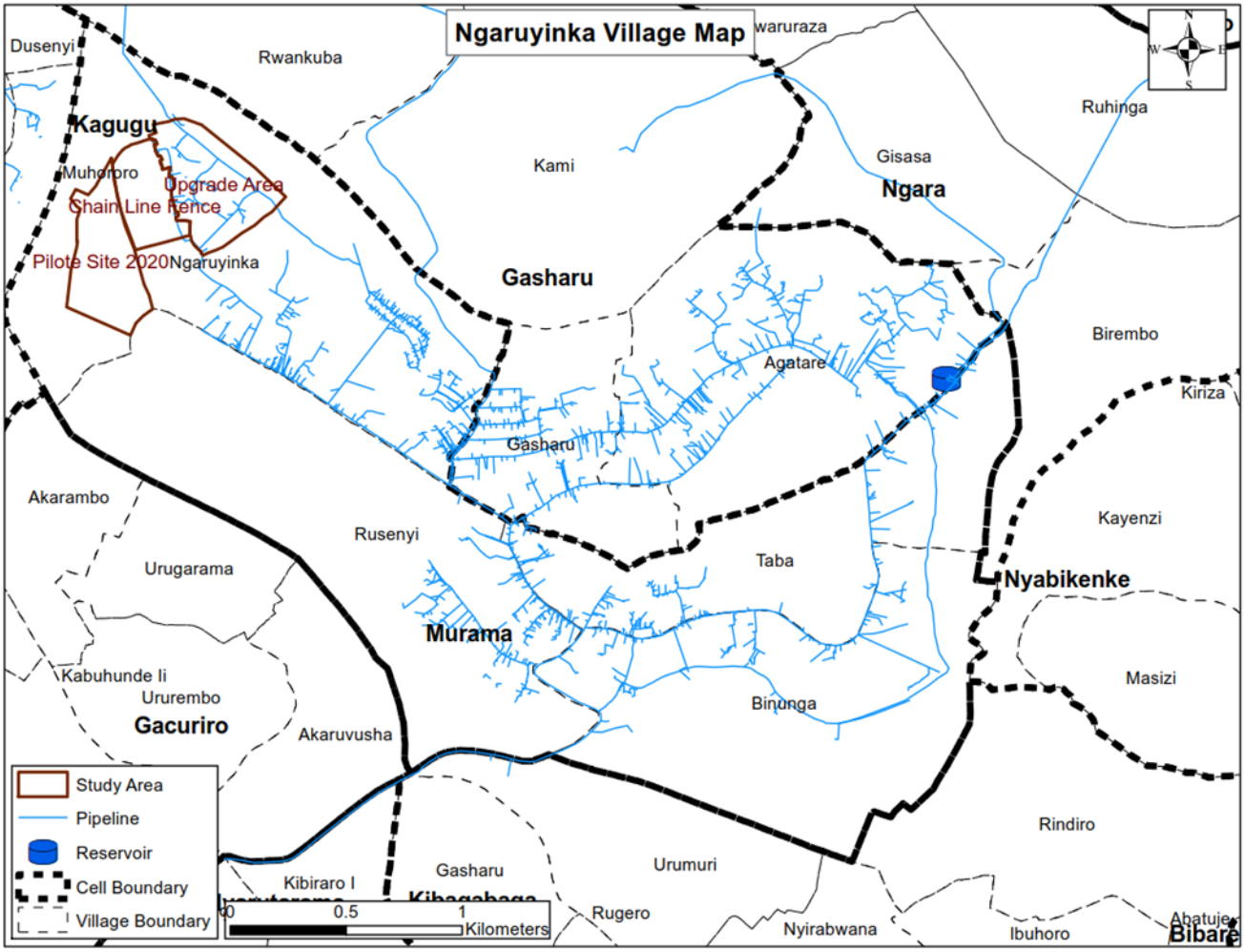


Figure 5-22: Location of the water distribution system in the settlement (WASAC, 2020)

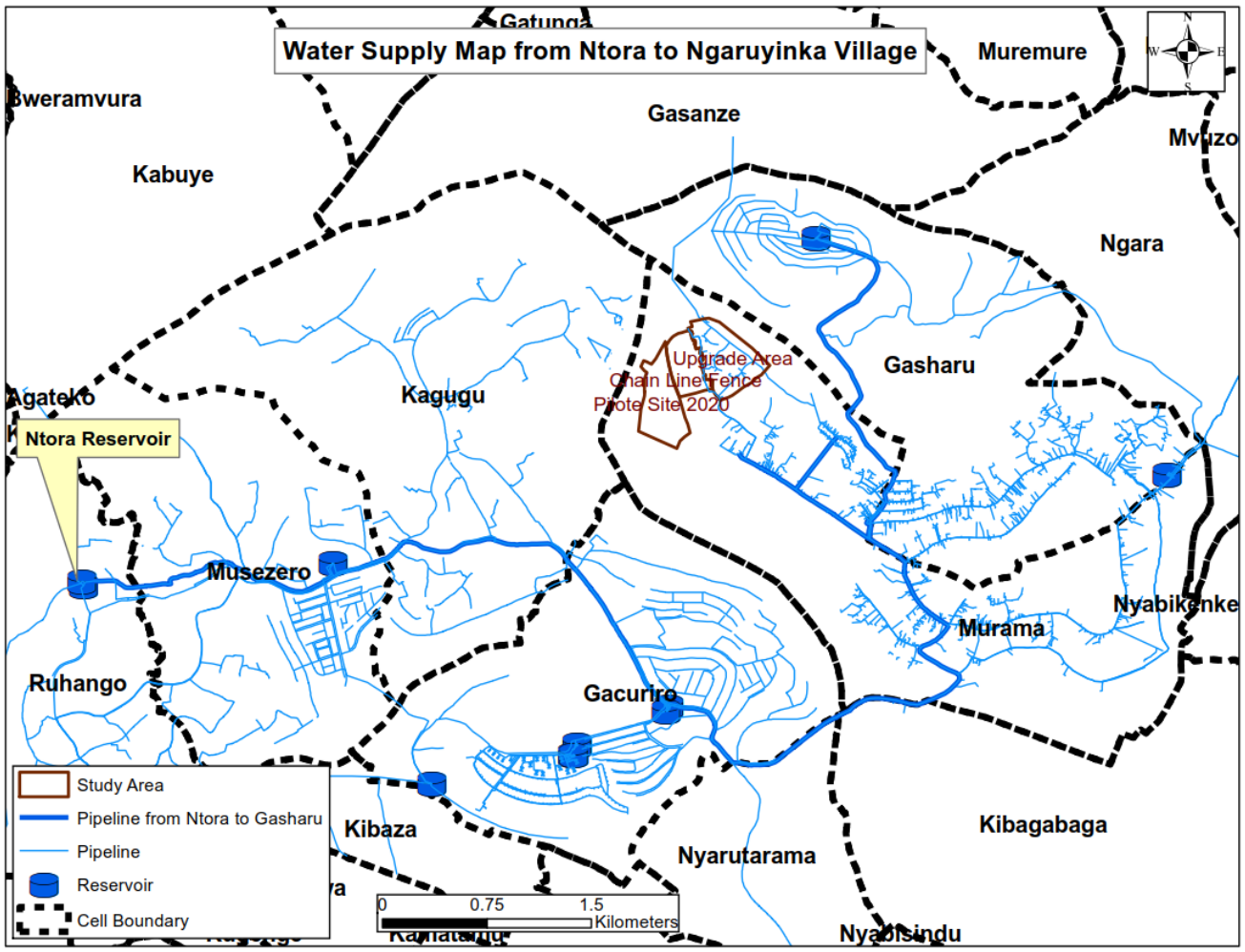


Figure 5-23: Wider water distribution system serving the community (WASAC, 2020)

Figure 5-24: Pictures of water connections at households in the settlement. In the image on the right, the lock box is used to prevent unauthorised use of the tap.

Currently approximately 43 households are connected to the central water supply, according to WASAC. In order to obtain a household connection, residents need to pay for the materials to connect, which is approximately 70 000 RWF and unaffordable for some residents. For the households that lack a connection, typically residents purchase water from the community kiosk (estimated at less than 500m for most residents). The kiosk is privately owned, and the tariff is regulated to 20 RWF per 20L jerry can.

Figure 5-25: Water kiosk where residents can purchase water.

Demand for water is generally lower during the rainy season since people can use rainwater for some household purposes (typically not for drinking). Approximately 6 households have rainwater harvesting systems, according to the community leader.

Figure 5-26: Images of rainwater harvesting that is common throughout the settlement. Roofs often have gutters, and residents use small containers to collect the water.

Currently there is a need to do intermittent rationing of water in the system (for instance, supply water 3-4 days/week) since the demand in Kigali exceeds the supply. Households often try to store water at home for periods when the supply is shut off. If households run out of water, they may go to other sources, such as local springs, surface water sources, other kiosks, etc. Occasionally water tanker trucks will supply water to the area if

there is a longer water shortage. The cost is typically approximately 100 RWF per jerry can, which is too expensive for many residents.

The water quality from the central supply is good when it leaves the water treatment plant, but contamination can occur in the network. Therefore, WASAC recommends boiling the water prior to drinking. However, residents report that boiling water takes too long and is expensive due to the need to purchase charcoal.

WASAC has plans to upgrade and expand the network and to increase the supply for the whole area. WASAC is currently developing a master plan for the area, and this plan includes adding more reservoirs. There is a large reservoir that supplies water to this area by gravity, so pumping stations are not needed here.

Generally, boreholes are used in more rural areas that are further from the central supply. Boreholes will not be added to the current central system in Kigali since this would be more difficult to manage and harder to ensure the quality.

The water supply in Kigali is increasing over the upcoming years with investments in new infrastructure. For example, the Kigali Bulk Water Supply Project is a public private partnership (PPP) that involves the design, construction and operation of a 40,000 m3/day bulk water facility located south of Kigali. This will increase Kigali's existing water capacity by one third. Kigali Water Limited will supply the bulk water to WASAC, who will then sell it to local consumers.

5.3.4 Sanitation

Rwanda has achieved significant progress in public health over the past few decades, in part due to advancements with sanitation coverage. Open defecation has practically been eradicated, and most households have constructed on-site private sanitation facilities. Approximately two thirds of these facilities comply with the international standard definition of an improved facility. The Rwanda National Sanitation Policy adapts the Joint Monitoring Programme for Water and Sanitation (UNICEF/World Health Organization (WHO)) definition for an "improved" sanitation facility as one that hygienically separates human excreta from human contact.

Table 5-3: Definition of Improved and Unimproved facilities from the National Sanitation Policy (and the UNICEF/WHO Joint Monitoring Programme definitions)

Improved sanitation facilities	Unimproved facilities

Use of the following facilities in home/compound:
• Flush/pour-flush to:
  ○ piped sewer system
  ○ septic tank
  ○ pit latrine
• Ventilated improved pit (VIP) latrine
• Pit latrine with slab
• Composting toilet
	• Use of the following facilities anywhere:
	  ○ Flush/pour-flush to elsewhere
	  ○ Pit latrine without slab/open pit
	  ○ Bucket
	  ○ Hanging toilet or latrine
	• Use of a public facility or sharing any improved facility
	• No facility, bush or field (open defecation)

According to the Kigali Urban Sanitation Study (2016), one million of the 1.2 million people living in Kigali use pit latrines, and only around 90,000 people use septic tanks. There is no central sewer network, and there are only a few decentralised networks that serve small populations in certain areas.

The common practice with pit latrines is to close them when they become full and to dig a new pit latrine in another location. This is because exhauster trucks cannot reach many unplanned settlements in Kigali and because the cost for emptying is too high for most households (range from 50-80,000 RWF, depending on manual empty versus exhauster truck and on the volume of faecal sludge).

Based on field visits to Nagaruyinka, it was confirmed that most households in the area currently use pit latrines, with some meeting the definition of improved as outlined above. Some of the pit latrines have a slab, while others do not. Although less common, pour-flush latrines, where a small amount of water is used to flush excreta down a short pipe to a pit, are also used in the settlement. The normal practice with pit latrines is to cover them when full and build a new one, but now there is less space to do that.

Figure 5-27: Unimproved pit latrine at Ngaruyinka (left) and improved pit latrine (right)

Figure 5-28: Typical outhouse structures for latrines.

Figure 5-29: Pour-flush latrine in Ngaruyinka

There is a sewer tariff study on-going. As of now, there is not a wastewater tariff. Any wastewater treatment system constructed would need to be licensed by the Rwanda Utilities Regulatory Agency. There are established discharged standards. It is necessary to use licensed operators. The City of Kigali is responsible for issuing construction permits, and as part of this process, WASAC would be involved with reviewing the design and plans for O&M. In the future (possibly about 2024), responsibilities for operating semi-centralised / decentralised wastewater treatment systems will be transferred to WASAC.

The National Informal Settlement Upgrading Strategy includes the guidelines related to sanitation and liquid waste. It states that pit latrines should only be permitted in areas with over 150 p/ha if regular emptying services is ensured and vehicular access to the pit latrine is possible. It states that simplified sewerage should be considered if population densities are higher than 150 p/ha and where water use is higher than 60 l/p/day. The density at Ngaruyinka is currently approximately 90 p/ha, but it is planned to increase to above the 150 p/ha standard. The strategy indicates that ventilated improved pit latrines are favoured over conventional pit latrines to help reduce odours and flies. For treatment options, the strategy suggests that percolating filters are best for peri-urban settlements.

5.3.5 Energy

In the area, the main source of energy used for lightning is the electricity provided from the national grid (94%). Approximately 30% are still using candles and kerosene lamps named agatadowa (1.9%). Very few use gas (0.3%) and solar (1.5%). Approximately 87% of the population use charcoal for cooking while 32% use gas and only 4.5% use electricity.[10]

Microwaves, water kettle and other electrical appliances are present in some higher income households, but for preparing food other sources of energy are preferred. For higher income groups LPG tends to have higher usage as compared to lower income households (NISR 2018).

Inefficient cook stoves are used in the settlement. Most cooks are women, and they are often assisted by girls. Cooking often takes place indoors. The health burden of indoor air pollution exposure in Rwanda is one of the largest in the world. Approximately annual 12,500 deaths and 493,000 disability-adjusted life years (DALYs) are

[10] GCK High-level ESIA

attributed to solid fuel use[11]. Approximately 5.8% of the total burden of disease is caused by solid fuel use. Women and girls are much more likely to be exposed to indoor air pollution.

Figure 5-30: Outdoor charcoal cooking arrangement.

Figure 5-31: Electricity pole (left) and high voltage lines (right).

[11] Accenture, 2012. https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/170-1.pdf

5.3.6 Solid Waste Management

There are several policies and regulations that set out requirements and targets for solid waste management in connection with urban development. Below is a short overview of the guiding documents followed by an analysis of both potential gaps and implementation problems.

The Rwanda Urban Planning Code has a chapter on Planning of Solid Waste Management and Location of facilities. The document has requirements for different waste generators, for example office buildings or businesses should use waste bins for temporary storage.

The planning code stipulates that solid waste should be sorted at source in the following fractions: biodegradable, recyclables (plastics, metals and glass), other non-biodegradable, and hazardous waste. The planning code also says that organic materials should be composted, briquetted, or digested, and that domestic/household organic waste should be composted on site.

The plot level services and infrastructure section of the Urban Planning Code (2015) states that source separation is a requirement for both single family homes as well as apartments. The Rwanda Green Building Minimum Compliance System (2019) also requires source separation, which is mandatory for commercial buildings. Urban Planning Code Section 4.5.2, states that waste collection points, separation and recycling commerce shall be co-located. It is not clear how this is implemented on the ground. All waste drop-off points should have possibility to sort at source.

The planning code expresses that the local authorities shall support private sorting, i.e household source separation. It is common in planning guidelines to differentiate requirements for different waste generators, households, businesses, institutions etc. However, this is not clear in the Rwandan planning code. It is common to have instructions for businesses to organize themselves the collection of at least business specific waste and recyclables while household like waste often is collected by solid waste management companies organized by or procured by the municipality.

The Plot level service and sanitation infrastructure section of the housing policy states that non-biodegradable refuse shall be stored in proper containers for collection. Biodegradables shall be separated from non-biodegradable waste and composted. Where there is no refuse collection organized through the District, non-recyclable refuse shall be deposited in sites approved by the District. The maximum distance to solid waste disposal point is 250 meters for households, however, does not indicate a maximum distance for businesses and other waste generators. The policy restricts where waste disposal sites can be located, for example landfills should be built in suitable geological areas away from faults, wetlands, flood plains or other restricted areas.

Review of the current solid waste management system in Kigali and Ngaruyinka:

Kigali is often referred to as the “cleanest” city in Africa, pointing to that the city has less littering and informal disposal of solid waste than many of the capitals in neighbouring countries in East Africa (Kabera et. al 2019). This success has been much attributed to strong governance. Rwanda was quick to adopt single use plastic bag ban (2008) and carries out communal monthly clean-up exercises (Umuganda).

The solid waste collection is organized by the city of Kigali and operationalized by the three city districts. The services are carried out by private operators bidding for three-year contracts in 35 sectors (collection areas). Households have weekly collection and businesses have collection as needed (daily collection). The weekly collection does not always take place from households in areas with difficult road access for waste collection trucks, households then bring waste materials to a collection area with the truck can stop.

Households pay a fee for waste collection, which is collected at the cell level and paid to the collection company directly. Households pay fees according to their Ubudehe classification, with the poorest (Category 1) receiving a free service. The fee for Category 2 is RWF 1,000 (US$ 1.2) per month and for Category 4 (the richest) RWF 5,000 (US$ 6) per month. Households who do not agree to contract a solid waste collector are fined. The waste management fee is often bundled with payment for neighbourhood security patrols. The fees from households are

covering costs for waste collection but not that of treatment and other aspects of the solid waste management system. The city districts themselves estimate the coverage of services they provide and on average the city of Kigali has solid waste collection for about 88% of the households.

The estimated waste generation in the City of Kigali is about 638 tonnes per day (tpd), or 233,000 tonnes per year. This corresponds to a per capita MSW generation of 0.57 kg/day, or 205 kg/year (Kabera et al 2019).

The collection service is poorer to certain low-income areas, usually located in the outskirts of the city where road infrastructure is an obstacle for waste vehicles to travel on. The basic solid waste collection system is that household store their waste in individual containers (or more commonly in bags as containers are expensive), which are then collected door-to-door on a weekly basis. Commercial areas have communal containers. Not all households however put waste in containers or bags, but rather in piles on the ground when waiting for collection. During rains the waste can get washed away and clog up drains and channels.

There is a lack of reliable data on how much waste is generated and how it is managed in Kigali (Kabera et al 2019). The Nduba dumpsite (which is the main waste disposal site) does not have a weighbridge in daily use, so waste amounts are estimated based on the number of vehicles arriving. Waste composition surveys on incoming waste are also few in numbers. There is only one composition study that has been carried out in recent years, in 2012. According to research carried out by Kabera et al (2019) the MSW waste composition can be estimated at: organics 70% by weight; paper and cardboard 5%; plastics 5%; and metal 3%. According to contacts with professionals in the field, there are no available data are for waste density, moisture content, or calorific value.

There are two small scale compost facilities in Kigali, but they are treating a very small part of the organic waste. The only company in working on composting is called Company for Environment protection and Development (COPED) and their workers sort waste on site (separation after collection). COPED offer services to compost organic material from households, hotels and industries. COPED is actively working on incentivizing households to sort waste at source and is planning to start renewed efforts to carry out household source separation, starting with a pilot sector next year.

Households have waste collection once a week and businesses as often as needed (mostly daily). There are currently no large waste generators in the area. There are no waste treatment facilities like community composts at the hill, nor small scale recyclers or scrap workers. At Ngaruyinka, waste collection occurs every Wednesday, and households pay 3,000 RWF per month. Households that have a vegetable garden or fields compost organic waste behind their homes and then use apply it to the soil when it is ready.

At Kinyinya Hill, solid waste is currently managed by the Isuku Kinyinya Company Ltd, a waste collection company that is operating in the project area. This company started as a women's cooperative in 2009, with the aim of creating jobs[12]. At Ngaruyinka, waste collection occurs every Wednesday at one location at the top of the hill (outside the bounds of the settlement), and households pay 3,000 RWF per month. There is also sporadic collection along the road at the bottom of the hill of the settlement. These collection points are inconvenient for most residents, and some residents choose to dispose of waste informally, in their latrines, or by burning the waste in the evening (burning waste is not allowed but is done sometimes). Households that have a vegetable garden or fields compost organic waste behind their homes and then use apply it to the soil when it is ready. There are no waste treatment facilities like community composts at the hill. There is some informal collection of plastic bottles for recycling. Women from Gisozi collect plastic bottles from the area and resell them to manufacturing companies.

5.4 Future Carrying capacity

The purpose of calculating the future carrying capacity of the settlement is to provide a baseline for assessing the needs and requirements of the settlement that the upgrade will be designed for. The carrying capacity assumes an

[12] http://imvahonshya.co.rw/isuku-kinyinya-company-ltd-irashimira-perezida-kagame-wayihaye-umusingi/

urban densification approach in line with Green City Kigali. The climate rationale for this is set out clearly in the introductory sections to this report. Carrying capacity is an estimate using a number of assumptions set out in the GCK Feasibility Study and elaborated below to arrive at development parameters. Using this carrying capacity as a baseline, options can be assessed in two formats:

- A 'Business As Usual' approach (BAU)
- A 'Climate Responsive' approach (CR)

The methodology for calculating the future carrying capacity of the settlement follows that which was used as part of the Green City Kigali Feasibility Study.

5.4.1 Suitability mapping

Following the GCK methodology, areas that are suitable for urban densification are identified by first eliminating unsuitable areas (see Figure 5-32). These unsuitable areas are defined as:

- Existing buildings & market square
- Formal farms
- Forests
- Areas over 20% grade (none evident within the study area)

The resulting suitable area is an aggregated area which is available for buildings, plots and rights of way.

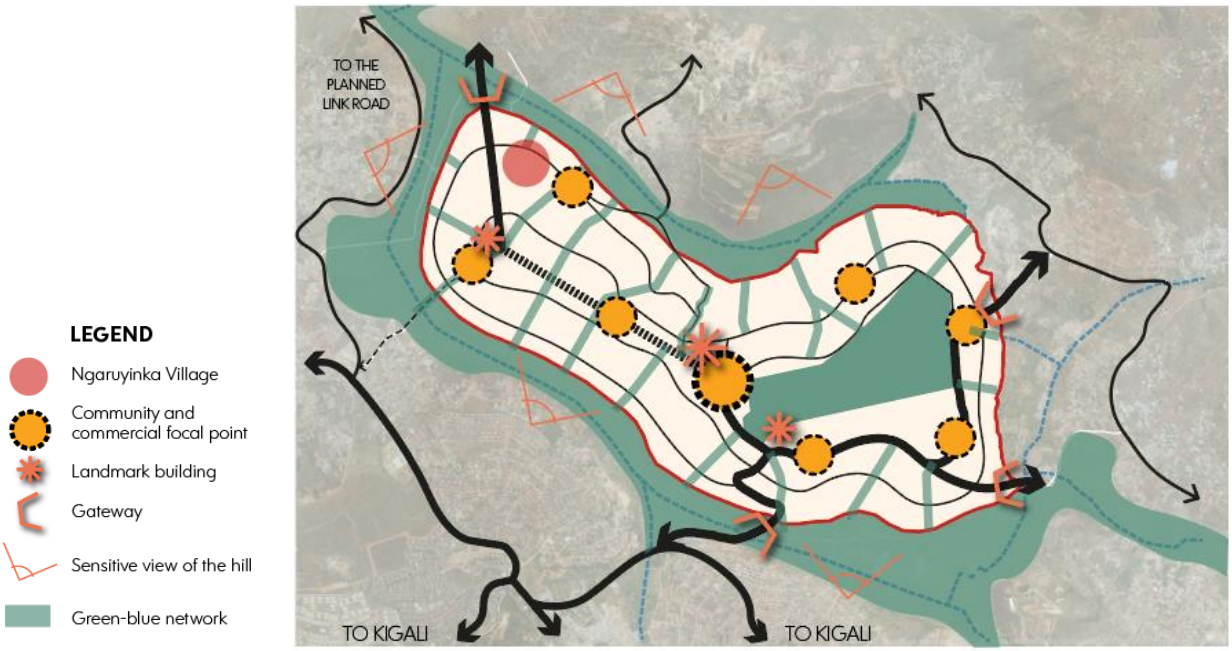


Figure 5-32: Ngaruyinka in the context of the GCK physical scenario for the spatial planning of Kinyinya Hill

Figure 5-33: Areas suitable for development

5.4.2 Primary Rights of Way

Assuming an urban densification approach, a primary ROW network is established to serve the community for accessibility and storm drainage. The primary network follows a business as usual approach and is shown Figure 5-34.

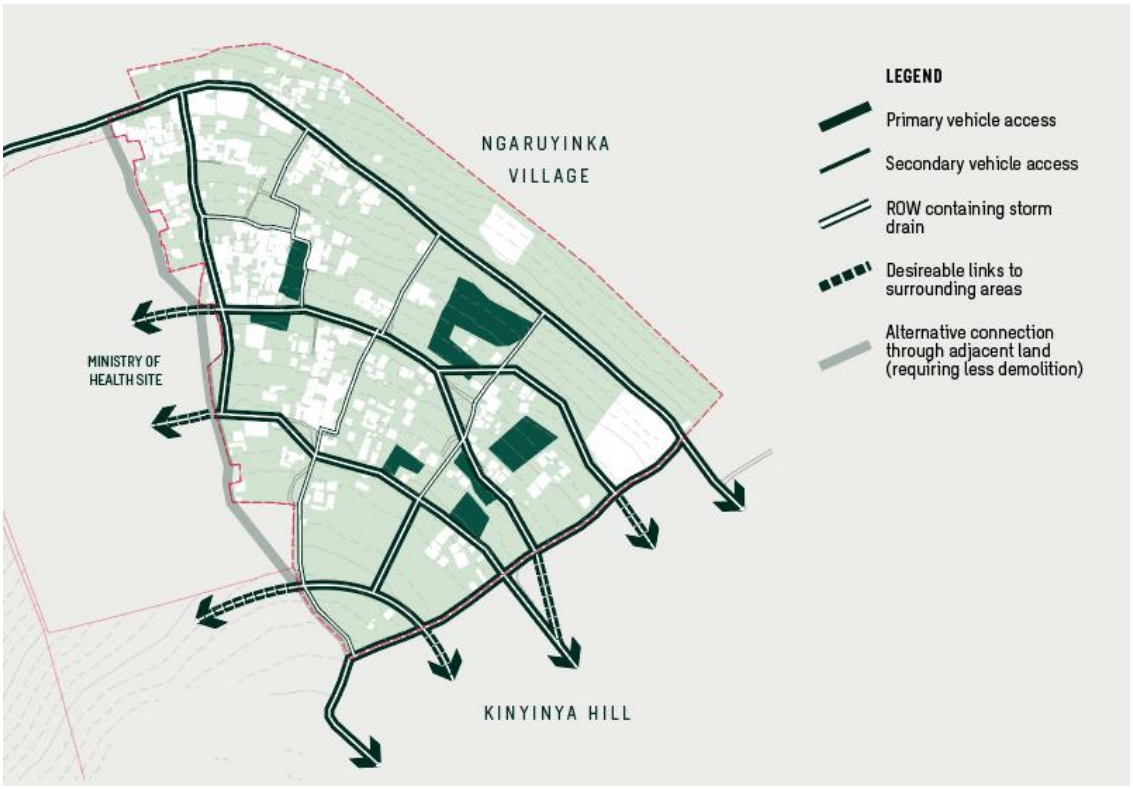


Figure 5-34: Proposed rights of way following a Business as Usual approach

5.4.3 Carrying Capacity

The subsequent Gross Developable Area (GDA) is defined in Figure 5-35. The GDA is defined in 3 density bands which follow the same approach as the Green City Kigali Feasibility Study, albeit with some adjustment to allow for:

- Physical integration with the existing small scale, low density development.
- Continued domestic-level farming in and around the residential areas particularly on existing green field areas (crops).
- No development exclusion zone beneath high voltage and medium voltage lines.

Table 5-4: GCK density bands adjusted to apply to Ngaruyinka

Density Band	Defining parameter (GCK approach)	GCK Floor Area Ratio (FAR)	Ngaruyinka Floor Area Ratio (FAR)
Higher	Closest to the ridgeline and Kinyinya Centre	1.75	1-1.5
Medium	Around the existing higher density clusters in the settlement	1.2-1.4	0.5
Lower	On existing green field land / crops	1	0.25

The Gross Development Area (GDA) organized in terms of density bands is shown in Figure 5-35. Commercial / community plot are identified for enhancement; as noted above their locations are currently in convenient locations for accessibility (200m radii).

Figure 5-35: Gross Development Area (GDA) organized in terms of density bands

The resulting carrying capacity of the settlement is shown in Table 5-5.

Table 5-5: Total future carrying capacity of Ngaruyinka in terms population

Density Band	**GDA (m2)**	**Efficiency to allow for secondary & tertiary ROWs**	**NDA (m2)**	**FAR**	**Average dwelling size (GCK)**	**Nr. dwellings or H'holds**	**Population (4.15 p/h'hold) (GCK)**
High	18 837	80%	15 070	1-1.5	60	296	1 227
Medium	7 111	80%	5 689	0.5	45	238	986
Low	39 295	80%	51 790	0.25	45	175	725
Sub-Total	**65 243**		**52 194**			**708**	**2 938**
Existing population							1 634
Total future population							**4 572**

6 URBAN PLANNING PRINCIPLES

6.1 Vision Statement

The overall vision for the upgrade of Ngaruyinka is:

'A scalable model for sustainable informal settlement upgrading in Rwanda which through holistic, strategic and innovative urban planning reduces capital costs whilst increasing the climate-responsive return on investment'.

6.2 The Climate Responsive Approach

The climate responsive urban planning approach for Ngaruyinka combines three interrelated urban planning principles in a dynamic way to reduce capital investment cost while increasing resilience of the area to climate change, enhancing quality of life and controlling its carbon footprint in terms of the entire life-cycle of the settlement:

Circularity: The efficient use, preservation and replenishment of resources through strategic planning of synergies between urban systems such as energy, waste, water, materials, transportation and biodiversity.

Urban livability: The gradual increase in quality of life for residents through reducing inequalities, supporting strong communities, and increasing access to a cycle of local wealth creation.

Ecosystem Services: The protection, replenishment and sustainable use of the biosphere to sustain human life in a way that contributes to circularity and urban livability.

6.3 GGK Urban Planning Objectives

The objectives which GCK project aims to deliver on and thus provides context for the approach taken for the Ngaruyinka upgrade are as follows:

I. **Provide housing that is affordable for all**: Housing options will be provided for all income groups that will begin to address the shortage of affordable housing in Kigali, combining innovative purchase options together with low construction costs. Existing settlements will be upgraded, and densities increased.

II. **Help to build a strong sense of community and ownership**: Green City Kigali will comprise a series of neighbourhoods and districts each with its own distinctive character together with a high-quality public realm that will encourage social interaction. In addition, buildings and neighbourhoods will be sensitively designed taking into account Rwandan culture to provide a sense of safety, home and comfort.

III. **Support the development of a vibrant local economy**: Green City Kigali will feature a mix of uses and facilities enabling residents to live and work within the city, maximising the opportunities for start-ups and small to medium sized enterprises.

IV. **Be well-connected and pedestrian friendly**: Green City Kigali will connect with the local transport network while reducing the need for and impact of motorised vehicles. Compact, mixed-use planning where the higher densities are oriented toward public transport corridors will help create walkable neighbourhoods which enhance the viability of regular and quality public transport, while pedestrians and cyclists will enjoy a network of shaded routes throughout the city.

V. **Utilise local labour, skills and materials**: The construction of Green City Kigali will be used as an opportunity to build knowledge and capacity by training a skilled workforce, utilising local labour and local materials wherever possible; thereby maximising the benefit to the local economy while minimising environmental impact.

VI. **Adopt passive design strategies together with the use of natural systems**: The design of the city will maximise the use of passive design strategies and create a pathway to a net-zero future, working within the site's natural capacity while maximising the use of natural systems such as sustainable urban drainage, rainwater harvesting, sewerage treatment, waste recycling, energy production etc.

VII. **Work with nature in all its forms**: The layout of the city will work with the natural topography of the site, safeguarding its natural water resources while protecting and enhancing its ecosystem and biodiversity.

VIII. **Be resilient and climate change ready**: Green City Kigali will adopt a range of strategies to mitigate climate change effects such as increased temperatures and water scarcity.

IX. **Adopt a SMART city concept**: The city will make use of ICT and SMART City technology to enhance the convenience and safety of residents while supporting the development of a knowledge-based economy and supporting services.

X. **Complete at every stage**: At each stage in its development, Green City Kigali should be complete within itself and should not be reliant on future phases.

XI. **Provide a catalyst for change in Kigali and beyond**: Green City Kigali will create an exemplar by setting new standards in the provision of affordable homes and sustainable communities in Rwanda and the wider region.

6.4 Ngaruyinka Settlement Urban Planning Principles

In order to achieve a climate responsive upgrade for Ngaruyinka, the recommendations in this Study will therefore seek specifically to:

I. Maximise the resilience of the settlement to increased weather events especially storms, floods, erosion, landslides and increasing ambient temperatures.

II. Control and seek to reduce the embodied carbon footprint of the settlement.

III. Control and seek to reduce the carbon footprint of the settlement in terms of its whole life cycle.

IV. Control and seek to reduce demands for key resources including energy and water.

V. Improve access to community services for all residents regardless of gender, age, or ability.

VI. Improve public health and sanitation for all residents regardless of gender, age, or ability.

VII. Create opportunities for local jobs and training related to the implementation and maintenance of recommended technologies and construction components.

VIII. Achieve all the above while allowing for urban densification in line with the Green City Kigali model for sustainable urban development in Kinyinya.

IX. Achieve all the above while minimising and making the most effective and efficient use of capital investments.

6.5 Specific Considerations with regard to Covid 19

There is heightened concern for informal settlements in the context of the Covid 19 pandemic because the combination of population density and limited infrastructure makes such communities highly vulnerable to the spread of the virus. Although Ngaruyinka is not considered a very high-density situation by global comparisons or even within Rwanda, it is important to consider what specific measures may be adopted to help protect residents in the settlement from the spread and impacts of COVID-19. This has also been a key factor in devising the recommendations in this Study and underpins the special focus on non-climate related topics such as water, public health and sanitation.

7 APPRAISAL OF OPTIONS

A number of different technical options have been evaluated against a baseline in order to arrive at recommendations that achieve the vision of the project. Each technical option that has been considered falls into one of the following scenarios:

- **Take No Action scenario (TNA)** - the perpetuation of the current situation with no GCK densification of the settlement.
- **Business As Usual scenario (BAU)** - assumes the adoption of conventional current practices for upgrades assuming the densification of the settlement in line with GCK. This scenario would meet the requirements set out in the National Upgrading Strategy, but climate risks are not adequately factored into the design. This is considered a realistic baseline for assessing more Climate Responsive (CR) alternatives.
- **Climate Responsive (CR)** – technologies and practices that potentially achieve more in terms of climate mitigation and adaptation as a return on investment.

The technical options are organized according to conventional sectors as follows:

- Transport and Mobility
- Stormwater Management
- Water Supply
- Sanitation
- Solid Waste Management
- Energy
- Community facilities

7.1 Multi Criteria Analysis Methodology

For Ngaruyinka, the technical options have been assessed using a Multi Criteria Analysis (MCA). An MCA is a decision-making method that provides a structured comparative analysis of different alternatives according to parameters that reflect an objective (or set of objectives). The analysis serves as an aid to disaggregate a complex issue by measuring the extent that different options achieve certain objectives. These parameters are often weighted to reflect certain priorities among a set of objectives.

The technical options have been assessed against the six GCF investment criteria introduced in Section 3.

Table 7-1: Summary of the criteria used and the associated weighting.

Criteria	Weighting
Impact Potential (mitigation): potential of the activity to contribute to the shift to low-emission sustainable development pathways	15%
Impact Potential (adaptation): Contribution to increased climate-resilient sustainable development	35%

Paradigm shift potential: potential for scaling up and replication; potential for knowledge and learning; contribution to the creation of an enabling environment; contribution to the regulatory framework and policies; contribution to climate-resilient development pathways	10%
Sustainable development potential: environmental co-benefits; expected positive social and health impacts	15%
Needs of the recipient: vulnerability and financing needs of the beneficiary country and population	10%
Country ownership: Beneficiary country ownership of, and capacity to implement, a funded project or programme (policies, climate strategies and institutions)	5%
Efficiency and effectiveness: cost-effectiveness and efficiency regarding financial and non-financial aspects, industry best practices	10%

Table 7-2: Summary of the indicators used for the criteria.

Criteria	Indicator
Mitigation	Expected tonnes of carbon dioxide equivalent (t CO2eq) to be reduced or avoided
	Degree to which activity avoids lock-in of long-lived, high-emission infrastructure
Adaptation	Degree to which the activity avoids lock-in of long-lived, climate-vulnerable infrastructure
	Degree to which beneficiaries have reduced vulnerability by enhancing adaptive capacity and resilience (for water projects, consider beneficiaries with year round access to reliable and safe water supply)
	Degree to which physical assets are made resilient to climate variability and change.
Paradigm shift	Opportunities for targeting innovative solutions, new market segments, developing or adopting new technologies, business models, modal shifts and/or processes
	Scaling up the scope and impact of the intended project/programme without equally increasing the total costs of implementation
Sustainable development	Degree to which the project or programme promotes positive environmental externalities such as air quality, soil quality, conservation, biodiversity, etc.
	Social co-benefits for women and men as relevant, in areas such as health and safety, access to education, improved regulation and/or cultural preservation
	Economic co-benefits, such as expanded and enhanced job markets, job creation and poverty alleviation for women and men; change in water supply and agricultural productivity in targeted areas, etc.
Needs of the recipient	Degree to which vulnerable groups are protected/supported from climate risks (flooding, landslides and heatwaves etc.)
Country ownership	Programme or project contributes to country's priorities for low-emission and climate-resilient development as identified in national climate strategies or plans, such as Nationally Appropriate Mitigation Actions, National Adaptation Plans, Nationally Determined Contributions or equivalent, and demonstrates alignment with technology needs assessments, as appropriate
	Potential to implement through local institutions as well as use and enhance local capacity
Efficiency and effectiveness	Estimated cost per t CO2eq (PMF-M Core 2) as defined as total investment cost/expected lifetime emission reductions, and relative to comparable opportunities
	Application of best available technologies and/or best practices

7.2 Options Analysis

The options considered, along with their benefits and disadvantages / challenges, are described in the tables below.

7.2.1 Transport & Mobility

Table 7-3: Summary of transport / mobility options

Transport / Mobility		
Options Evaluated	**Benefits**	**Disadvantages / Challenges**
Current situation (Take No Action): dirt roads, unimproved cuttings, basic packed earth drains, sandbags. Minimal addition of extra laneways, access and footpaths from packed earth. Minimal and local basic maintenance of existing infrastructure. Modal split: high walking	Inexpensive Uses existing local skills and implementing locally Low carbon infrastructure	Vulnerable to heavy rain events – causes disruptions and associated economic and social costs Minimal extra access for faster modes of transport (even for cycling) Limited extra walking/cycling links, such as walking/cycling links diagonally uphill Safety and security issues from uneven, damaged and slippery roads and poor lighting Can not accommodate development growth adequately nor Kinyinya Hill through-travel or objectives
Business as Usual Upgrade with Conventional Rights of Way Network: Standard width ROWs High degree of vehicle permeability. Trip mode share: 40-45% walking and cycling 40-45% public transit 10-15% mototaxi and cars (Note: mode shares are also driven by household budgets) More collector roads (one + one lanes, up to 17m ROW throughout their length, requiring demolition of some existing dwellings), and wider access roads (up to 15m requiring extensive demolition of homes)	Increased parking capacity to allow for increased vehicle use. More convenient for through-traffic and moderate motorised vehicle speeds.	Selective demolition & rehousing would be required. Expensive for government and developers Higher carbon cost Not fit-for-purpose for existing community, especially their walking needs
Business as Usual Upgrade with Conventional construction methods and materials: Drivepaths: Asphalt	More resilient right of way network	Higher carbon and financial cost Relies on timely external maintenance (by MININFRA).

Parking: Asphalt Footpaths: Cobbles Kerbs: Concrete Bridges: Concrete Steps: Concrete & steel railings		Higher erosion potential outside of the right of way, especially due to poor infiltration within the ROW, increasing vulnerability to climate change
Green Rights of Way network: Reduced width ROWs with strategic pinch-points based on modal split target, carbon and affordability demands. Additional diagonal pedestrian / cycle links servicing key desire lines. Minimal parking capacity (short term delivery / drop-off at commercial areas only) Low degree of vehicle permeability; additional traffic calming measures. **Trip mode share:** 60-70% walking and cycling 20-30% public transit 5-10% mototaxi and cars	No demolition & rehousing required High walking and cycling through-traffic, possibly e-scooters also. Low vehicle through-traffic Fewer serious injuries or fatalities from crashes High travel time reliability High resilience to network disruption (e.g. from flooding, erosion) due to less ROW surface area Lower cost of ROW and property impact Lower embodied carbon	Low motorised vehicle speeds
Green construction methods and materials: Drivepaths: Packed aggregate, brick, some asphalt in vulnerable areas (slope & traffic dependant) Parking: Packed aggregate Footpaths: Compacted earth, some brick in vulnerable areas (slope / traffic dependant) Kerbs: Brick Bridges: Timber Steps: Brick & timber & timber railings Furniture: Solar PV chargers, up-cycled furniture	Built & maintained by community with support from MININFRA. Locally sourced & processed materials with less cost and carbon footprint. Tools, repairs workshops provide spin-off uses and benefits. Reduced flooding and erosion impact for outside of the right of way due to greater infiltration within the right of way Reduced embodied carbon in construction materials and maintenance	Requires time and resources to upskill the community for construction and maintenance Requires increased on-going maintenance in the right of way (however it is relatively simple maintenance).

7.2.2 Stormwater Management

Table 7-4: Summary of stormwater management options

Stormwater Management

Options Evaluated	Benefits	Disadvantages / Challenges
Current situation (no action): sandbags used in some locations, reactive erosion control	Low investment, locally maintained / constructed	Need for maintenance after rain events High erosion High damage to infrastructure and houses during heavy rains. Population vulnerable to landslides, etc. Discharge impacts wetlands
Business as Usual Upgrade with Conventional stormwater management: concrete drains, street gutters, pipes, pavement, etc.	Robust if dimensioned correctly Residents can build on their properties without much consideration to stormwater	Expensive High embodied CO2 emissions Vulnerable if pipe system Limited recharge to groundwater Requires maintenance of pipes and drains
Optimised Blue/Green infrastructure Green, permeable network of swales, gullies and detention-filtration-percolation areas	Increased groundwater recharge Cheaper investment cost and maintenance compared to conventional systems Climate adapted for flooding, groundwater and urban heat islands Local maintenance Reduced need for maintenance compared to business as usual case Reduced vulnerability of the population and infrastructure to rain events Can cultivate fruit trees and some crops on stormwater infiltration areas	Requires maintenance of the ditches and blue/green areas Requires rules from private property – that residents minimise stormwater from their plots to the streets and divert it prior to discharge

7.2.3 Water Supply

Table 7-5: Summary of water supply options.

Water Supply		
Options Evaluated	**Benefits**	**Disadvantages / Challenges**
Current situation (no action): Central water supply to the area, some households with a connection, other households purchase water at a kiosk, intermittent rationing of the supply, limited rainwater collection	Most households have access to an improved water supply	When the supply is turned off, some residents rely on unimproved water sources, such as surface water, which poses a health risk and also requires additional time for collection (typically done by women).
Business as Usual – Central Water Supply Connections to some households. Other households purchase water from a kiosk.		Currently the demand exceeds the supply in the central water supply. Expanding the central water supply will increase the demand further.
Business as Usual Treatment: Boiling drinking water	Households have the equipment needed to boil water	Residents typically use charcoal as fuel for boiling water, which is expensive and is not environmentally sustainable
Expansion of Central Water Supply 100% of households have connections to central water supply	Would ensure that all residents have access to an improved water supply Health benefits from increased access to water Economic benefits from easier water access (time saved from collecting water from a kiosk)	Requires more investment in and maintenance of water supply infrastructure
Rainwater harvesting, as supplement to central supply	Allows for a more robust system and provides water even when the central supply is off Helps reduce stormwater runoff Low CO2 compared to central supply	Necessary to ensure the quality meets requirements May not be adequate for some households Requires maintenance
Point of use household water treatment technologies, water efficient fixtures	Household water treatment technologies allows for a more environmentally friendly option compared to boiling Efficient fixtures help reduce demands on the water supply system.	Filters require some training and maintenance.

7.2.4 Sanitation

Table 7-6: Summary of sanitation options.

Sanitation		
Options Evaluated	**Benefits**	**Disadvantages / Challenges**
Current situation (no action): Unimproved and improved pit latrines and some septic tanks Greywater is discharged directly to the ground or in soak pits.	Many households have access to improved sanitation (improved pit latrine, septic tank). Systems are inexpensive to build.	Households with unimproved pit latrines lack access to improved sanitation and have increased health risks. Latrines are typically closed when full, and a new one is then constructed nearby. Space will become more limited in the future to build new ones. Affordable emptying services are lacking. Systems may cause groundwater contamination. Systems do not allow for recovery of energy or resources. Greywater discharged directly to the ground can cause contamination or breeding ground for mosquitoes.
Business as usual upgrade – convert to all improved pit latrines with increased focus on emptying. Improved greywater management	All households would have access to improved sanitation. Greywater is managed to allow for local treatment prior to groundwater recharge.	Systems would still pose a risk to groundwater. Systems do not allow for recovery of energy or resources. Emptying services are too expensive for most households.
Semi-centralised wastewater treatment system with biogas recovery	Reduces risk of groundwater contamination compared to septic systems or pit latrines (as long as the treatment system is maintained) Residents do not have to build / maintain their own systems Allows for recovery of energy (biogas) and resources (sludge for fertiliser)	Requires on-going operation and maintenance Risk of pollution to surface water and groundwater if the system fails Requires installation of a sewer collection system (expensive) Requires water to be used for flushing
Biogas system installed	Allows for recovery of energy (biogas) and resources (sludge for fertiliser)	Requires on-going operation and maintenance

7.2.5 Solid Waste Management

Table 7-7: Summary of solid waste management options.

Solid Waste Management		
Options Evaluated	**Benefits**	**Disadvantages / Challenges**
Current situation / Business as usual: private waste collection company collects waste	Waste is collected, knowledge about the complying with municipal system is wide spread	Waste vehicles cannot access most areas in the settlement. People have to carry waste long distances. Waste dropped on the ground, burned or thrown in latrines. Causing odur, vermin, soil pollution, hazards to grazing animals
Community Composting	Allows for recovery of nutrients from garden and potentially food waste. Compost could be used in a plant nursery or in gardens. Fairly simple equipment required (grid/sifter, tumbler) Could provide employment opportunities for community members	Requires on-going operation and maintenance
Neighbourhood collection point for residual waste and organic waste To serve residents who live in areas where waste collection trucks cannot access	Allows for separate collection of organic waste. Easier for trucks to access a neighbourhood collection point.	Requires maintenance of the collection point.
Recycling centres	Allows for separate collection of recyclables and hazardous waste (batteries and small electronics)	Requires maintenance of the recycling centres

7.2.6 Energy

Table 7-8: Summary of energy options.

Energy		
Options Evaluated	**Benefits**	**Disadvantages / Challenges**
Current situation / Business as usual: connection to the electrical grid. Households are encouraged to use solar lighting kits, solar is preferred for street lights	Reliable Fairly inexpensive	The electricity mix includes fossil fuels. Solar kits likely to be beyond the affordability of many households.
PV panels (street lighting, community facilities, private homes, etc)	Reduces dependence on fossil fuels for electricity, thereby reducing greenhouse gas emissions	Capital costs and repairs are likely more expensive
Clean cooking technology (more efficient, emit less emissions)	Improved efficiency reduces the amount of fuel used for cooking, which reduces deforestation and greenhouse gas emissions Reduced emissions leads to improved health, especially for women and children Cost savings due to reduce charcoal use Reducing time and physical burden for collecting firewood, especially for women and girls who typically collect it	
Energy efficient lighting and appliances	Reduces dependence on fossil fuels for electricity, thereby reducing greenhouse gas emissions Reduced cost during operation	Higher initial capital cost

7.2.7 Community Facilities

Table 7-9: Summary of community facilities

Community Facilities		
Options Evaluated	**Benefits**	**Disadvantages / Challenges**
Current situation / Business as usual: Nursery School, local commercial shops, services and market responding to demand	Facilities may continue to serve basic needs of the settlement	Facilities will be ad-hoc with the risk of being sub-standard and particularly vulnerable to climate related problems listed above. Facilities can be appropriated for uses that do not benefit the community
Additional community hubs & market squares	Provides an integrated hub of mixed community services within walking catchments of every home. Reduces the need for travel to outlying areas to reach facilities. Community cohesion and assisting with sustainable lifestyles e.g shared services, collection, repair, information. Job opportunities and local economic activity. Early years education & childcare. Climate-responsive construction – low carbon and resilient.	Capital cost coverage.
Establishment of a Technical and Vocational Education and Training (TVET) Centre	The centre could include programming in fields related to climate change mitigation and adaptation (such as technical training on how to install rainwater harvesting systems, biogas systems, etc). Students at the centre would gain hands-on experience that they can use to obtain employment	The centre will require investment in high quality programming with committed teachers in order to ensure a high standard of education. On-going budget is required for centre operation.

7.3 Results of the Multi Criteria Analysis

The results from the multi-criteria analysis are summarised in the table below. Scores for indicators within each criterion, as well as more detailed comments regarding the scoring can be found in the spreadsheet used for the analysis. Each green enhancement activity was evaluated against the business as usual scenario. In the table below, the green shading indicates that the activity performed better than the business as usual scenario, yellow indicates that the activity scored the same as the business as usual case, and red indicates that the activity scored worse. The total score for a business as usual scenario was pegged to a total of 3.

Based on the analysis, most options evaluated proved to score well compared to the Business as Usual alternative identified. The semi-centralised / decentralised wastewater treatment option did not score as well against the criteria, and therefore it was not considered further as an option. However, we do recommend that a semi-centralised system is considered in the future for the settlement, once the density has increased and if it is determined that the residents would be able to afford the operation and maintenance costs.

The remaining options were evaluated further and are described in more detail in Section 8.

Table 7-10: Summary of the MCA Results

	Criteria							Total
	Mitigation	Adaptation	Paradigm shift	Sustainable development	Needs of the recipient	Country ownership	Efficiency and effectiveness	
	Max: 0.75	Max: 1.75	Max: 0.5	Max: 0.75	Max: 0.5	Max: 0.25	Max: 0.5	Max: 5
Construction of green rights of way	0.75	1.55	0.50	0.75	0.50	0.25	0.50	**4.80**
Green road construction methods	0.75	1.75	0.45	0.75	0.50	0.25	0.50	**4.95**
Blue/Green stormwater management systems	0.75	1.75	0.50	0.70	0.50	0.23	0.50	**4.93**
Expansion of central water supply (100% connection rate)	0.45	1.55	0.30	0.65	0.50	0.25	0.40	**4.10**
Rainwater harvesting (as supplement to central supply)	0.75	1.65	0.50	0.75	0.50	0.25	0.50	**4.90**
Filters for Household Water Treatment	0.75	1.35	0.50	0.75	0.30	0.18	0.45	**4.28**
Semi-centralised wastewater treatment system with biogas recovery	0.30	1.25	0.30	0.50	0.40	0.18	0.30	**3.23**
Biogas system at the TVET / market	0.70	1.30	0.50	0.65	0.30	0.25	0.50	**4.20**
Latrine Improvements / Education / Improved Greywater management	0.60	1.40	0.45	0.70	0.30	0.23	0.40	**4.08**
Community composting	0.75	1.65	0.40	0.70	0.40	0.23	0.50	**4.63**
Neighbourhood Waste Collection Point	0.75	1.35	0.45	0.70	0.40	0.25	0.45	**4.35**
Recycling collection stations	0.75	1.35	0.50	0.75	0.30	0.25	0.50	**4.40**
Solar PV	0.75	1.40	0.40	0.60	0.30	0.25	0.50	**4.20**
Improved Cook Stoves	0.70	1.35	0.50	0.75	0.40	0.25	0.50	**4.45**
Energy Efficient Lighting and Appliances	0.75	1.20	0.50	0.65	0.30	0.25	0.50	**4.15**
Establishment of a Technical and Vocational Education and Training (TVET) Centre	0.75	1.65	0.50	0.75	0.40	0.23	0.45	**4.73**
Additional Community Focal Points & Market Squares	0.75	1.75	0.40	0.70	0.40	0.25	0.50	**4.75**

8 PROPOSED INTERVENTIONS

8.1 Description of Selected Interventions

Based on the results of the multi-criteria analysis, the following climate responsive options were selected for further development:

Sector	Activity
Transport / Mobility	Construction of green rights of way
	Green road construction methods
Stormwater Management	Blue/Green stormwater management systems
Water Supply	Expansion of central water supply (100% connection rate)
	Rainwater harvesting (as supplement to central supply)
	Filters for Household Water Treatment
Sanitation	Biogas system at the TVET / market
	Latrine Improvements / Education
Solid Waste Management	Community composting
	Neighbourhood Waste Collection Point
	Recycling collection stations
Energy	Solar PV
	Clean cooking technology
	Energy Efficient Lighting and Appliances
Community Facilities	Establishment of a Technical and Vocational Education and Training (TVET) Centre
	Additional Community Focal Points & Market Squares

These are described in greater detail in the following sections.

8.1.1 Transport / Mobility

The proposed transport interventions are the construction of a green / climate responsive rights of way network, and the green / climate responsive road construction methods. These can be described as construction of a reliable transport network that meets community needs, is resilient to climate change (especially heavy rain events) and is affordable to maintain. The right of way network proposed can also satisfy other sectors' infrastructure needs. The elements are as follows:

- A long term network. Note: not all pathways are shown as their locations rely on specific development proposals and detailed planning
- Stormwater-resilient paths and roads using combination of improved surfaces consisting of packed aggregate, volcanic setts/tiles/ bricks, asphalt (where slope or heavy vehicle function requires), drains, ditches, appropriate gradients and cross-gradients
- 2 main roads (collector level, with up to 1 + 1 lanes, designed for heavy vehicles) that can accommodate through traffic but in a traffic-calmed way, for example with narrowing down to 1 lane at pinchpoints, with raised crossings, etc.
- A wetland-edge walking and cycling path for the settlement residents and for through traffic
- Lighting on buildings and poles – solar-panel powered or wired – covering all formal footpaths and vehicular rights of way all night
- Community tool and repair centre including bicycle workshop, repair service, e-cycle options, and share-bike options, moto-taxi and bike-taxi hub.
- Local maintenance of drains, paths, stairways, ditches, road-related vegetation (supported by including local cultivation centre) – for all surfaces except the through–links and one or two asphalted downhill roads
- Under-road piping for other systems as required

Figure 8-1: Green / climate responsive right of way network

Indicative cross sections are shown and annotated below. Further detail relating to right of way stormwater treatments is provided in the subsection following this transport and mobility sub-section.

Figure 8-2: Indicative cross section for a collector road.

- 12.7m wide
- Drive lanes need durable surface for heavy vehicles
- Bicycles use drive lanes
- Collector roads have low slope (on the study site they will run with the contour lines) so ditches are generally preferred to hard drains
- Ditches are within the 1.5m green/ tree zone

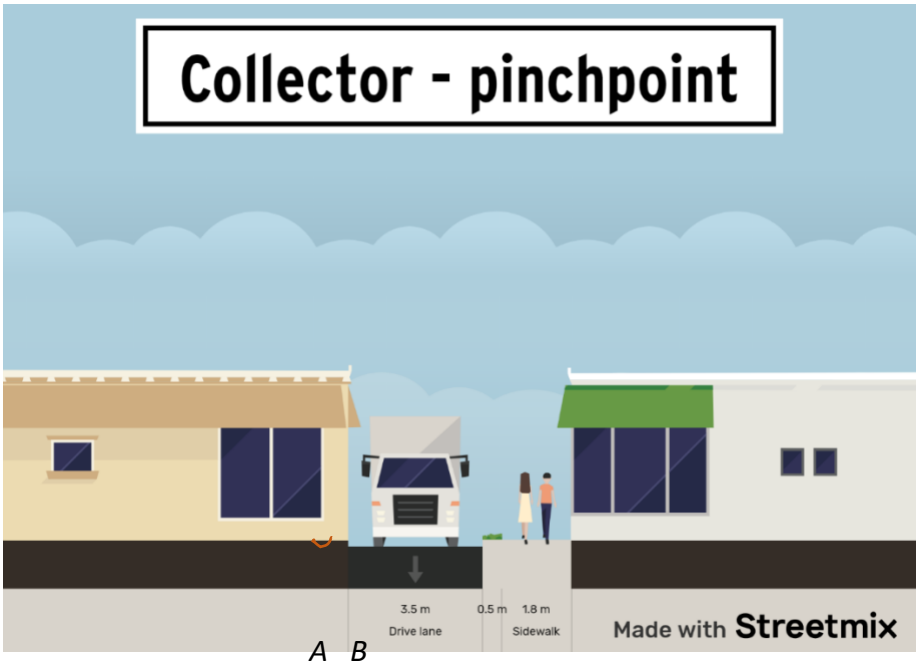


Figure 8-3: Indicative cross section for a pinchpoint on a collector road.

- 5.8m wide at pinchpoints due to existing dwellings adjacent to the lower collector road
- Hard drains or culverts may be required due to higher property threat from stormwater.
- The drain/verge (0.5m) at “A” could swap positions with the footpath at “B”, for example if the cross-profile slope and drainage requires that to protect properties.

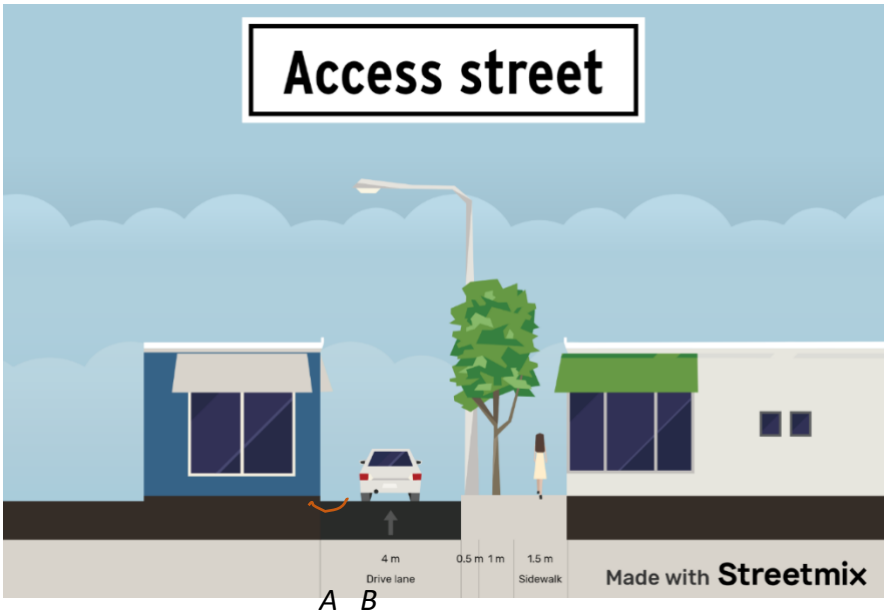


Figure 8-4: Indicative cross section for an access street.

- 7.0m wide
- Access streets have low demand with very minimal or no through traffic. Bicycles use drive lanes
- In Ngaruyinka many access streets exist already, with restricted widths due to buildings
- The drive lane does not need a highly durable surface for heavy vehicles
- On higher slope access streets at c.10% gradient, durable surfaces are required to prevent erosion
- Ditches or drains will be used, depending on road gradient, in the lamp / green zone (TBC)
- The drain/verge/ditch (0.5m) at "A" could swap positions with the footpath at "B", for example if the cross-profile slope and drainage requires that to protect properties
- Vehicle turning points will be required in some locations like at dead ends.

Figure 8-5: Indicative cross section for a pinchpoint on an access street.

- 4.0m wide at pinchpoints (due to existing dwellings on many existing and some proposed access streets)

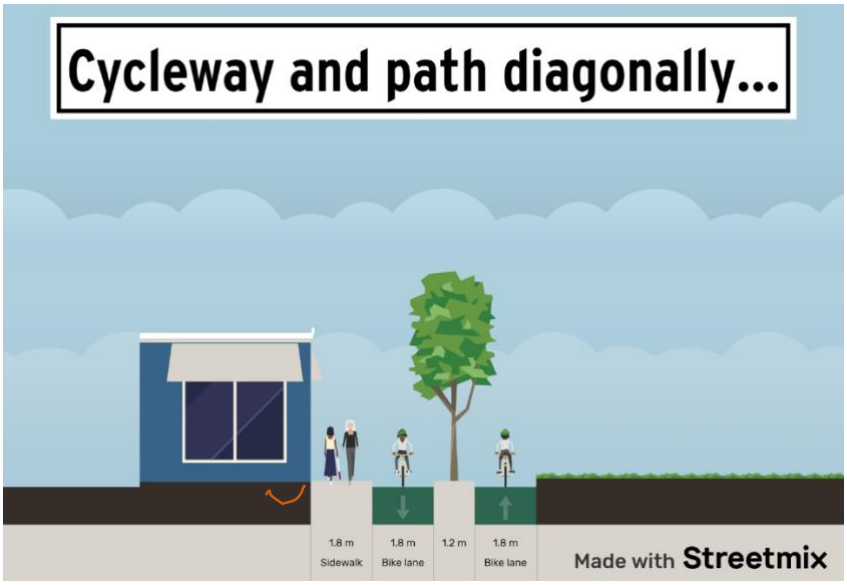


Figure 8-6: Indicative cross section for a cycleway and path.

- 6.6m wide
- The cycleway and pathway is primarily for moderate-gradient cycling access up and down the hill, including for through-trips. Moto-taxi use should be prevented, but this may be a challenge.
- The surface will need a high-grip and durable surface in some locations where slope or erosion risk is higher.
- Ditches will be mainly used, depending on gradient (used in the 1.2m green verge), although some drains may be needed at interfaces with other roads for example.

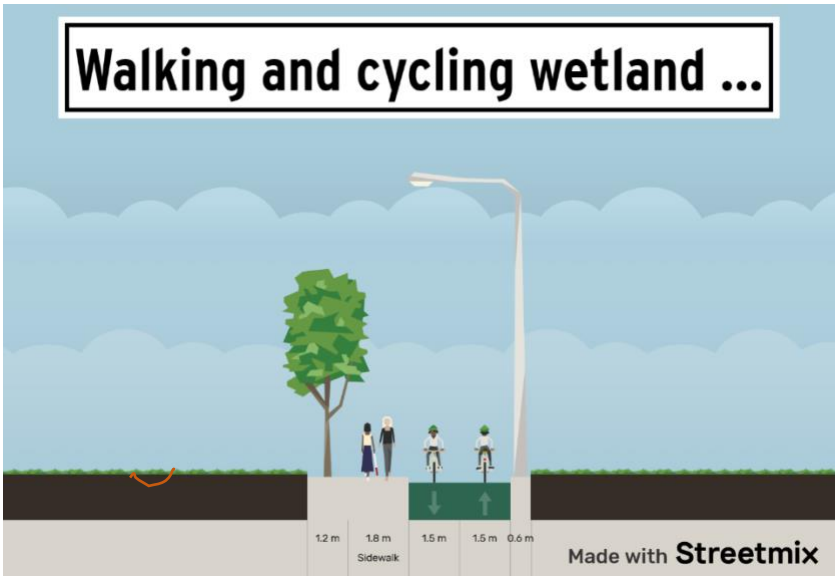


Figure 8-7: Indicative cross section for a walking an cycling pathway above the wetland.

- 6.6m wide
- The cycleway and pathway is an edge trail just above the wetland and below the Ngaruyinka site, and should extend around the entire hill

- Moto-taxi use should be prevented if possible.
- The surface may not need an asphalt surface
- Ditches will be adequate, rather than drains.

Figure 8-8: Indicative cross section for a path.

- 2.3m wide
- The path materials depend on stormwater and erosion context, ranging from compacted earth and mini-swale to culvert with bricked path.

Figure 8-9: Indicative cross section for a pinchpoint on a path.

- 1.0m wide
- At constrained locations the width is minimal. The path materials depend on stormwater and erosion context, ranging from compacted earth and mini-swale to culvert with bricked path. The potential culvert would be about c 0.5m wide

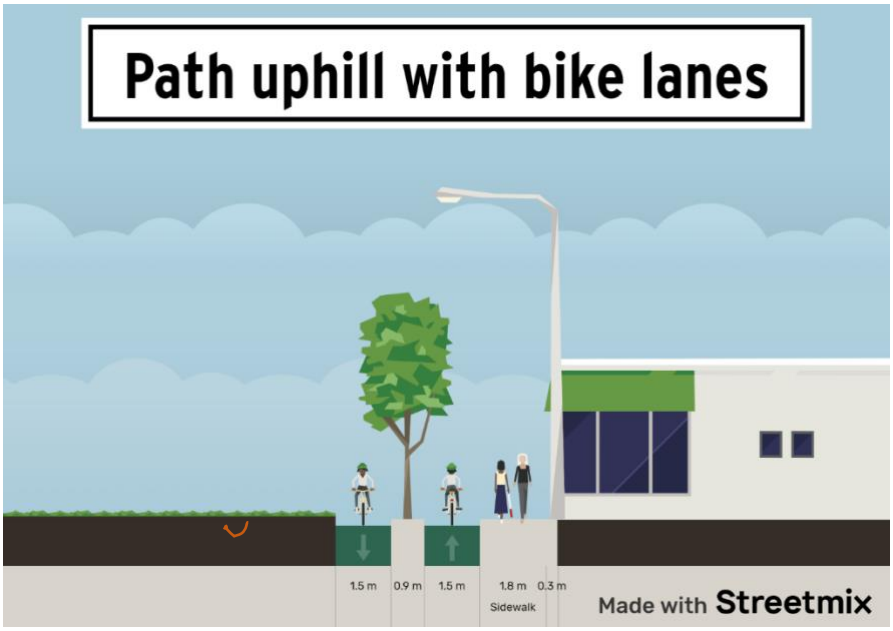


Figure 8-10: Indicative cross section for a path uphill with bike lanes.

- 6m wide
- The bike lane that is separated (further away) from the footpath is intended to be the downhill (faster) bike lane, for improved safety.

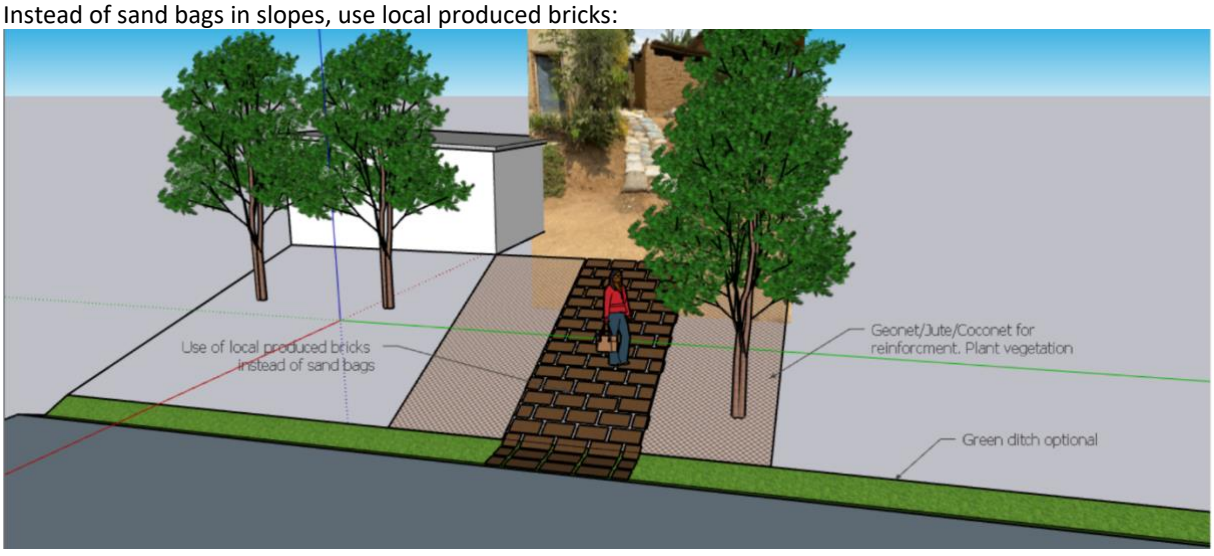
8.1.2 Stormwater Management

A thorough storm water intervention will solve one of the biggest problems of the settlement, the erosion problem. The storm water will also be one resource for household water use, maintaining the natural ground water recharge and watering the plants and trees of the settlement. The storm water action needed is summarized below:

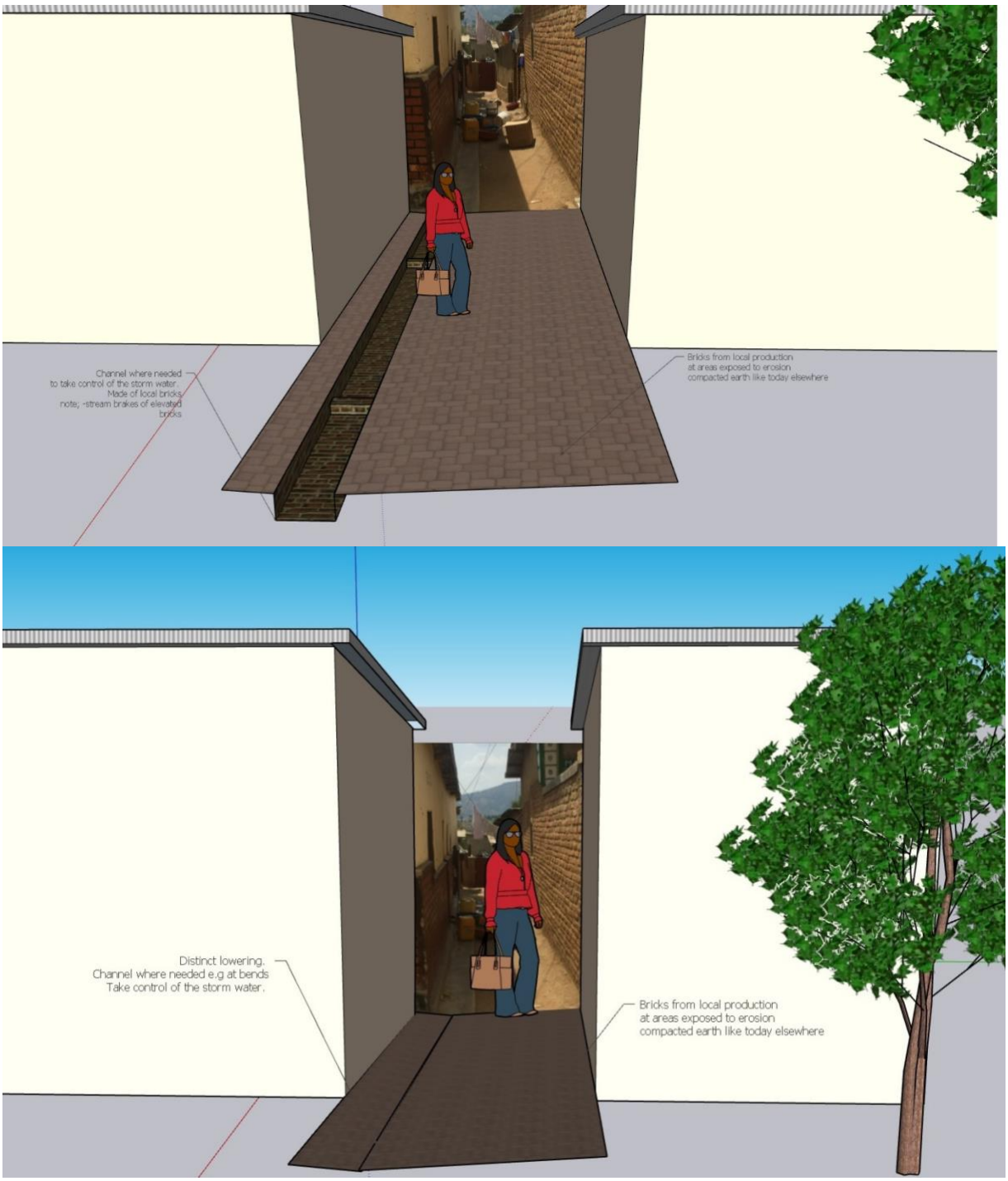
Existing settlement upgrade

Before expanding the development in the area with new roads and buildings the existing settlement and the internal smaller roads have to be upgraded. Suggestions of storm water and erosion protection improvement is shown, using some relevant pictures from the field visits.

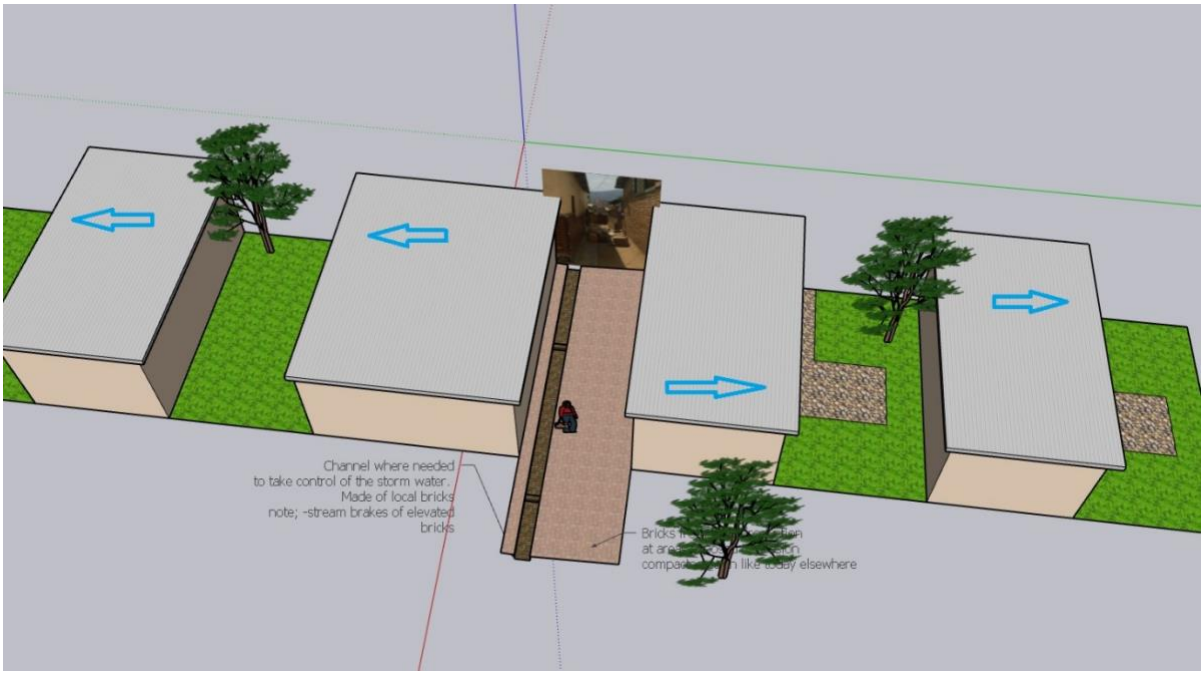
Instead of sand bags in slopes, use local produced bricks:



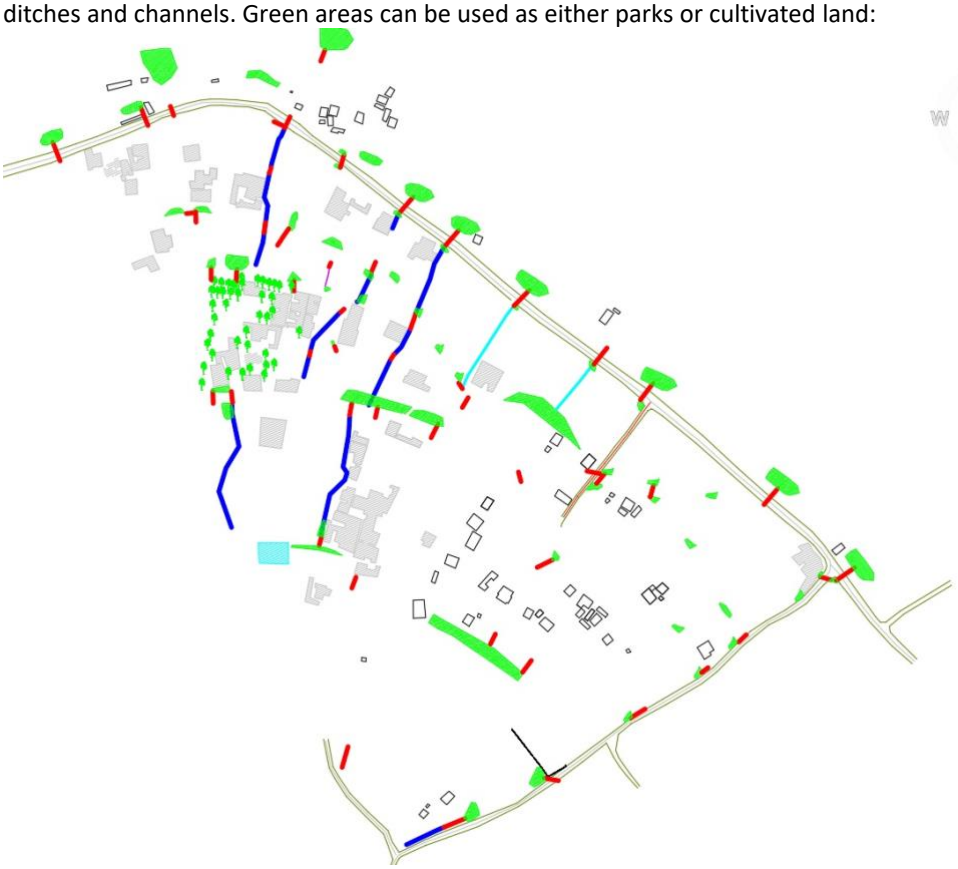
In narrow streets where erosion occurs through the existing settlement, the recommendation is to build a channel with local produced bricks to take control of the stream. In the main parts a new topping will be enough:



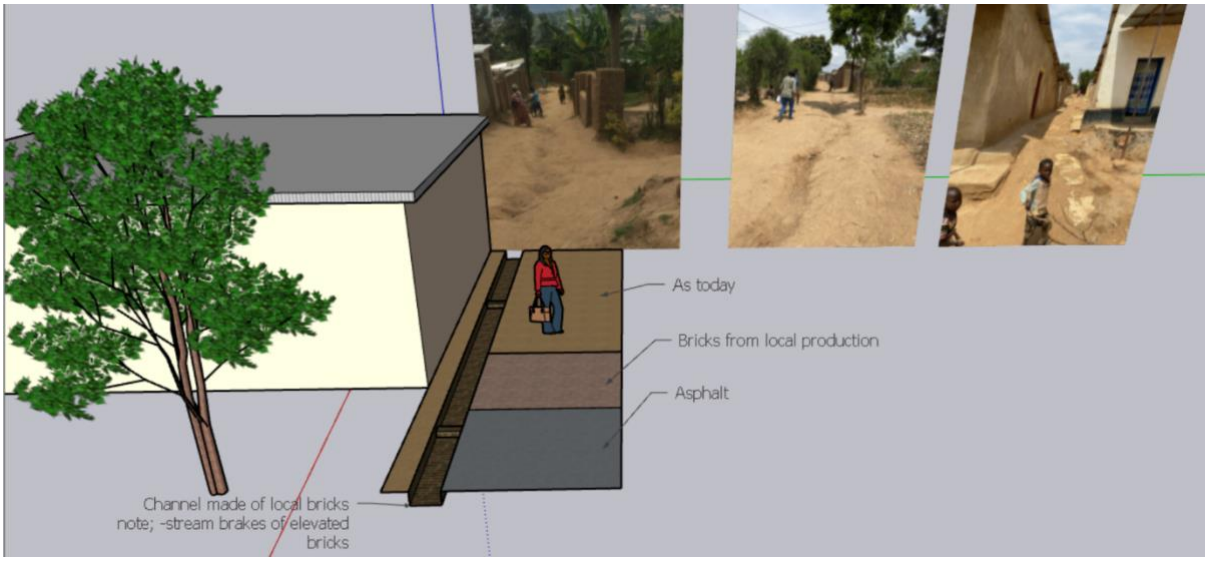
However, the most important measure is to handle the storm water locally in each plot by means of minimizing the hard top surface, implement rain water harvesting and the diversion of the roof water into cultivated permeable soils in the backyards:



One measurement as important as the previous is to divert the accumulated storm water into green swales and green detention areas before being excessively accumulated and before entering the settlement. In the map below the green areas show a distribution of such areas. The red lines show the need of placement of culverts under the roads to connect ditches and channels. Green areas can be used as either parks or cultivated land:



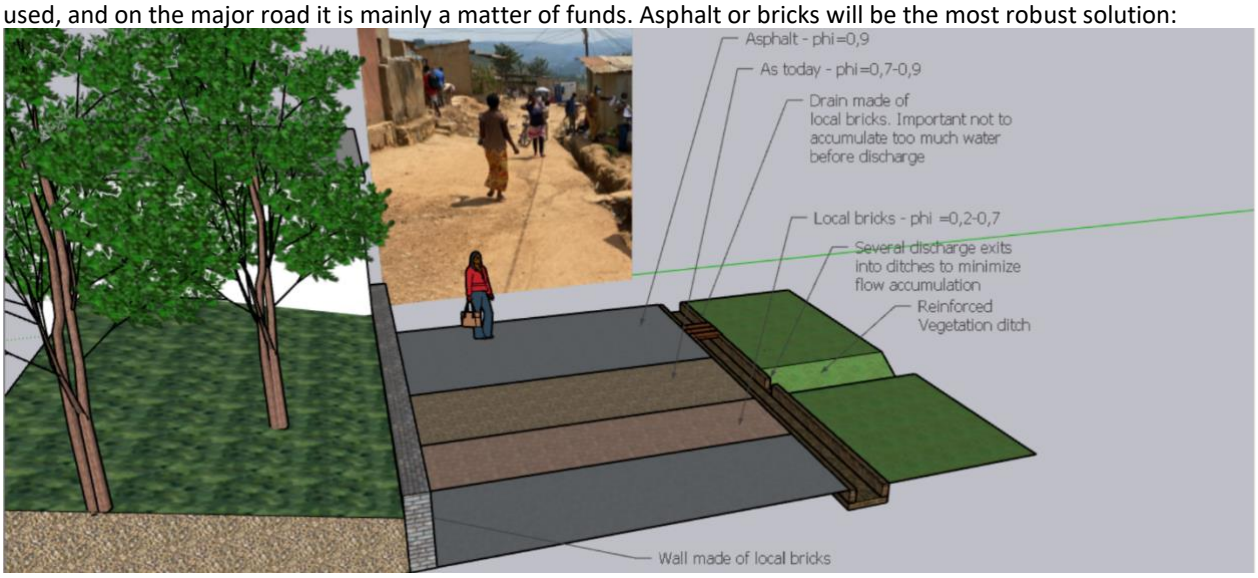
The top of the roads in the settlement can either be kept as today, be paved with bricks from local factory production or in certain severe erosion prone areas be asphalted:



Along steep roads, bricks can be used to form a diversion of the water flow into green ditches along the road:

Existing major road on the foot of the hill, along the curves should be upgraded by establishment of a green ditch on the lower side of the road:

Where the street is narrower a channel should be made by the use of locally produced bricks. Different pavings can be used, and on the major road it is mainly a matter of funds. Asphalt or bricks will be the most robust solution:



To save land (and effort) the ditches and drains for the roads along the contours can be placed on the lower side only, as long as the storm water coming from the mountain side is under control, infiltrated, stored, and/or diverted under the road by means of culverts. In any circumstances, slope stabilisation has to be made somehow. One solution is to build walls with local produced bricks and use geonets made from plants like palms or jute. Another is to stabilize the slopes with vegetation.

Before – after:


Hedges stabilize, divert and infiltrate storm water and protect from erosion and create a natural and aesthetic boundary compared to walls or fences:

Street expansion

To save resources and thus carbon emissions, the solutions of the storm water handling of the street expansion should be tailor made taking into account some base factors:

- Low or no traffic - Much traffic

The more traffic, the higher is the need of pavement.

- Along contours – Against contours

Against the contours increases the speed, decreases the exit into ditches and therefore the erosion is increased.

- Run off – Infiltration

Different topping of the road options available:

a. Like today – soil
b. Like today – soil - but more even and a maintenance programme (salt, levelling, compacting, walls on the upside)
c. Asphalt
d. Bricks that can sustain wet conditions
e. Crushed stones
f. Cut stones
g. Geonet + vegetation

If the road is paved or not does not affect the possibility to infiltrate at more intense rains. Studying the pictures from the field visits it seems like the compacted soil has very low infiltration capacity. However, using bricks or crushed stone

increase the surface attached to the soil and therefore the time for the storm water to infiltrate. For less intense rains, the infiltration capacity will be increased dramatically.

Below the picture shows bricks perhaps suitable for making channels and one example of crushed stones topping of road. It will be necessary to be careful in the selection of bricks to ensure that they can meet the required specifications.

General recommendations:

- Difficult roads should be paved with asphalt + channels with bricks and/or stones.
    - Heavy traffic roads
    - Very steep roads with much storm water accumulation
- Semi difficult roads should be paved with bricks and/or stones + channels with bricks/stones or green ditches
    - Steep and narrow pedestrian roads
    - Erosion prone roads
- Easy roads can be kept like today but with maintenance programme + channels with bricks/stones or green ditches
    - Flat roads
    - Flat/moderate steep pedestrian roads

Settlement expansion – preferred architecture/structure and placement

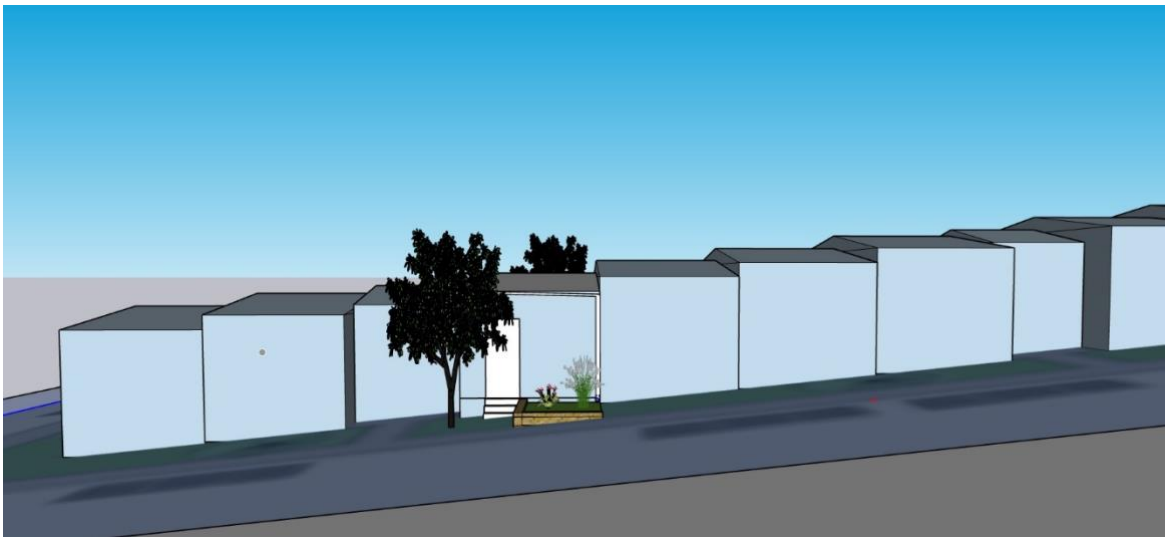
Very important is to not place the houses too dense and to not build in natural streamlet terrain and in green storm water discharge areas needed to detain the flows to protect downstream urban areas.

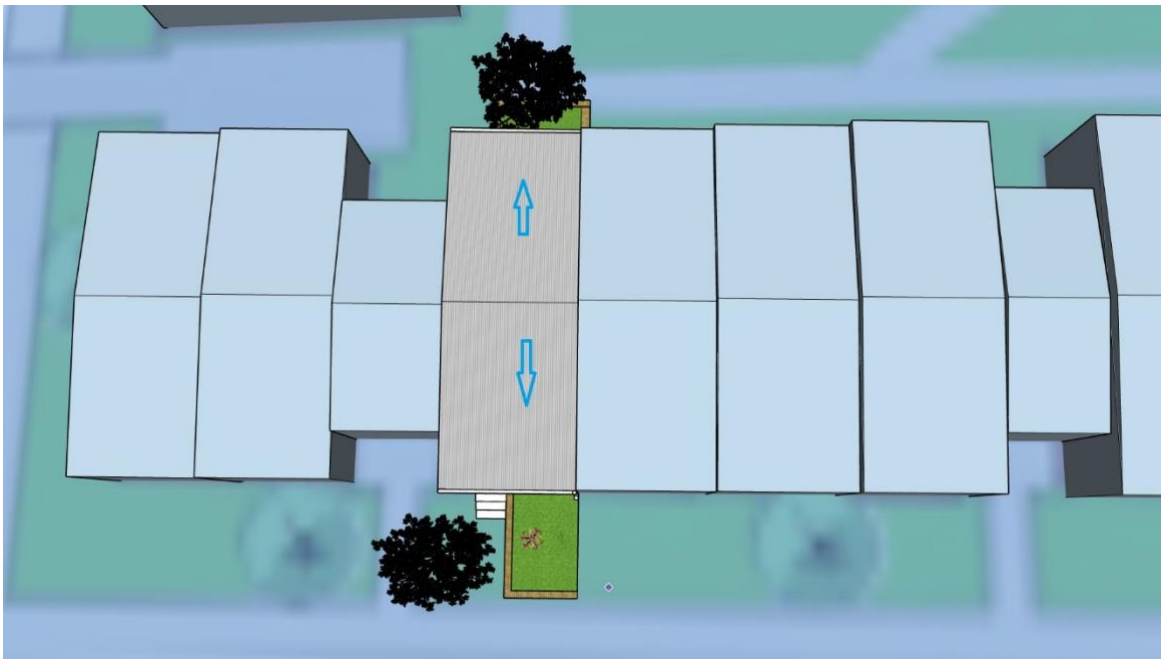
Settlement expansion development must be properly planned and located. The goal is to minimize the run off from the urban development. This will not deteriorate or even improve the storm water erosion situation. Suggestions of regulation:

- Mandatory green gardens for every house
- Mandatory creation of brick walls or similar to flatten the terrain thus storing the storm water on the plot minimizing discharge and erosion.
- Mandatory rain water harvesting

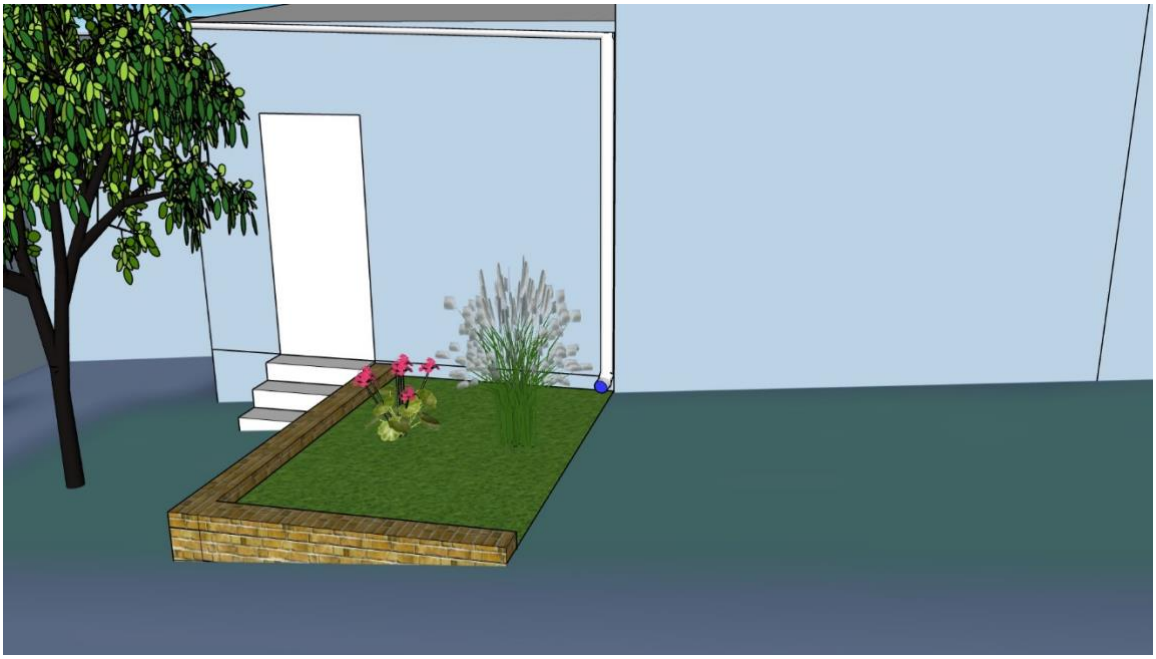
The pictures below show the ideal outline of a local sustainable drainage system of one house.

The pictures below show the ideal outline of a local sustainable drainage system of one house where the garden is at least 25% of the roof area diverted to the land. In order to function, the garden has to be framed with bricks 100 mm high around the garden and the garden has to be cultivated or planted with





Garden at the front and at the back. Garden size at least 25 % of the size of the attached roof. If the permeable soil structure (10% average porosity) is one meter deep the garden can infiltrate.



This table below shows that the total storage capacity of the garden is corresponding to more than a 30 mm rain with high intensity since no runoff will occur.

Table 8-1: Case study for 30mm rain

Case study 30 mm rain	
Rain 30 mm (m)	0,030
Roof area (sqm)	20,00
Rain volume created from roof (qbm)	**0,60**
Rain volume created in garden (qbm)	**0,15**
Total rain volume created (roof + garden)	**0,75**
Garden area (sqm)	5,00
Available flooding over garden (100 mm embanked)	0,50
Available infiltration volume in garden (600 mm deep soil, 10 % porosity)	0,30
Total storage capacity available	**0,80**

Conclusion: 0,80 > 0,75, thus the available storage capacity in and above the soil > volume storm water run off created from roof and garden.

8.1.3 Water Supply

Several interventions are proposed for the site in order to increase the climate-resilience of the water supply system and ensure that residents have access to a year-round water supply.

Expansion of Central Water Supply

We propose the installation of new water connections to serve all households in the settlement. Currently many households walk to a water kiosk to purchase water. We understand from WASAC that that capacity of the water supply system is being increased, so there should be more reliable service delivery in the future. Improvements to the distribution system are needed in order to supply more water to the settlement, and this will be included as part of the work along the ridge road. WASAC has completed a preliminary design of the expansion, and this is shown in the drawings below. More detailed layouts and sizing will be completed during the detailed design stage.

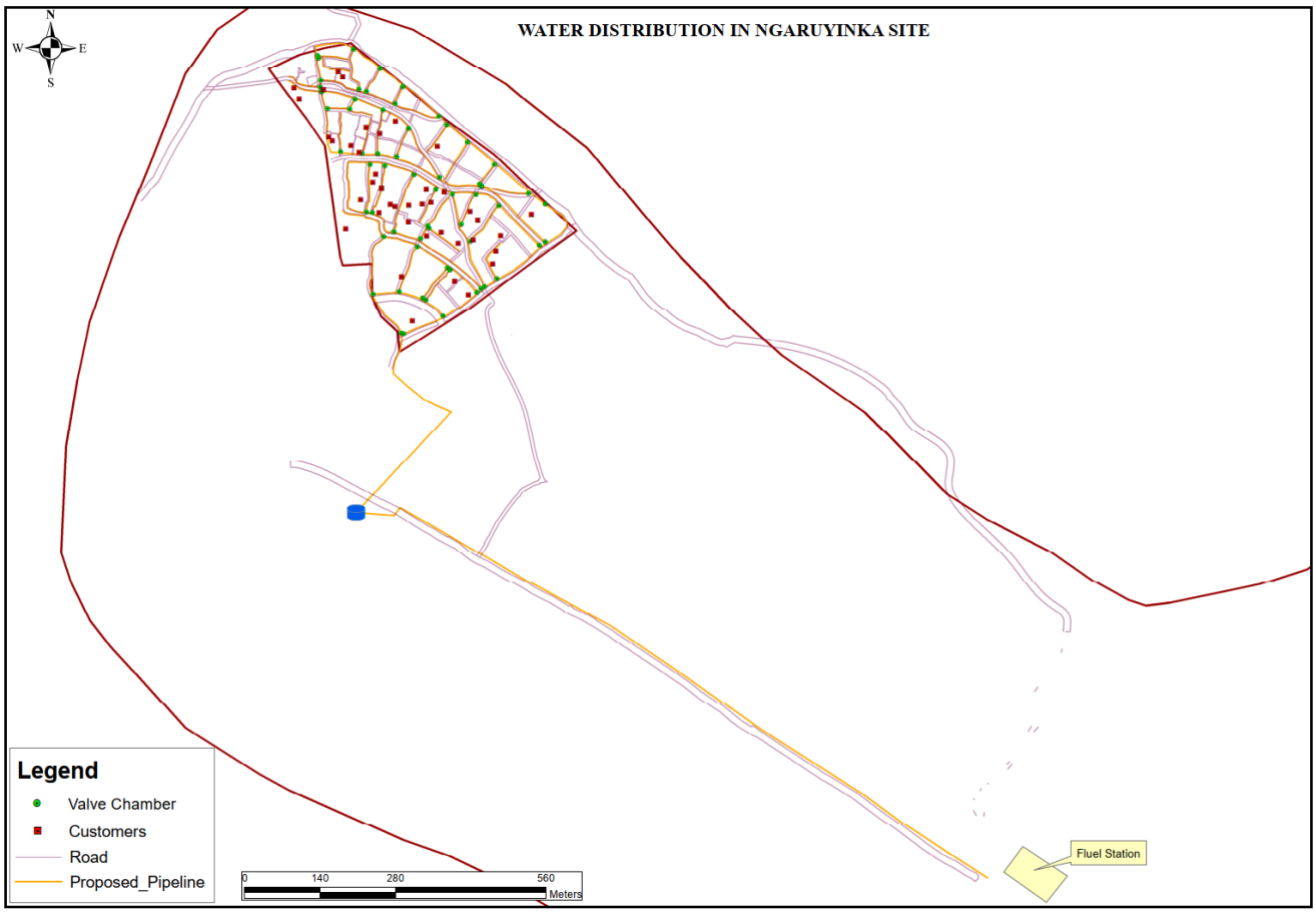


Figure 8-11: Water distribution, from the fuel station to the settlement

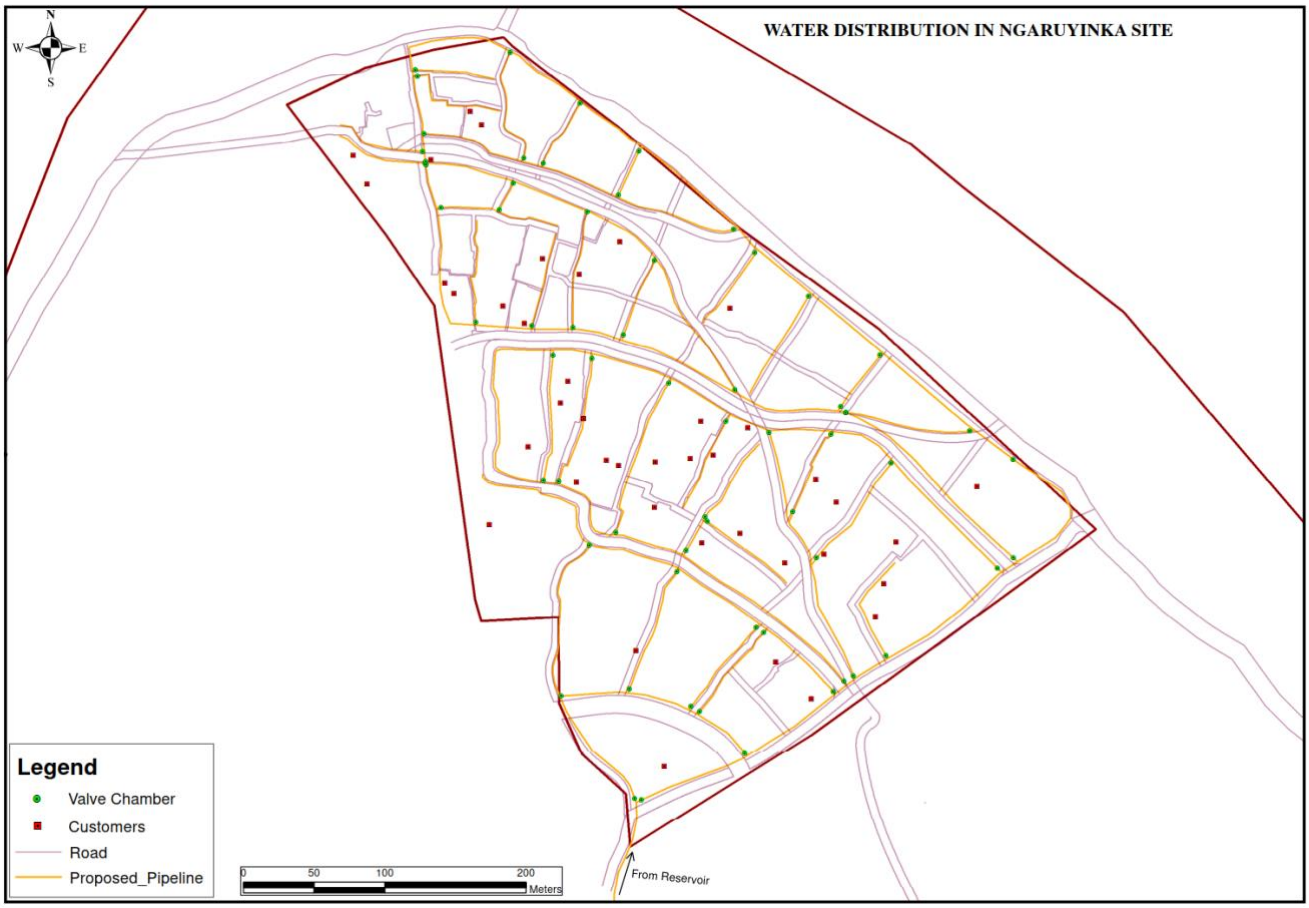


Figure 8-12: Proposed water distribution expansion within the settlement.

Rainwater Harvesting Systems

We propose to install rainwater harvesting systems on community structures such as the market space and TVET, as well as on some private households, which will be selected based on vulnerability and technical feasibility. Based on discussions with the community and observations of informal rainwater collection throughout the settlement, this is an approach that the community is very interested in. Rainwater harvesting will decrease the dependency on the central water supply, and thereby increase resiliency during times that the central water supply is unable to meet demand. Rainwater can be used for household domestic purposes, as well as gardening. Rainwater harvesting is used in many households throughout Rwanda, and the Government of Rwanda encourages this as a sustainable solution to help residents have year-round water access. Some developments have community-level underground rainwater harvesting systems. Vision City, for example, has an underground water harvesting system that collects water from roofs and reuses it for gardening purposes. However, household-level rainwater harvesting systems would be more appropriate in Ngaruyinka since there would be clear responsibilities for the operation and maintenance of the system at the household level.

The proposed rainwater harvesting system is based on the recommendations in Rwanda Standard RS 187: Rainwater Harvest Systems. This standard indicates that on-site collection and use of rainwater is an accepted alternative to public mains water supply, and it provides benefits for attenuation of surface water runoff.

The Rwanda Standard provides recommendations on the design, installation, testing and maintenance of rainwater harvesting systems in Rwanda. For sizing of the water tanks, we recommend following the simplified approach for sizing rainwater harvesting systems for non-potable domestic use. The steps include the following:

- Estimate the roof plan area draining to the storage tank (varies from household to household)
- Determine the annual average rainfall depth for the location (approximately 1000 mm per year)

- Determine the storage capacity read from the graph provided in the Rwanda Standard (image below), based on the roof plan area and the annual average rainfall. The Rwanda Standard recommends basing the capacity on household size if the roof is large, but most housing structures in Ngaruyinka are not so large, so it is appropriate to use the lines on the graph to size the tanks according to roof area and rainfall.

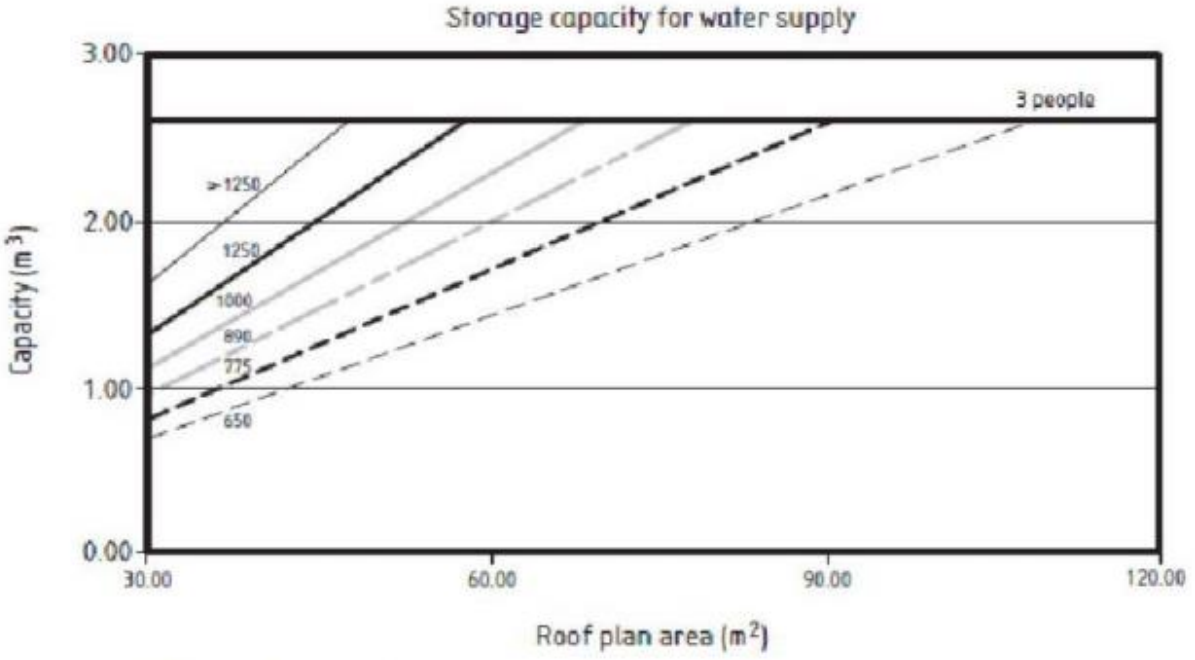


Figure 8-13: Storage capacity for water tank based on roof area and rainfall.

Based on the approach above, a house with 30m^2 roof area in Ngaruyinka should have a water system with approximately 1.2 m^3 (1200 litres) capacity. Larger houses (about 50m^2) could have capacities of 2 m^3 (2000 litres).

The following points describe the design of the system for Ngaruyinka, based on the Rwanda Standard:

- Roof guttering and pipework will allow for access for routine maintenance and cleaning. Pipework will be free draining to avoid stagnation of water.
- Filtration will be incorporated in the system before the rainwater enters the storage tank to prevent debris from entering. The filter system will be water and weather resistant, removable and accessible for maintenance purposes, have an efficiency of at least 90%, and pass a maximum particle size of 1-25mm. The storage tank will also be fitted with a calmed inlet to prevent any other floating debris from entering.
- The storage tanks for will be constructed from materials that create watertight structures without encouraging microbial growth. The tanks will have screened ventilation and fitted lids to prevent contamination. They will be sited so that stored water does not attain temperatures that could encourage multiplication of Legionella. The above ground tanks will be insulated and opaque to minimise warming and algal blooms.
- An overflow will be fitted to the tanks to allowed excess water to be discharged during extreme rain events. This will likely be connected to a soakaway.
- The systems will be based on gravity, without pumps, to minimise investment costs and operation and maintenance costs.
- The tanks will be securely mounted to the ground and supported on a firm level base capable of withstanding the weight of the filled tank.

Periodic maintenance needs to include:

- Gutters/downpipes: check that there are no leaks or blockages, clean the gutters if necessary (annually)
- Filter: check the condition of the filter and clean (annually)
- Storage tank: check that there are no leaks, that there has been no build up of debris and that the tank is stable and the cover correctly fitted (annually). Drain and clean the tank (every 10 years or more often if necessary).
- Installation of a first flush / foul flush. A first flush mechanism ensures that the first amount of rain that is diverted away from the tank since this water typically contains the most materials that accumulated on the roof.

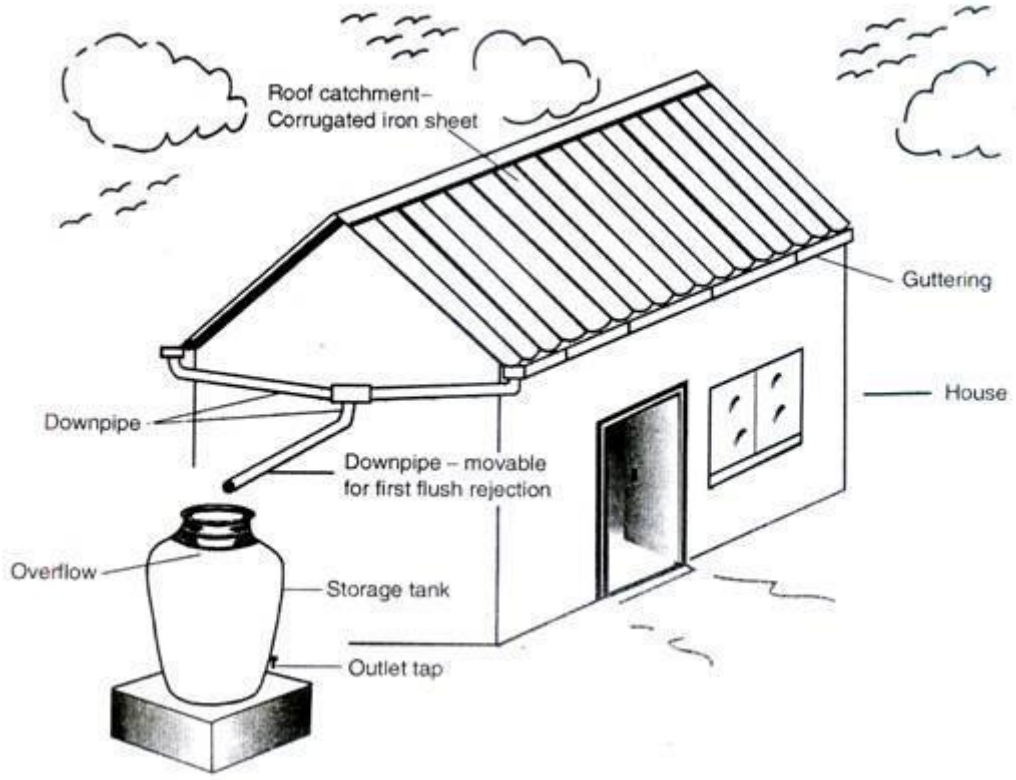


Figure 8-14: Illustration of a rainwater harvesting system[13].

Implementation plan:

Implementation of these systems will be based on FONERWA's extensive experience with other rainwater harvesting projects. The Rooftop Rainwater Harvesting in High Density Areas of Nyarugene, Gasab, Kicukiro, Musanze, Nyabihu and Rubavu Districts Program[14], led by the Rwanda Natural Resources Authority, for example, included work to strengthen the existing loan scheme for rainwater harvesting facilities, support a subsidy and loan system based on Ubudehe categorisation, disseminate very low cost rainwater harvesting techniques for rural poor households, and construction rainwater harvesting systems for selected public buildings and collective household systems. Lessons learned from that will be applied for this project. The following is the proposed approach:

- The project will provide workshops to raise awareness of the rainwater harvesting systems. The project will provide extensive training and demonstration of the systems. The project will also organise study

[13] https://waterportal.rwb.rw/toolbox/464
[14] http://www.fonerwa.org/sites/default/files/RNRA_Project%20Document_Final.pdf

tours to see systems in use in other areas in order to learn about the benefits and maintenance requirements.

- All rainwater harvesting systems will be constructed by firms hired through a procurement process.
- The project will provide followup for at least one year to ensure that households understand maintenance requirements.

Point of Use Household Water Treatment

We propose point of use household water treatment technology as a more sustainable alternative to boiling water. Treatment options will be on display at the TVET, and local companies will have the opportunity to explain how their products work. Depending on the quality of the water (e.g., turbidity, etc), options could include: addition of chlorine drops (e.g., SûrEau), ceramic water filters, solar disinfection (SODIS), solar pasteurisation, etc. Using these methods instead of boiling would reduce the need to use wood or charcoal. These systems could make it possible for households to use rainwater harvested water for drinking and increase resilience during water shortages. Through consultations with local companies as part of the feasibility study, it is confirmed that these solutions are available locally and are produced with local materials.

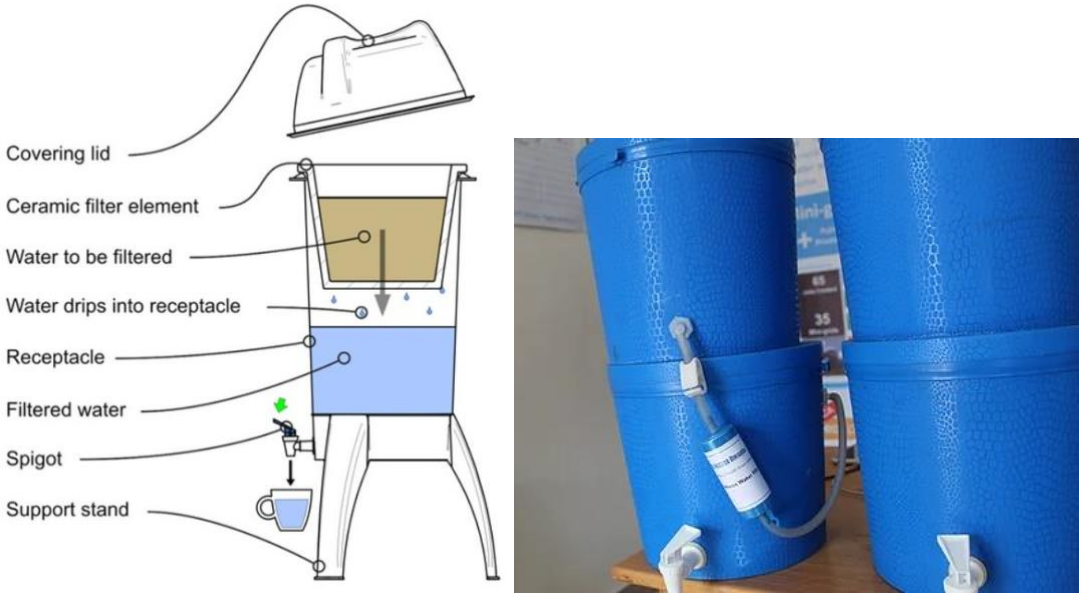


Figure 8-15:Schematic of how a ceramic pot drinking water filter works (left).[15] Picture of the sub-micron household filter for sale by Water Access Rwanda in Kigali (price 44,850 RWF). The filter lasts 5 years, filters 60L per hour, and removes protozoa, bacteria, parasites and suspended solids.[16]

Efficient Water Fixtures

Efficient water use is important in order to minimise capital costs and operating costs of the drinking water supply, as well as minimise CO2 emissions associated with the water supply. Efficient water use also minimises the cost of water to residents and reduces loads on greywater or wastewater systems. The TVET will include demonstrations of water efficient fixtures, including low flow taps, showerheads and aerators, which would help reduce water use and emissions associated with the water supply system.

[15] http://trendsupdates.com/potpaz-ceramic-water-filter-simple-and-functional/
[16] https://www.warwanda.com/product-page/sub-micron-household-filter

8.1.4 Sanitation

Collective toilet with biogas production for cooking (at TVET / market area):

Collective toilets with biogas production are proposed to be installed at the TVET/ market area. This type of system is considered feasible in denser areas or in combination with waste from livestock. There are currently biogas systems at over 80 Rwandan boarding schools and in all the nation's prisons[17]. The biogas from the latrines is used for cooking. These systems provide environmental benefits since they reduce the need to use firewood or charcoal for cooking, which causes deforestation in Rwanda. Challenges include having sufficient waste to produce biogas, access to water to push the waste into the digestor, and sufficient training and education for operation and maintenance. The TVET will help support such an installation by providing training and technical assistance.

Figure 8-16: Image from a boarding school in Kigali where an underground biogas digestor is connected to latrines. The biogas is used for cooking at the school and has reduced the need for wood for cooking by one third.

The proposed design for the TVET and market area is based on other biogas systems used commonly in Rwanda, as illustrated in the image below. A toilet will lead to an underground digester, connected to an expansion chamber and sludge drying bed. The waste from the toilets enters the digester, where gas is produced and collected in the dome. The digested slurry then flows to the outlet tank to an opening where it is then collected and composted. The gas is supplied from the storage area, through a pipe to where is it used for cooking.

The digestor should be sized according to the estimated biogas production from the people using the toilets at the TVET and market. We estimate that approximately 300 people go to the market each day and assume that approximately 10% would use the latrine there. We estimate that approximately 50 people will go to the TVET each day and that all would use the latrine there. The following calculations are based on the methodology used in the study titled "Contribution of Modern Biogas Plant to Energy Source and Environment Protection in Rwanda" by Kundwa et al (2018).

[17] https://www.nytimes.com/2018/09/21/climate/biogas-curb-deforestation-rwanda.html

Biogas production: The specific biogas production from the digestion of toilet water is about 40 litres per person per day, but we lower this estimate since few people are staying at the TVET or market all day. We estimate 80 people times 20 litres per person per day = 1600 L per day.

Biogas demand for cooking: the TVET will use the biogas for cooking student lunches. We assume that the gas consumption of one flame is about 175 liters of biogas per hour. Therefore, the system could supply about 9 hours of cooking time per day. We assume this would likely be divided across three cooking stoves, for three hours per stove each day.

Sizing the gas holder: The volume of the gasholder needs to be sized correctly according to the relative rates of biogas generation and gas consumption.

The hourly biogas production (Y_M) Y_M= 1600 litre/ 24 h = 67 l / h.

The maximum hourly biogas consumption (D_M) D_M = 525 l/h (by the 3 cooking stoves)

D_M-Y_M= 525 – 67 = 458 l/h The longest period of maximum biogas consumption is 3 hours Hence, the necessary gasholder volume (VG1) during consumption is VG1= 458 × 3 = 1,374 l.

The longest interval of zero-consumption is approximately 21 hours. VG2= 67 l/hr * 21 hours = 1407 l.

The larger volume (VG1 or VG2) determines the size of the gasholder. Allowing for the safety margin of 25%, the gasholder volume (VG) is thus: VG= 1407 l × 1.25= 1759 l, or 1.759 m^3.

Sizing the digestor: The estimated amount of toilet water would be approximately 80 people times 2 l per person per day = 160 liters. With a hydraulic retention time of 50 days, the volume of sludge held in the digestor would be 8000 litres, or 8 m^3.

The total volume of the digestor is then the volume of gas plus the volume of sludge, 1.759 m3 plus 8 m3, for 9.759 m3. To calculate the radius of the digestor, we use the following formula: $V = 2\pi r^3/ 3$, which gives a radius of approximately 1.67 meters.

These figures will be discussed and validated at the detail design stage.

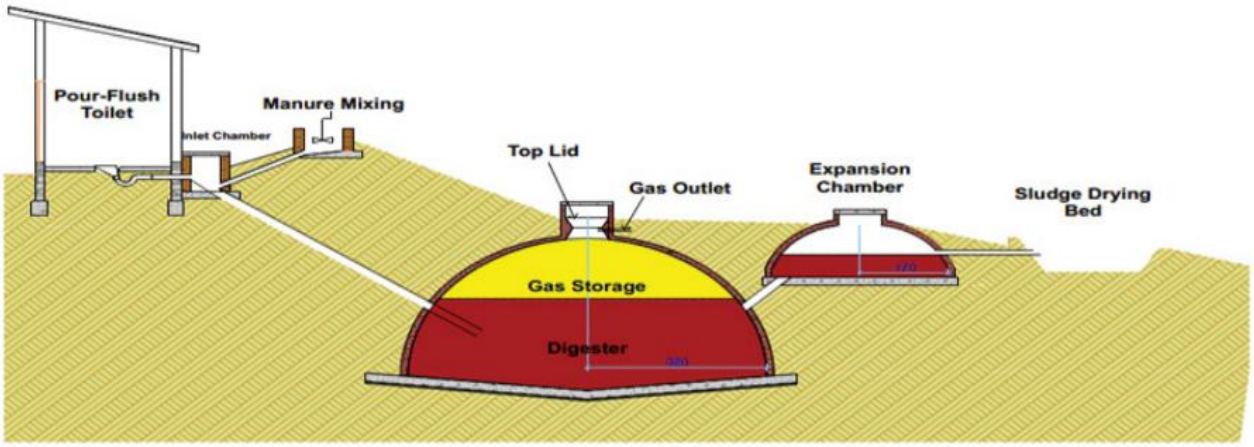


Figure 8-17: Design schematic for biogas system.[18]

[18] https://www.hilarispublisher.com/open-access/contribution-of-modern-biogas-plant-to-energy-source-and-environment-protection-in-rwanda-2165-784X-1000325.pdf

Implementation procedure:

The biogas system would be funded by the project. The operation would be managed by the TVET centre. A small fee could be collected from people from the market using the facility, which would help cover the costs for cleaning the toilet. The TVET operator will be responsible for the operation and maintenance of the biogas system.

Sanitation improvements:

The project will partner with a local organisation to provide training on improving the standard of latrines and/ septic tanks in Ngaruyinka to better protect the environment and human health. One option is a ventilated improved pit latrine. The project will also encourage suitable / affordable faecal sludge emptying options.

Greywater management

The project will promote safe greywater management that allows greywater to be treated through layers of soil / gravel prior to infiltrating the groundwater.

8.1.5 Solid Waste Management

There is great potential for improved solid waste management at Ngaruyinka. We propose the establishment of neighbourhood-level collection points and community composting in order to increase resource recovery and reduce emissions associated with waste.

Community Composting

There is pressure on natural resources in Ngaruyinka, leading to land degradation. Climate change induced extreme weather events such as extreme rains causes increased soil erosion, fertility decline and decreased agricultural production. Rwanda is dependent on imported inorganic fertilisers, which have an adverse impact on the environment and climate change. Composting organic waste is a means to recover nutrients, and the compost can be applied to restore and maintain soil fertility. This will reduce the need to use inorganic fertilisers, thus reducing GHG emissions from producing and importing such fertilisers.

Community members in Ngaruyinka have expressed strong interest in community composting. A small enterprise will be established to operate and maintain community composting. The composting station will accept garden waste and food waste from some households. This operation will allow the recovery of nutrients from organic waste, which is a climate friendly alternative to using chemical fertilisers. The operation will improve the farming output through the application of nutrients from the compost. Hands-on trainings will be offered by a local organisation that has long experience with composting in Kigali. These trainings will ensure that the community has the knowledge to manage the composting operation over the long-term. Licensing of the operation will be done if necessary.

Figure 8-18: Pictures of composting training sessions offered by the organisation One Acre Fund in Rwanda.[19]

This activity will make the community more resilient to the effects of climate change. It will also reduce the amount of organic waste landfilled.

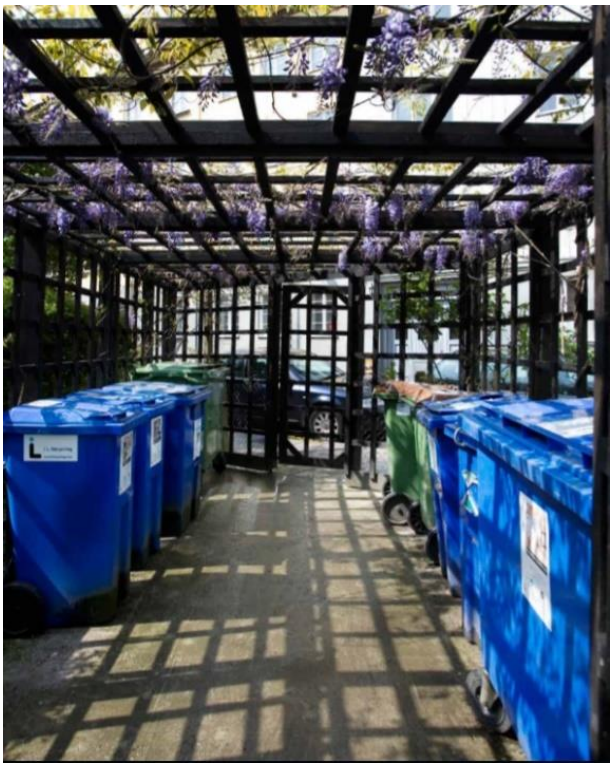


Figure 8-19: Simple structure to limit access to waste drop off to residents/potentially local businesses.

Waste and Recycling Collection Points

Two waste and recycling collection points are proposed for the area. The collection point will include bins for recyclables (plastics, metals, glass) and hazardous waste (batteries and small electronics). Collection point capacity and the number of bins will be based on waste composition estimates and the number of households served. This arrangement will make it easier to separate recyclable and hazardous waste at the source, which supports efforts to increase recycling and reduce GHG emissions. The first collection point planned under the project will be located near the market, and the second will be located in proximity to areas with denser populations.

[19] https://oneacrefund.org/blog/why-one-acre-fund-trains-farmers-composting/

The collection points will be locked, to allow for access only by the households and waste collectors. The waste bins hold a value and should be clearly marked to deter theft. Restricted access is a measure to improve sorting practices from the households. Several studies have shown that waste sorting is improved when a limited number of users have access to the sorting room.

The City of Kigali has previously introduced source separation of household waste; however, these efforts have not generally been successful. Waste bins were placed in the community, but their installation lacked accompanying communication regarding how the residents should sort and what the benefits of sorting are. The project will employ waste ambassadors who give instructions to residents about waste separation. It is also important to set a culture of keeping the waste sorting rooms clean and hygienic. Using waste ambassadors to implement new SWM systems or improving compliance with older systems has been successfully implemented in many countries.

The recycling collection points will also be used as centres for information on the importance of reducing waste and sorting waste to enable recycling and energy recovery. To revive confidence in source separation the inhabitants need to see that their contribution (source separation) will improve the environment and they need to have further understanding of the value that can be derived from waste.

8.1.6 Energy

Solar PV Panels and Solar Water Heaters

Opportunities to install solar photovoltaic (PV) systems on the roofs is possible. Any production that is fed into the grid will have to be negotiated with Rwanda Energy Group (REG) to find price and generation requirements. The opportunity to have a net energy metering (NEM)[20] arrangement is not found in Rwanda at present. Renewable energy provision is supported in the Green Building minimum compliance system (RHA 2019, annex 3) but is presented as optional. We recommend using solar PV for street lighting, as well as for community structures and for affordable housing in the 16ha GCK pilot development. We also recommend solar water heaters for households in the pilot development.

Clean Cooking Technology

Improved cook stoves would help prevent deforestation, reduce GHG emissions, improve the health of women who suffer from breathing in emissions and who shoulder the burden of collecting firewood. A number of projects and companies in Rwanda work to encourage the adaptation of improved cook stoves. For example, a new project titled "GCCA+ Reducing Climate Impact of Cooking in Rwanda through Improved Cooking Systems" aims to support a nation-wide transition to more efficient cooking systems[21]. The best options for Ngaruyinka will be discussed with FONERWA based on their recent project experience.

We note that there are efforts underway to promote LPG in Kigali. Using LPG would reduce emissions compared to charcoal. However, we understand that this cannot be considered for support from GCF. Such work would need to be financed by other sources.

Energy efficient lighting and appliances

Light should be provided via energy efficient solutions and should make use of daylight wherever possible. Any lamp fittings should be designed with low-energy solutions. The TVET could include programming regarding energy efficient lighting and appliances.

8.1.7 Community Facilities

Community Hubs & Market Squares

Community hubs should be located within walking distance of every home (circa 200m) including new areas of housing to be provided as part of the densification of the area and should serve a catchment of circa 1500 residents each. Locations have been recommended based on the spatial analysis of the settlement in section 2. Hubs should include space for the following facilities clustered around the public space:

- Commercial shops / stalls / kiosks – can be ground floors of homes — Circa 80m2 in small units
- Day care / teaching space / community meeting room — Circa 30m2
- Covered public square / market inc. stalls, benches and waste bins — Circa 30m2
- Integrated play area (e.g climbing wall / frame)
- Service / delivery / drop-off parking — 4 spaces

[20] NEM allows consumers that have generate electricity to use the grid as a storage. The excess is fed into the grid and credits are given. These credits can then be utilized later in time.

[21] GCCA 2020. https://www.gcca.eu/stories/rwanda-tackling-climate-change-one-kitchen-time

Figure 8-20: Example of a settlement community hub with integrated public space / market square, room for combined community uses and a children's climbing wall

Figure 8-21: Suggested locations and walking catchments for community hubs

Technical Vocational Education and Training Centre

TVET centres combine education, training and skills development relating to a wide range of potential occupational fields, production, services and livelihoods. TVET, as part of lifelong learning, can take place at secondary, post-secondary and tertiary levels and includes work-based learning and continuing training and professional development which may lead to qualifications. In the case of Ngaruyinka, the TVET centre would provide an investment opportunity to facilitate the implementation and upscaling of the upgrade model by providing training for production of climate responsive materials, use of technologies, construction and repair of the settlement infrastructure. It can also have a value for awareness raising within the community and wider, showcasing green technologies and the benefits and successes of the upgrade investment.

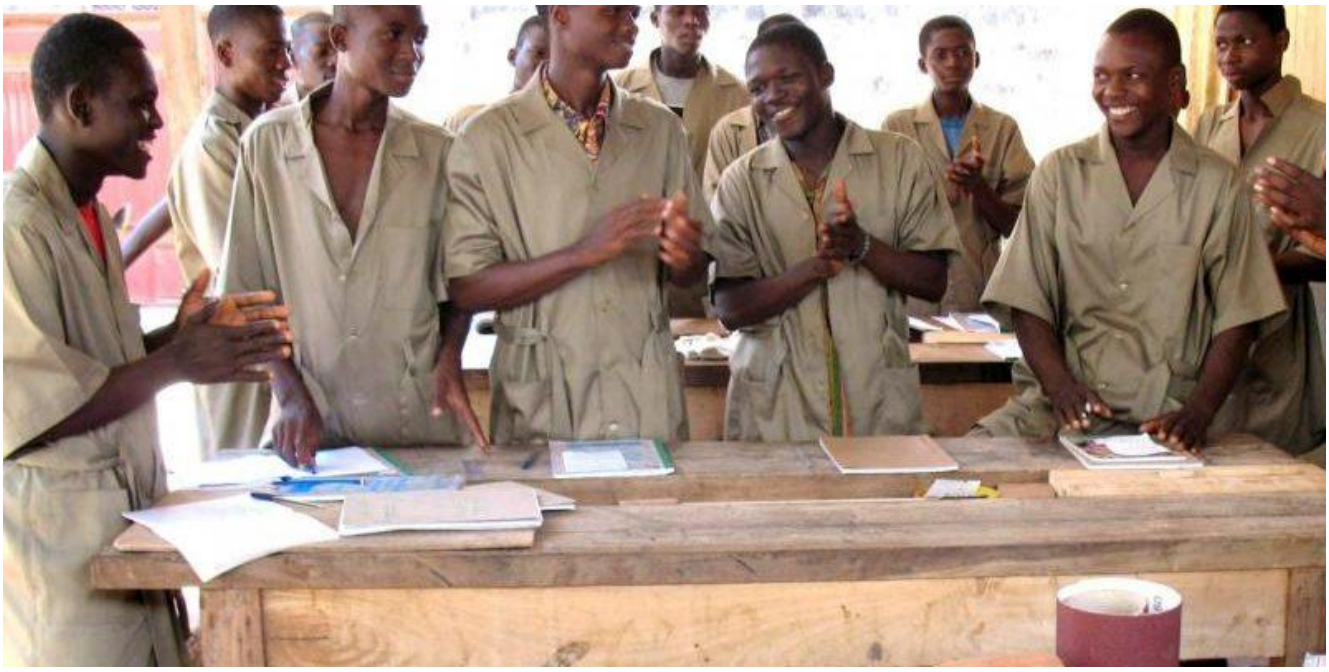


Figure 8-22: Students at a TVET centre in Kenya

8.2 Proposed Interventions Mapped Against the Solutions Tree

The proposed solutions have been mapped onto the Solutions Tree Analysis in Figure 8-23.

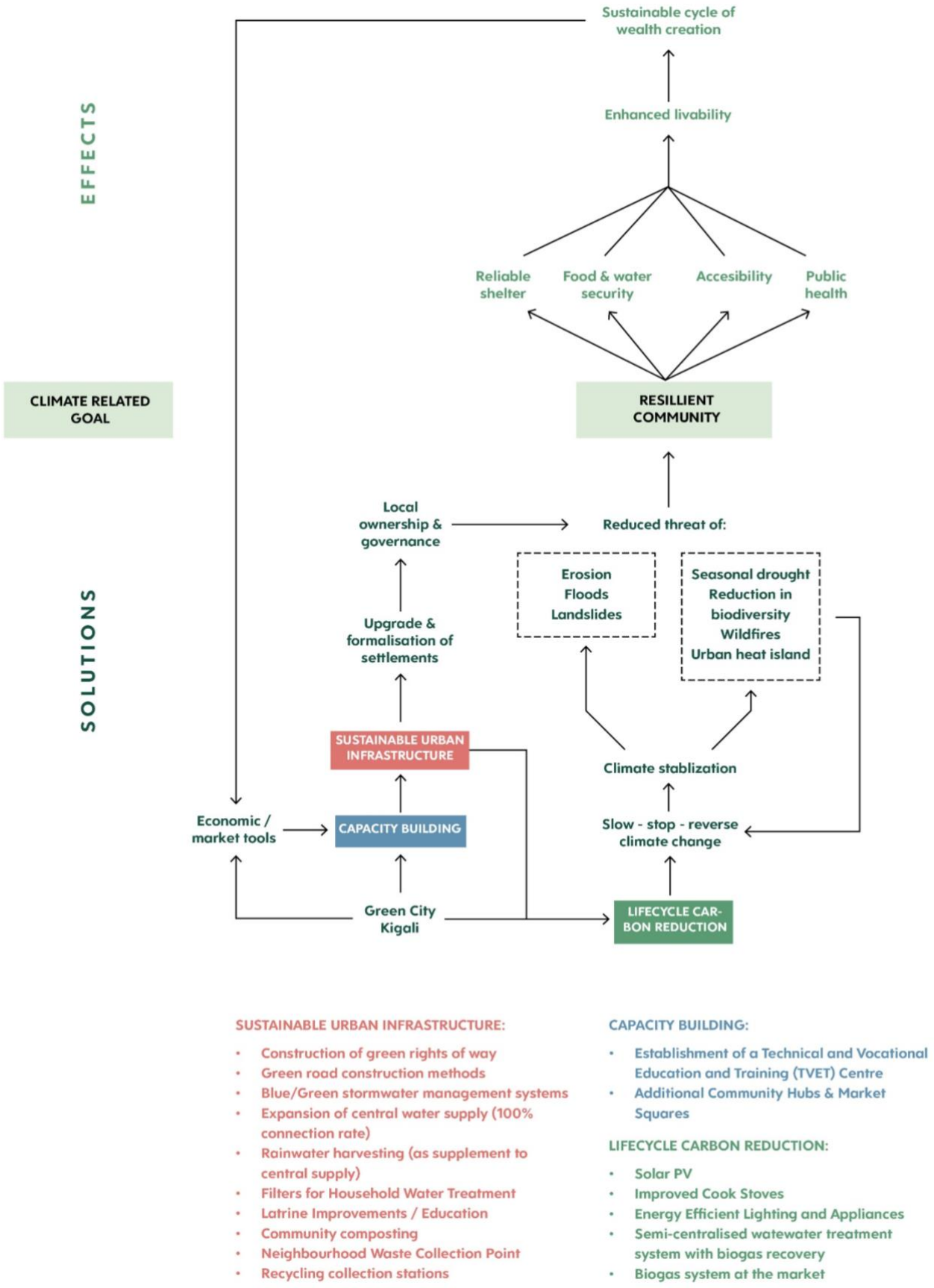


Figure 8-23: Proposed Interventions Mapped Against the Solutions Tree

8.3 Summary of the Land Development Plan

Rwanda's National Informal Urban Settlement Upgrade Strategy (2017) requires that a Land Development Plan (or preliminary design) is prepared for upgrading projects. The LDP was based on the findings in this Feasibility Study, and together the two documents form an important part of the baseline for other annexes in the GCF application. Full details on the LDP can be found in the associated annex.

8.4 Estimated Costs

Estimated costs have been developed based on the Feasibility Study and the Land Development Plan. Please refer to Annex 4: Budget Plan for detailed cost estimations.

9 POTENTIAL IMPACT OF THE PROPOSED PROJECT

9.1 Adaptation Benefits

The table below summarises the adaptation benefits that are expected from the selected intervention, in connection to the expected climate change impacts at Kinyinya Hill. These climate change impacts were identified in Section 2.

Table 9-1: Summary of Adaptation Benefits from Selected Interventions

Aspect	Change by 2050	Impacts for Kinyinya Hill	Adaptation Benefits from Selected Interventions
Temperature	Increase average annual temperature of 1.4 – 2.3 degrees Celsius. Increased duration of heat waves by 7-22 days.	Decreasing water quality, increase vector borne diseases, impact on biodiversity, heat stress and increasing electricity demand due to increased demand to cool buildings.	Rainwater harvesting enables households to store water and be more resilient to poor water quality or water shortages in the central network. Household water treatment filters enable residents to treat water, increasing resilience. Stormwater drainage reduces stagnating water, thus reducing breeding grounds for mosquitos Community composting will help agriculture be more resilient to increased heat waves More efficient lighting and appliances produce less waste heat and keep indoor temperatures cooler, increasing resiliency during heat waves.
Rainfall patterns	Increase in average rainfall (range -3 to +9 percent). Increased heavy rainfall event frequency (7-40 percent) and intensity (2-11 percent).	Flooding, landslides, damage to houses, roads and other infrastructure, water shortages, power cuts, pollution of water resources.	Green road rights of way have high resilience to network disruption (e.g. from flooding, erosion) due to less runoff from less surface area Permeable road construction materials, as well as better stormwater management, will allow more infiltration and less and slower runoff, which will help protect houses, roads, other infrastructure and nearby surface water bodies. Improvements to the central water supply system, supplemented by rainwater harvesting will increase residents' resilience during water shortages. Improved waste management will reduce pollution to the environment during increased rain events. Solar PV would enable local power production in the event of power cuts. Community focal points and market squares would be constructed with resilient design standards.
Droughts	Likely increase in the duration of dry spells with a	Water shortages, habitat degradation, decreased air quality.	Rainwater harvesting would increase resilience to droughts.

	range of 0 to +7 days.		Improved cook stoves would reduce the collection of firewood for cooking and reduce unhealthy emissions, increasing resilience and limiting further habitat degradation and health impacts from decreased air quality.

9.2 Mitigation Benefits and Carbon Methodology

Climate change mitigation benefits have been evaluated and can be found in Annex 22, along with a detailed description of the carbon methodology and expected GHG emissions reductions.

9.3 Theory of Change

A Theory of Change has been developed and included in the GCF Application.

10 INSTITUTIONAL AND IMPLEMENTATION ARRANGEMENTS

The Ministry of Environment – the Accredited Entity (AE) - will lead in the overall management, reporting and supervision of the project with GCF. In Rwanda, FONERWA (the national fund for Environment and Climate Change) is the primary vehicle through which environment and climate change finance is channelled, programmed, disbursed and monitored in Rwanda and therefore FONERWA will execute the project. A Programme Management Unit (PMU) will be established. The PMU will be housed within the Fund Management Team of FONERWA.

Activities will be implemented using the Ministry of Environment existing management and financial systems. FONERWA will coordinate delivery of the programme outputs. The GCF activities will be overseen by a Steering Committee chaired by the Ministry of Environment. The Steering Committee will serve as the project coordination and decision-making body and will ensure it delivers its outputs and achieves its outcomes. The Committee will periodically review progress and evaluations, facilitate implementation (ensuring the necessary resources and support are provided in a timely manner) and provide guidance to the PMU. The Steering Committee will reflect the multi-sectoral nature of the project and will include senior-level representatives from GoR and partner organisations, as well as civil society. The Steering Committee will meet every 6 months to review progress and approve work plans, budgets and any major changes in implementation. The activities and funding will be programmed through the PMU and will be executed through relevant Government partner organisations, in line with relevant mandates. This will include MININFRA, Rwanda Housing Authority (RHA) and REG as well as Ministry of Trade and Industry (MINICOM).

To increase uptake and scale up of the interventions the PMU will ensure that results are communicated through Sector Working Groups (SWGs). The SWGs provide a forum for dialogue that includes development partners who provide support in the sector as determined by the GoR division of labour. These groups build synergies in policy formulation and implementation. The PMU will regularly report results to the SWGs and provide inputs as a measure for continuous improvement of delivery.

The table below gives an initial summary of possible responsibilities during implementation and O&M.

Table 10-1: Summary of responsibilities during implementation and O&M for each activity, along with funding sources.

Project Component	**Responsibilities during implementation (funding as indicated below)**	**Responsibilities during O&M (funding by the responsible actor listed below; no GFC funding)**
Transport / mobility improvements (Construction of green rights of way, green road construction methods)	FONERWA will contract qualified companies for the detailed design and construction of the road works Funding: GCF	City of Kigali will be responsible for road maintenance required. The community will perform some on-going maintenance.
Blue/Green stormwater management systems	FONERWA will contract qualified companies for the detailed design and construction of stormwater management systems (as above). Funding: GCF Community members will be responsible for implementing measures on their land. Funding: Community contribution	City of Kigali will be responsible for maintaining the stormwater management systems. The community will perform some limited on-going maintenance. Households will be responsible for maintaining the measures on their land.

Project Component	Responsibilities during implementation (funding as indicated below)	Responsibilities during O&M (funding by the responsible actor listed below; no GFC funding)
Expansion of central water supply (100% connection rate)	FONERWA will contract qualified companies for the detailed design and construction of the central water supply expansion. Funding: GCF.	WASAC would be responsible for O&M of the system, with funds from the water tariff from users.
Rainwater harvesting (as supplement to central supply)	FONERWA will contract qualified companies for the detailed design and installation of the systems, with communication with local residents. Funding: GCF	System owners will be responsible for maintaining the systems
Filters for Household Water Treatment / Efficient Fixtures	FONERWA will contract an organisation to provide workshops/training on household water treatment options and efficient fixtures. Funding: GCF	Households would be responsible for maintaining any systems if purchased.
Biogas system at the TVET/ market	FONERWA will contract qualified companies to do the design and construction of the biogas system. Funding: GCF and beneficiary contribution.	The community will identify responsible parties for performing operation and maintenance.
On-site sanitation improvements / Improved Greywater management	FONERWA will contract a local organisation to provide workshops/training on on-site sanitation improvements (latrines, septic tanks) and improved greywater management. Funding: GCF	Households would be responsible for maintaining the systems.
Community composting	FONERWA will contract qualified firms to design and construct the facility, as well as an organisation to provide training on community composting and to procure any equipment needed to start the operation. Funding: GCF	The community will identify a team of persons responsible for the community composting.
Waste and Recycling collection stations	FONERWA will contract companies for the design and construction to build waste and recycling collection points. Funding: GCF	The waste collection company will pickup all waste and recyclables on a regular basis. The community will repair the collection point if needed.
Solar PV	Solar PV for the roads would be included in the road design and construction contracts, listed above.	Maintenance of solar PVs on public roads would be done by the City of Kigali

Project Component	Responsibilities during implementation (funding as indicated below)	Responsibilities during O&M (funding by the responsible actor listed below; no GFC funding)
	Solar PV and solar water heaters for the pilot will be supplied and installed by qualified companies. Funding: GCF	Maintenance on other structures would be done by the owner and/or home owners associations (HOAs) representing the owners.
Clean Cooking Technology	FONERWA will contract trainings on the use of improved cook stoves. Users would need to purchase the stoves themselves. Funding: GCF and beneficiary contribution (we note that efforts to shift to LPG would need to be financed by other sources)	Operation and maintenance would be done by the cook stove owner.
Efficient lighting and appliances	FONERWA will contract the work for efficient lighting on community structures. The TVET will offer training regarding efficient lighting and appliances. Funding: GCF	Operation and maintenance would be done by the owner.
Community hubs & market squares	FONERWA will contract qualified companies to design and build the market improvements and other community facilities. Funding: GCF	The City of Kigali will be responsible for maintenance of public spaces. The community will be responsible for some maintenance of public spaces as well.
Establishment of a Technical and Vocational Education and Training (TVET) Centre	FONERWA will contract qualified companies to design and build the TVET Center Funding: GCF	The Rwanda TVET Board will be responsible for the operation and maintenance of the TVET Center.

11 ALIGNMENT WITH GCF ENVIRONMENTAL AND SOCIAL SAFEGUARDS

GCF requires that environmental and social considerations are incorporated into projects in ways that not only include safeguard measures of "do no harm," but also improve environmental and social outcomes and generate co-benefits to the environment and the communities, including indigenous peoples, that depend on it. All GCF funded activities must comply with Rwanda's national laws and/or obligations of relevant international treaties and agreements, whichever is the higher standard.

All projects should be screened according to GCF's "Sustainability guidance note: screening and categorizing GCF-financed activities". Each project is to be assigned a risk category by the AE, which will be independently screened by GCF. It should be noted that MoE is accredited to manage projects up to a Risk Category of B.

The GCF is in the process of creating its own safeguard standards but in the meantime, it has adopted the International Finance Corporation (IFC) Performance Standards as its safeguard standards. The IFC Performance Standards consist of one overarching standard (PS 1) and seven standards covering specific issue areas (PS 2-8). PS 1 covers the elements that need to be in place to help ensure that the remaining seven standards are implemented. PS 2-8 are listed below:

PS2: Labor and working conditions

PS3: Resource efficiency and pollution prevention

PS4: Community health, safety and security

PS5: Land acquisition and involuntary resettlement

PS6: Biodiversity conservation and sustainable management of living natural resources

PS7: Indigenous peoples

PS8: Cultural heritage

Further information can be found by consulting the GCF Environmental and Social Policy as adopted by the GCF board in decision B.19/10.

It is anticipated that, and upon initial assessment, that this project aligns with the GCF's activities according it a Risk Category of B.

"Category B. *Activities with potential limited adverse environmental and/or social risks and impacts that, individually or cumulatively, are few, generally site-specific, largely reversible, and readily addressed through mitigation measures."*

Please refer to Annex 6 for the Environmental and Social Impact Assessment (ESIA) and Resettlement Action Plan (RAP).

Gender-sensitive project design

Projects submitted to the Fund are required to be aligned with national policies and priorities on gender and with the Fund's gender policy. As well as requiring that women and men have equal opportunity to benefit from what the project delivers, GCF requires projects to demonstrate that there has been equitable participation in stakeholder consultations and decision-making during project and programme preparation, implementation and evaluation. This includes support for initiatives that address the inequity of climate change impacts and provide gender-sensitive solutions to climate change mitigation, adaptation or readiness. The Fund's gender policy has four main objectives:

1. To ensure that by adopting a gender-sensitive approach, the Fund will achieve greater, more effective, sustainable, and equitable climate change results, outcomes and impacts, in an efficient and comprehensive manner in both its internal and external procedures and activities;

2. To build equally women and men's resilience to, and ability to address climate change, and to ensure that women and men will equally contribute to, and benefit from activities supported by the Fund;

3. To address and mitigate against assessed potential project risks for women and men associated with adaptation and mitigation activities financed by the Fund; and,

4. To contribute to reducing the gender gap of climate change-exacerbated social, economic and environmental vulnerabilities.

There are three reasons for the GCF's emphasis on gender sensitivity. Firstly, women, as well as men significantly contribute to combating climate change. Shifting the paradigm towards low-emission and climate-resilient development pathways, which is the GCF's mandate, requires a large number of individual and collective decisions by women and men. A gender-sensitive approach is therefore part of a paradigm shift. Secondly, climate change impacts women and men differently, to the detriment of women, and existing gender inequalities are likely to be exacerbated by climate change. Thirdly, gender inequality, exacerbated by climate change, is linked, as are other development areas, to vulnerability and risks. The greater vulnerability of women to climate change stems from gender norms and discrimination that result in the imbalanced division of labor, lower income, and lesser livelihood opportunities; less access and control over land and other productive assets; fewer legal rights; lesser mobility and lesser political and professional representation.

The GCF proposal must include a Gender Assessment and a Gender Action Plan. The Gender Assessment is required to collect baseline data, and to:

1. Determine how the project can respond to the needs of women and men in view of the specific climate change issue to be addressed;

2. Identify the drivers of change and the gender dynamics in order to achieve the project adaptation or mitigation goals;

3. Identify and design the specific gender elements to be included in the project activities;

4. Estimate the implementation budgets;

5. Select output, outcome and impact indicators; and

6. Design project/programme implementation and monitoring institutional arrangements.

Please refer to Annex 8 for the Gender Assessment and Action Plan for detailed information.

12 NEXT STEPS

12.1 Next Steps

This Feasibility Study represented an early step in the GCF project application process and was one component of on-going work on the overall GCK project. Analyses that were developed following the Feasibility Study are listed below. These analyses developed the proposed activities in greater detail and linked in and provided feedback to this Feasibility Study, which has now been incorporated.

- Economic and financial analyses
- Detailed budget plan
- Implementation timetable including key project/programme milestones
- Environmental and Social documentation corresponding to project categorisation
- Summary of consultations and stakeholder engagement plan
- Gender assessment and project/programme-level action plan
- Legal due diligence (regulation, taxation and insurance)
- Procurement plan
- Monitoring and evaluation plan
- Additional GCF application documents, such as NDA no-objection letter(s), AE fee request, co-financing commitment letter, term sheet including a detailed disbursement schedule

Analyses that were developed/documented as part of the GCF application form:

- Detailed project information related to climate context, theory of change, implementation arrangements, exit strategy and sustainability, etc.
- Financing information
- Expected performance against GCF investment criteria
- Logical framework (paradigm shift objectives, performance indicators, targets, etc.
- Risk assessment and management

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13.2 Annex 2: List of persons interviewed

The list below includes the interviews conducted during the development of the Feasibility Study. Additional people were interviewed as part of the overall GCF Application preparation, and this can be found in Annex 7.

Name	**Organisation**	**Position**
John Mugabo	City of Kigali	Solid &Liquid Waste Officer
Felix Uwitonze	City of Kigali	Urban Planning
Abias Mumuhire	City of Kigali	Urban Planning
David Musonera	City of Kigali	Urban Planning
Solange Muhirwa	City of Kigali	Urban Planning
Frank Gisagara	Isuku Kinyinya Waste Management Company	Manager
Jean Claude Munyaneza	Ngaruyinka	Village Leader
Jean Marie-Vianney Habiyambere	Ngaruyinka	Village Leader
Jaqueline Nsabiyaremye	Ngaruyinka	Health Representative
Jean Leonard Rutaganira	Ngaruyinka	Community Information
Alphons Muramutsa	Ngaruyinka	Community Security
Clementine Nzanzamahoro	Ngaruyinka	Women Representative
Jean Claude Munyaneza	Ngaruyinka	Village Leader
Dominique Murekezi	Water and Sanitation Corporation (WASAC)	Manager of Water &Sanitation Infrastructure Planning
Ammos Shyaka Kazora	Water and Sanitation Corporation (WASAC)	Acting Head of Sewer Operations
Vincent de Paul Mugwaneza	Water and Sanitation Corporation (WASAC)	Director of Rural Water & Sanitation Services
Paulin Buregeya	COPED	CEO
Aimable Rwanzunga	COPED	Business Development Expert
Delphine Uwase	Water Access Rwanda	Operations Manager
Patrick Emile Baganizi	Rwanda Transport Development Agency (RTDA)	Deputy General Manager
Fabrice Barisanga	Rwanda Transport Development Agency (RTDA)	Division Manager of Planning, Quality Assurance & Research
Emmanual Ahabwe	MININFRA	Urban and Rural Settlement Senior Engineer
Eric Hakizimana	MININFRA	Physical Planning Senior Engineer