The Provision of Consultancy Services for Study and Design of Storm Water Drainage System and Preparation of Drainage & Sanitation Development Plan(DSDP) for Arusha City for a Period of 2020-2040

UNITED REPUBLIC OF TANZANIA PRESIDENT'S OFFICE REGIONAL ADMINISTRATION AND LOCAL GOVERNMENT

ARUSHA CITY COUNCIL

TANZANIA STRATEGIC CITIES PROJECT (TSCP) SECOND ADDITIONAL FINANCING (AF2) (IDA CREDIT NO. 5947-TZ)

The Provision of Consultancy Services for Study and Design of Storm Water Drainage System and Preparation of Drainage & Sanitation Development Plan (DSDP) for Arusha City for a period of 2020-2040

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FINAL DSDP REPORT

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CHEIL ENGINEERING

AJOMA CONSULT LIMITED

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Abbreviations:

ACC	Arusha City Council
AICC	Arusha International Conference Centre
AfDB	African Development Bank
AF2	Second Additional Financing
AUWSA	Arusha Urban Water Supply and Sanitation Authority
CAPEX	Capital Expenditures
CBD	Council Business District
CC	City Council
CN	Curve Number
CV	Coefficient of Variation
C1, C2, C3	Catchments
DC	District Council
DPO	Development Project Objective
DRR	Disaster Risk Reduction
DSDP	Drainage and Sanitation Development Plan
CSO	Combined Sewer Outflow
DTM	Digital Terrain Model
ESA	European Space Agency
GIS	Geographical Information System
GST	Geological Survey of Tanzania
Ha	Hectare
IDA	International Development Agency
IDF	Intensity Duration Frequency
Km	Kilometer
Km^2	Square Kilometer
LGA	Local Government Authority
MC	Municipal Council
MK Test	Mann-Kendall Test
ML	Machine Learning
MoM	Method of Moment
MoW	Ministry of Water
NAWAPO	National Water Policy
NEMC	National Environmental Management Council
NUWSSP	National Urban Water Supply and Sanition Programme
OPEX	Operation Expenditures
PBWB	Pangani Basin Water Board
PO-RALG	President's Office – Regional Administration and Local Government
RF	Random Forestry
RVWD	Rainfall of Very Wet Days

SD	Standard Deviation
SFD	Shit Flow Diagram
SWM	Solid Waste Management
TANROAD	Tanzania National Road Agency
TARURA	Tanzania Rural and Urban Road Agency
TMA	Tanzania Meteorological Agency
ToR	Terms of Reference
TSCP	Tanzania Strategic City Program
TZS	Tanzanian shilling
WB	World Bank
WSDP	Water Sector Development Program

EXECUTIVE SUMMARY

Background information

The Government of the United Republic of Tanzania has received a credit from the international Development Association (IDA) towards the cost of Tanzania Strategic Cities Project (TSCP) - Second Additional Financing (AF2). It is intended that part of the proceeds of the credit will be used to cover eligible payments under the contract for the provision of consultancy services for study and design of storm water drainage system and preparation of Drainage & Sanitation Development Plan (DSDP) for Arusha City under the TSCP _Second Additional Financing (AF2).

Project Objectives

The main objective of the assignment is to develop an integrated Drainage and Sanitation Development Plan. The second objective is to propose about a 5 years duration with a conceptual Engineering level which would implement the first priorities identified in the Plan

Study Areas

Arusha City is one of the seven Districts of Arusha Region, others are Arumeru, Monduli, Ngorongoro, Longido, Arusha Rural and Karatu which forms the Districts within Arusha Region and it's headquarter the region located in northern Tanzania. This district comprises of 25 wards. It is one of the fastest growing cities in Tanzania. It is the head quarter of the East African Community and hurb of Northern Tourist zone of Tanzania

Population

The City has the highest population density in the Arusha region. Arusha City has a population of 416,442, as compared to the population of 1,694,310 in Arusha region, with more than 75 percent of the city's population residing in planned areas. The current population density of Arusha City is about 2,002 p/km^2, which is eight times the regional density (According to a 2012 Census)

Population coverage areas

Project	Area

ARUSHA MASTERPLAN(2015-2035)	-The entire Arusha City Council, parts of Arusha District Council and Meru District Council
NORPLAN(March, 2015)	-Arusha City including Moivo, Sokon II, Kiranyi
AUWSA(2017)*	-Arusha City including Moivo, Sokoni II, Kiranyi, Bangata, Mateves, Olmotonyi, Kimnyaki

Note: ARUSHA SUSTAINABLE URBAN WATER AND SANITATION DELIVERY PROJECT (July, 2107, AUWSA)

Scope of the project

The task of consultancy services has been classified into 6 large categories: Baseline Assessment; Methodology and Outline of Draft DSDP; Validation Workshop and Consultation; Draft DSDP; Consultative Period; and Final DSDP.

Study of Existing Drainage and Sanitation

River Basin

The Pangani Basin is a Tran's boundary basin shared by Tanzania and Kenya. It covers 56,300 square kilometers and 5% of this area is in Kenya. In the Tanzanian part, there are 18 districts falling within the administrative regions of Manyara, Arusha, Kilimanjaro and Tanga. Several streams that contribute to Pangani Basin cut across Arusha City. Some of the rivers include; Burka, Ngarenaro, Naura, Themi, Kijenge and Goliondoli which all converge to join the Themi River in the southern part of the Arusha District. These rivers have two extreme flow fluctuations over the period of a year.

Water supply infrastructures

In ACC 94.6% of residents had access to an improved water sources in 2012 (Tanzanian Bureau of Statistics, 2016). This is in line with other urban areas in the region and significantly higher than the average for rural areas, 68.3%.

Sanitary infrastructures.

The distribution of sanitation provision services in Arusha City Council is generally higher than urban areas nationally and regionally, more than 87.6%. Connection to sewers in ACC, in common like any other urban areas in Tanzanian is low, account only for 7.6%. The National Sanitation Campaigns report of 2017, depicts that approximately 5% Arusha city had no access to toilets or have the toilets in their premises traditional pit latrines (or toilets that discharge directly into the environment) or practicing open defecation which we describe as a low sanitation status and its within Sombetini, Ngarenaro, Olmoti and Ungalimited wards. And the areas with high sanitation status which are close to sewer for almost 7.6% found within Engutoto, Lemara, Ungalimited and Kati wards

The exiting waste water stabilization pond is found at Themi ward and the new one which is und erconstuction is at Terrat ward. These are the areas were the sorroundings wards are highly near t o the sewer (1) and hence reduce the disposal of waste water to the sorroundings but the wards w hich are found far from the waste treatment pond are highly affected by poor dispoal of waste wa ter and hence environmental pollution . For the existing and undercostruction sewerage sytem it will cover almost 30% percent of the whole city by 2030 to be connected by sewer networks. M ost of the part at Olasiti and Terrat wards will not be connected to sewer network, due to factthe y are far from the ongoing construction infrastructures.

Sanitation issues, gaps and challenges needing upgrading

On-site sanitation is still the most common forms of sanitation system used by most of the reside nt live in Arusha City Council. In Tanzania, only about 10 percent of the urban inhabitants are co nnected to sewer networks with the majority relying on diverse types of on-site sanitation system s. The challenge with on-sanitation system is that the generated faecal sludge needs to be emptie d and safely transported to treatment plants.

Encouragement to connect to the sewer network.

Many wards in Arusha city have traditional pit latrines 3,164, improved pit latrines 15,488, ventilated improved pit latrines 16,278 and few has pour flush with septic tanks 20,343. Unfortunately out of 20,343 only 4,703 have sewage connections including domestic, commercial, institutional and industrial customers. As consultants we are highly advising the authority responsible to increase the number of connections through educating people to improve the existing systems from improved pit latrine and ventilated improved pit latrines to pour flush system. Efforts are also to be made to traditional pit latrines by moving up to improved pit latrine.

Excreta Flow Analysis

In Arusha City Council, it was estimated that 99% of excreta is managed safely, of which faecal sludge being contained and not emptied in areas with low risk of groundwater pollution. The Shit Flow Diagram (SFD) was created through field-based research and interview from the indigenous community within the vicinity of the ARUSHA City council's wards .However, the SFD reflects the current status of excreta, 68% is safely managed which does not translate to future recommendations. The wastewater and faecal sludge that is delivered to treatment sites is treated in waste stabilization ponds. It is estimated that 90% of the wastewater and faecal sludge delivered to treatment is effectively treated

Sanitary cost implications

The charges to customers for emptying on-site facilities vary depending on the household location. Private sector operators interviewed and stated they charge approximately TZS 70,000 - 80,000 per trip for empting household latrines or septic tanks within the city and up to TZS 150,000 per trip outside the city. The charges for emptying the onsite facility from the authority (AUWSA) is TZS 73,000 per trip for the cesspit emptier truck with the capacity of 5000m^3 and 89,000 per trip for the cesspit emptier truck with the capacity of 10,0000 m^3.

Sanitation challenges in Arusha CC

There are deficiencies throughout the sanitation service chain in Arusha. These deficiencies are having a direct impact on residents' lives. Interviewed ward environmental and health officers explained that diseases linked to poor sanitation practices in Arusha city include diarrhea, typhoid, dysentery, worm infections and cholera outbreaks. **The last cholera outbreak, in which 856 cases were recorded, was from October 2015 to April 2016**.

Drainage systems for storm water

Drainage systems, particularly in the Arusha City Council, include but not limited to pipelines, o pen channels, natural surface channels and canals. The major drainage systems are almost certain ly include open channels and natural watercourses within urbanized (or urbanizing) catchment/ar eas

Existing drainage system

Based on the existing topography, Arusha City is divided into 3 main drainage catchment areas. The storm water runoff originates from Mount Meru, flowing mostly southward through Arusha City. Catchments C1 up to C3 drain to Themi River which joins the Pangani River about 20 km from the Arusha City boundary .The frequency of flooding has increased in recent years. This is attributed to:

i) Increased runoff caused by climate-related and land use changes in the catchments;
ii) Reduction of the buffer capacity of wetlands due to encroachment;

iii) Frequent disposal of solid was in open storm water channels leading to blockage;

iv) Inadequately design and constructed road side drainage channels and culverts among oth ers.

Flood prone areas

The information gathered from the field visit in Arusha City Council's wards shown the Storm w ater and grey water drainage are a further another challenge that contribute mostly to environmen tal degradation. Currently most of the surveyed area have unimproved drainage systems that coll ect the storm water during the rain seasons to the nearby water bodies or low laying area.

Storm Water Management Measures

Flood control and storm water drainage

Flooding is controlled by a combination of structural and non-structural measures enabling the riverside population to minimize its losses and continue to live in harmony with the river/water bodies.

Storm water Drainage Design Strategy

Only 20% of the residents live in Arusha City are following the City Planning drawing and got the building permit during the establishment of their residential/business buildings. Most of these areas are located at the following wards; Sekei, Kati, Themi, Levolosi, Kaloleni, Engutoto and some parts of Ngarenaro, Olasiti and Unga Limited .These areas are at the risk of flash flooding. Therefore, this particular configuration requires a special attention on the choice of the structural solutions in the flood-prone areas

Moreover, as paving and drainage system are improved as part of urban upgrading, runoff inevitably increases, which may exacerbate downstream drainage problems and lead to increased flooding.

Hydrological Design Criteria

Flood Return Period. The return period of flooding is the most important parameter used for design of urban drainage systems for flood protection. It determines both the hydraulic grade line for operation and the size of drains, and subsequently the costs of infrastructure.

Drainage System Typology. Storm water drains may be 'open' or 'closed' and closed systems may consist of pipes or drains with/out cover slabs

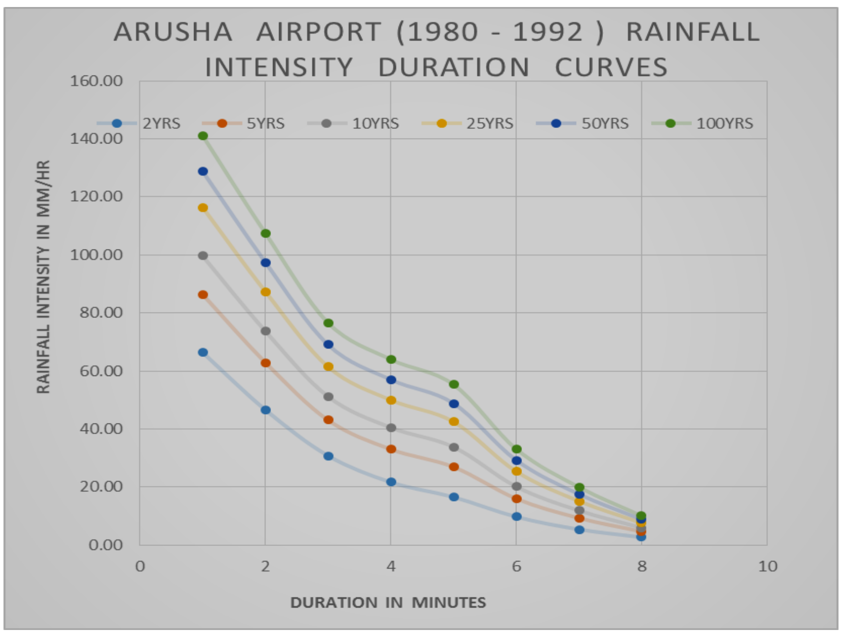
Roads and paving. Traditionally, the tendency has been to pave/rebuild roads by building on top of the previous road surface. This tends to create a situation in which road surfaces are above house plinth levels, so that any flooding affects houses rather than public rights of way.

Rainfall data

The collection of rainfall data involved extensive consultations with Pangani Basin Water Board, Tanzania Meteorological Agency (TMA) and other sources like researchers from academic and research institutions. For the daily rainfall data, statistic measures such as min, max, standard dev iation (SD), Coefficient of variation (CV), Skewness, Kurtosis and the total rainfall for very wet days (RVWD) were calculated.

New IDF Curve for Arusha City

Daily maximum rainfall data for the eight (8) were used to estimate maximum rainfall intensity for different return periods based on Gumbel distribution which is one of the most widely used probability-distribution functions of extreme values in hydrological and meteorological studies for prediction of flood peaks, maximum rainfalls, maximum wind speed, etc.



IDF Curve

Climate Change in Arusha

One of the major impediments to the analysis of climatic trends is the availability of long-term quality climate data. Reliable analysis of climatic trends requires high-quality data for at least 30 years, due to this fact only Arusha Airport rainfall station was selected in trend analysis which have 56 years of precipitation time series data unlike other stations that have less than 30 years' time series precipitation data and Monduli Station which is located outside the boundary despite having 60 years of precipitation data.

Catchment Delineation

The catchments inside the planning area have been delineated through a geo-processing tool. With the GIS software and by means of a 2 meters grid digital elevation model a total of three (3) catchments draining the ARUSHA CITY have been delineated. Catchments C1 up to C3 drain to Themi River which joins the Pangani River about 20 km from the ARUSHA CITY boundary.

Hydraulic Analysis

Design Return Period

Hydrologic Modeling System (HEC-HMS) was used to obtain synthetic hydrographs. HECHMS is designed to simulate the complete hydrologic processes of dendritic watershed systems.

Multi Criteria Analysis for Drainage Interventions

To assess their effectiveness for rainwater runoff reduction and consequently the reduction of combined sewer overflow (CSO) the software GIS water was employed for development of the urban catchment model. This software couples spatial data from GIS with EPA Storm water management model (SWMM). In accordance with the conditions in the urban catchment, five scenarios were developed consisting of following SuDS measures: infiltration basins, infiltration trenches, green roofs and their combinations. These scenarios were evaluated with multi-criteria analysis based on CSO reduction, CAPEX, OPEX, amenity, biodiversity, and feasibility regarding ownership.

Basing on multi criteria analysis, the hydrological studies, site visits and interviews conducted, several locations have been pointed out to be the most affected areas during the storm. These location were chosen for priority project, Kaloleni, Levolosi, Elerai, Ngarenaro, Sombetini, Ungalimited, Sokoni I, Kimandolu, Olorieni Themi, Osunyai, Muriet, Olmoti, Daraja II, Engutoto Sakina

Non-structural

Non-structural storm water quality best management practices (non-structural BMPs) are institutional and pollution-prevention practices designed to prevent or minimize pollutants from entering storm water runoff and/or reduce the volume of storm water requiring management

Early Warning Systems

The Disaster Management Act (2015) sets out a comprehensive legal framework for disaster risk management. It provides for the establishment of Tanzania Disaster Management Agency (TDMA), which is the national focal point for coordination of disaster risk reduction and management in the country. *The Agency shall act as the central planning, coordinating and monitoring institution for the prevention, mitigation, preparedness, response and post disaster recovery, taking into account all potential disaster risks*.

Sustainable Urban Drainage Systems

Green infrastructure (GI)-based approaches to urban drainage such as sustainable urban drainage systems (SUDS) could provide Sub-Saharan cities with an opportunity to address projected climate change impacts and existing deficits in their drainage infrastructure, even more so due to the synergies between an enhanced green infrastructure stock and sustainable urban development

Emergency response

Installation and maintenance of flood barriers, channeling flood waters away from certain high-value areas, search and rescue, evacuation of people stranded by flood waters, removal of people and their property from areas potentially threatened by floods are all possible response actions. In addition, accelerated maintenance, strengthening, and expedient repair of drainage infrastructure elements can also be considered as emergency response.

Land use management policies and practices

Land-use management policies and processes are a natural companion for urban flood management, and both contribute significantly to Integrated Flood Management and Integrated Water Resources Management

The vulnerability-based approach

This approach focuses on reducing the vulnerabilities of the affected population and considers economic activities and degree of development of the area, frequency and intensity of floods, land and land use, anticipated impacts of development activities and demand for resources throughout the community

Enforcement of the existing laws, regulations

It should come as no surprise that most of the physical, social and economic problems associated with City flooding, stem from inappropriate occupation of the floodplain, poorly-planned land use within the city, insufficient attention to drainage and storm water control facilities and haphazard enforcement of existing regulations

Institutional Storm Water Management

The following listed factors are directly linked to poor storm water management in most of African Urban

- Lack of knowledge
- Lack of coordination between sector stakeholders.
- Missed storm water management decentralization
- Poor alignment of planning to local capacities.
- Failure to take the populations' expectations into account.
- Limited local capacities for financing investment.
- Limited capacities for financing operation.
- Failure to comply with best construction practice.
- Review of Institutional Measures for Drainage System Management

Proposed Structural Measures for Sanitation

Construction of waste water treatment plants

The new ponds which are under construction are expected to serve almost all wards except Olasiti and Olmoti. The work is expected to be complete in the year 2020 as per our site visit asset Also apart from the construction of new WWTP the ongoing construction of sewer network will increase the coverage from 7.6% to 30% by the year 2030. These networks will involve the construction of Trunk mains that run through Sombetini, Mbauda, Muriet to WWTP. Additionally there will be a Trunk main that will run through Njiro to WWTP.

Proposed new waste water treatment plants

Based on the fact that the ongoing construction of the new sewerage systems will cater only for

30% of Arusha City residence, this DSDP proposes the additional waste water treatment plants that will accommodate the remaining 70% to ensure 100% coverage of the Arusha City inhabitants. The proposed systems will be design to collect all waste water generated within the city and convey it to sewage treatment works for treatment prior to the discharge into receiving watercourse.

The proposed waste water treatment plants will be designed to services the Arusha City areas based on the average per capital waste water flow rates that has been estimated projected from the percentage of the net water supply (m^3/d).

The new plan takes into account the terrain of Arusha city and plans a new sewage treatment facility that shares the areas of SITE 1(Engutoto, Olorieni_A, Themi, Sekei, Kaloleni, Kati), SITE 2(Olasiti) and SITE 3(Daraja II, Levolosi, Ngarenaro, Unga Ltd, Sombetini, Elerai, Lemara, Sokon I, Terrat) as a result of the review of ARUSHA MASTER PLAN 2015-2035. In addition, a Waste Water Treatment Plant was proposed for area (SITE 4, SITE 5, SITE 6, and SITE 7) not established in the previous plan. The table below shows the generation of sewage in each site in 2040.

The design of conventional gravity sewers is based on the following design criteria:

(a) *Long-term serviceability*: the design of long-lived sewer infrastructure should consider serviceability factors, such as ease of installation, design period, useful life of the conduit, resistance to infiltration and corrosion and maintenance requirements. The design period should be based on the ultimate tributary population and usually ranges from 25 to 50 years.

(b) *Design flow*: sanitary sewers are designed to carry peak residential, commercial, institutional, and industrial flows, as well as infiltration and inflow. Gravity sewers are designed to flow half full at the design peak flow.

(c) *Minimum pipe diameter*: a minimum pipe size is dictated in gravity sewer design to reduce the possibility of clogging. The minimum pipe diameter recommended by the Tanzania Standards is 200 mm.

(d) *Velocity*: the velocity of wastewater is an important parameter in a sewer design. A minimum velocity must be maintained to reduce solids deposition in the sewer, and most states specify a minimum velocity that must be maintained under low flow conditions. The typical design velocity for low flow conditions is 0.3 m/s. During peak dry weather conditions the sewer lines must attain a velocity greater than 0.6 m/s to ensure that the lines will be self-cleaning (i.e., they will be flushed out once or twice a day by a higher velocity). Velocities higher than 3.0 m/s should be avoided because they may cause erosion and damage to sewers and manholes.

(e) *Slope*: sewer pipes must be adequately sloped to reduce solids deposition and production of hydrogen sulfide and methane.

(f) *Depth of bury*: depth of bury affects many aspects of sewer design. Slope requirements may drive the pipe deep into the ground, increasing the amount of excavation required to install the pipe. Sewer depth averages 1 to 2 m below ground surface. The proper depth of bury depends on the water table, the lowest point to be served (such as a ground floor or basement), the topography of the ground in the service area and the depth of the frost line below grade

New faecal sludge treatment plants

As most part of unplanned settlements in Arusha City Council, prefer the use of onsite sanitation system as their mean of excreta storage; the issue of faecal sludge treatment should be set as the short term goal within this DSDP. In this regards, ACC in collaboration with one of the developing partner i.e. SNV have agreed to improve the health and quality of life of people in Arusha City through access to adequate, safe, equitable and sustainable sanitation. The agreed strategy entails the improvement of the quality and quantity of sanitation services provision to the community of Arusha City

Based on the above mentioned discussion and agreement between the parties SNV in association with INOSOLT Consulting – from Thailand have come up with the proposal and design of environmental friendly faecal sludge treatment plant that will be installed at Kimandolu and Lemara sites

Capital Expenditure (Capex), Operation Expenditure (Opex) and Sustainability

CAPEX Needs

Capital Expenditure (CAPEX) needs is the capital to be invested in constructing or purchasing of fixed assets of the masterplan. It includes essential ancillary equipment, vehicles or even office buildings that will support the operation of drainage and sanitation systems. It does not only cover hardware but includes the costs of one-off work with stakeholders prior to construction or implementation, extension, enhancement and augmentation (including costs of one-off capacity building). The CAPEX for the master plan is estimated at **TZS 477,316,786,361.66**

OPEX Needs and Sustainability

Considering the sustainability issues of the master plan, analysis of financial statements of AUWASA for the past eight years shows that the total revenues of the authority are **67,199,000,000**and total operation expenditures are **56,890,300,000**. This implies that the financial performance of AUWASA can sustainably run the operations of the master plan. The new expanded sanitation facilities in the master plan are also expected to expand revenues as a result of expanded services and customer base.

Cost Recovery Strategy

Tariffs /User Fees

Revenues received from water supply and provision of sewerage services in the course of the Authorities' activities will be collected and used in cost recovery. These revenues are water user fees from customers from Domestic, Commercial Institutions, Religious and Kiosks; and revenues from sewerage disposal services. Expansion of water supply and sewerage services customer base with the application of modern technologies to reduce costs of operations and collection of user fees will greatly enhance cost recovery

Institutional and Financial Arrangements

The three major players associated with the financing and operation of the master plan are the Local Government Authority partly for construction of infrastructure concerning waste management, AUWASA with mandate on sewerage and the Private Sector which offers financing and management opportunities. In the implementation of the master plan, an appropriate MoU to finance and operate the master plan can be set up between AUWASA, Local Government and Private Sector. The MoU should describe in detail responsibilities of parties in question for the financing and implementation of the master plan

SECTION 1: INTRODUCTION

1.1 Background information

The Government of the United Republic of Tanzania has received a credit from the international Development Association (IDA) towards the cost of Tanzania Strategic Cities Project (TSCP) - Second Additional Financing (AF2). It is intended that part of the proceeds of the credit will be used to cover eligible payments under the contract for the provision of consultancy services for study and design of storm water drainage system and preparation of Drainage & Sanitation Development Plan (DSDP) for Arusha City under the TSCP _Second Additional Financing (AF2).The development project objective (DPO) is to improve the quality of and access to basic urban services in participating Local Government Authorities (LGAs). This would be achieved through the rehabilitation and expansion of urban infrastructure and institutional strengthening activities aimed at improving the fiscal and management capacities of participating LGAs. The project targets eight selected urban LGAs of Tanga CC, Arusha CC, Mwanza CC, Ilemela MC, Kigoma Ujiji MC, Arusha CC, Mbeya CC, and Mtwara Mikindani MC. The development project objective (DPO) is to improve the quality of and access the quality to basic urban services in participating Local Government Authorities (LGAs). This would be achieved through the rehabilitation and expansion of urban infrastructure and institutional strengthening activities aimed at improving the fiscal and management capacities LGAs.

1.2 Justification for the Assignment

Whereas the DSDP' Component 1b consultancy carried out much useful work in investigating urgent drainage requirements in Arusha City. Also given that much storm water collected by the existing natural and constructed drainage networks is "combined" and that there are on-going initiatives to address wastewater collection and treatment PO-RALG now wishes that the Drainage Development Plan should also be expanded to a Drainage and Sanitation Development Plan.

In addition, AUWSA with donor support from the African Development Bank is also embarking on the design of a wastewater collection and treatment project at Terrat as well as off-grid sanitation, and this and other related initiatives including Korean support for sanitation infrastructure (e.g. wastewater treatment plants), need to be considered when developing an overall Drainage and Sanitation Development Plan.

Thus, Government of Tanzania through PO-RALG now wishes to have such an overall Plan prepared which will look forward for the next 20 years (2020-2040). This Drainage Development (Master) Plan will be funded through Component of the DSDP and building on the high priority, low risk physical investments to be carried out to the primary and secondary networks in the DSDP, **the Drainage and Sanitation Development Plan will prioritize further primary, secondary and tertiary drainage and sewerage and sewage treatment investments, develop operations and maintenance schemes and budgets and carry out related work for metropolitan urban resilience and capital works planning**

1.3 Outline of the project

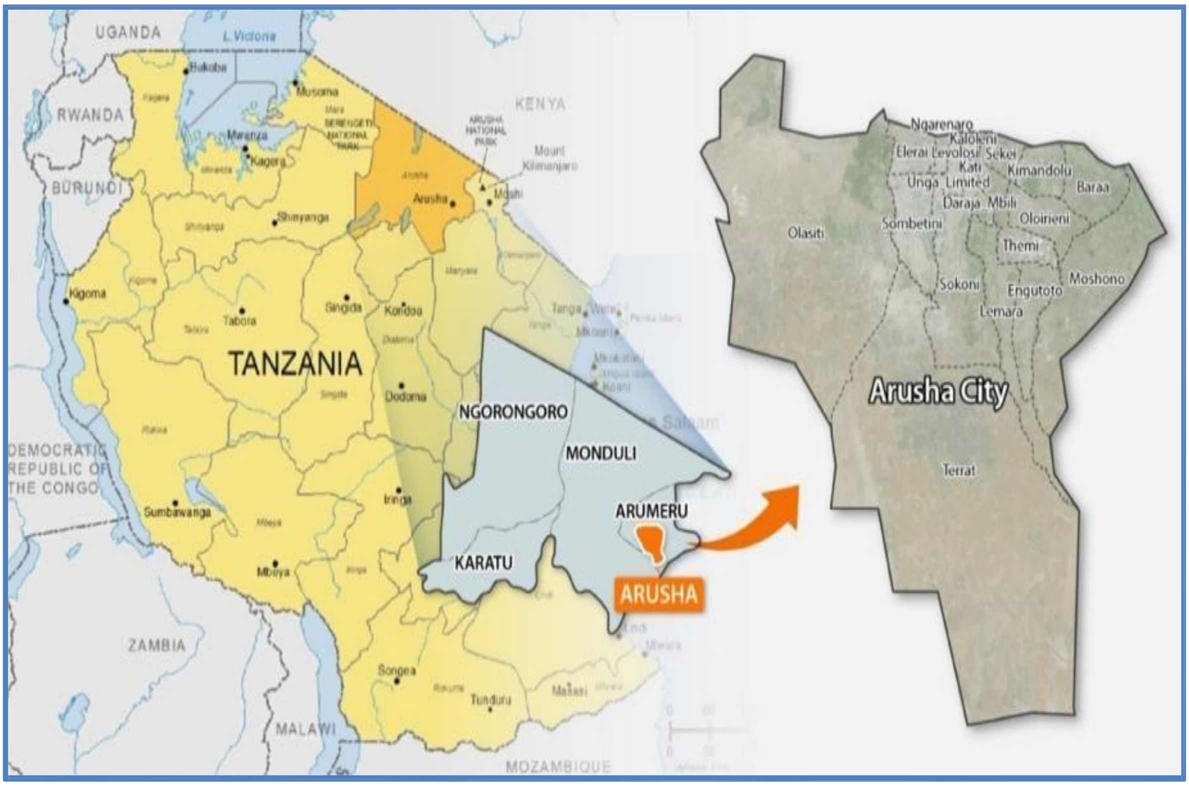
1.3.1 Project Objectives

The main objective of the assignment is to develop an integrated Drainage and Sanitation Development Plan. The second objective is to propose about a 5 years duration with a conceptual Engineering level which would implement the first priorities identified in the Plan.

The Drainage and Sanitation Development Plan (DSDP) cover storm-water drainage, wastewater collection, and treatment and faecal sludge management, from 2020 to 2040. It should define institutional, structural and non-structural measures needed to develop, operate and maintain drainage and sanitation systems within the Arusha City area.

1.3.2 Study Areas

Arusha City is one of the seven Districts of Arusha Region, others are Arumeru, Monduli, Ngorongoro, Longido, Arusha Rural and Karatu which forms the Districts within Arusha Region and it's headquarter the region located in northern Tanzania. This district comprises of 25 wards. It is one of the fastest growing cities in Tanzania. It is the head quarter of the East African Community and hurb of Northern Tourist zone of Tanzania. Due to strategic location, Arusha has continued to attract both migrant and tourist population from East Africa and around the Globe. It's located between latitude 20 and 60 south and longitude 34.50 and 380 east, surrounded by Arumeru District in all directions. It experiences two rainy season in which shirt rains between October and January, while long rains are between March and May. The cities is composed of rivers and numerous small streams which have their head water on the slope of mount Meru, such rivers include Burka, Engarenaro, Naura, Themi and Kijenge all of which coverage to join Themi river to the southern part of the city.



<Figure 1> Project Area

The boundary for the Arusha City stretches from Kisongo and Ngaramtoni in the west up to Tuvaila (Maji ya Chai ward) in the east. Towards the southern boundary it extends until Terrat. Due to the presence of steep topography, rivers and the active volcano in Mt. Meru, developments are restricted to about 2-3 km beyond the east west corridor (Moshi-Nairobi road).

<Table 1> Ward within Arusha City

No	Ward Name	Area (Ha)
W-1	Daraja II	136
W-2	Kaloleni	110
W-3	Levolosi	104
W-4	Ngarenaro	123
W-5	Sekei	297

No	Ward Name	Area (Ha)
W-5	Sekei	297
W-6	Unga Ltd	112
W-7	Sombetini	717
W-8	Themi	525
W-9	Kati	68
W-10	Oloirieni_A	530
W-11	Elerai	496
W-12	Lemara	936
W-13	Engutoto	617
W-14	Baraa	487
W-15	Kimandolu	529
W-16	Olasiti	7,135
W-17	Moshono	2,067
W-18	Sokon I	1,483
W-19	Terrat	10,453
W-20	Murriet	253
W-21	Mwaivaro	518
W-22	Sakina	319
W-23	Osunyai	39
W-24	Sinoni	57
W-25	Olmoti	45
Total Area(Ha)		**28,156**

Note:

New other six wards (Murriet,Mwaivaro, Sakina, Osunyai, Sinoni, and Olmoti) has been divided from the existing other wards and hence make total of 25 wards).

- **Population**

Arusha was officially declared a city on 1 July 2006 by the Tanzanian government. In 2007, the Government divided Arumeru Council into two district councils of Meru and Arusha. Arusha City as the capital of Arusha Region is higher above the sea level than other regions, the weather is better, the main coffee plant and the tourist complex is famous. It is also a gateway for tourists to climb Mount Kilimanjaro through the Ngorongoro crater and Serengeti National Park.

Therefore, this rapid population rise is a resultant of the tourism business in the recent years. Also, The City has the highest population density in the Arusha region. Arusha City has a population of 416,442, as compared to the population of 1,694,310 in Arusha region, with more than 75 percent of the city's population residing in planned areas. The current population density of Arusha City is about 2,002 p/km^2, which is eight times the regional density (According to a 2012 Census)

- **Population Projection**

Arusha City's National population census report of 2012 is the latest. According to 2012 Population census the regional annual growth rate for Arusha region is 2.7% and Master plan, NORPLAN, AUWSA has been used it. The ARUSHA MASTER PLAN 2015-2035 is a big difference from the area of the DSDP. The population prediction used is the population prediction formula applied by NORPLAN and AUWSA, which is a related to the area of the DSDP

<Table 2> Population coverage areas

Project Name	Area
ARUSHA MASTERPLAN (2015-2035)	The entire Arusha City Council, parts of Arusha District Council and Meru District Council
NORPLAN(March, 2015)	Arusha City including Moivo, Sokon II, Kiranyi
AUWSA(2017)*	Arusha City including Moivo, Sokoni II, Kiranyi, Bangata, Mateves, Olmotonyi, Kimnyaki

*Note : Arusha Sustainable Urban Water and Sanitation Delivery Project (July, 2107, AUWSA)

Where,

$$P_t=P_o(1+r)$$

r: Rate of growth (%)

t: Number of years over which growth is to be measured

P_t: Projected population after t years

P_o: Present population

At 2012, the population in Arusha city was 416,442. Assuming the same growth rate in 2040, the population will have grown to 728,675 people, see the table 3 below.

<Table 3> Population projection of Arusha City by 2040

WARD	Po	r (%)	2030		2040	
			t	Pt=Po(1+r)t	t	Pt=Po(1+r)t
Daraja II	19,491	0.027	11	26,128	21	34,105
Kaloleni	9,591	0.027	11	12,857	21	16,782
Levolosi	8,838	0.027	11	11,848	21	15,464
Ngarenaro	12,382	0.027	11	16,598	21	21,666
Sekei	9,213	0.027	11	12,350	21	16,121
Unga Ltd	17,342	0.027	11	23,247	21	30,344
Sombetini	48,268	0.027	11	64,704	21	84,458
Themi	9,458	0.027	11	12,679	21	16,549
Kati	3,114	0.027	11	4,174	21	5,449
Oloirieni_A	18,679	0.027	11	25,040	21	32,684
Elerai	40,749	0.027	11	54,625	21	71,301
Lemara	19,564	0.027	11	26,226	21	34,232
Engutoto	7,426	0.027	11	9,955	21	12,994
Baraa	12,498	0.027	11	16,754	21	21,869
Kimandolu	27,649	0.027	11	37,064	21	48,379
Olasiti	36,361	0.027	11	48,743	21	63,623
Moshono	20,698	0.027	11	27,746	21	36,217
Sokon I	73,331	0.027	11	98,302	21	128,312
Terrat	21,790	0.027	11	29,210	21	38,127

Total	**416,442**	**-**	**-**	**558,251**	**-**	**728,675**

➢ Climate and Climate Change

Arusha City have relatively low temperatures with comfortable humidity levels due to its elevation (1,400 metres) inspite of its close distance from the equator. Cool dry air is prevalent for much of the year. The temperature ranges between 13ºC and 30ºC with an average temperature of about 25ºC. It has distinct wet and dry seasons, and experiences an eastern prevailing wind from the Indian Ocean located a couple of hundred miles to the east.

The area experiences two rainy seasons in a year; short rains between October and January, and longer rains between March and May. The total rainfall between the two seasons ranges between 500 to 1200mm per annum with a mean average of 844mm. The weather is characterized by warm and cold temperatures ranging from 17ºC to 34ºC. The coldest season is between mid- April and mid-August, while the rest of the years are fairly warm.

Severe droughts, melting of glacier over Mt. Kilimanjaro, submerging of islands in Pangani and Rufiji and intrusion of sea water into fresh water wells in Bagamoyo are some of the visible effects of climate change in the country. The major impacts of climate change include severe floods, frequent and prolonged droughts, crop failure, loss of livestock, lower water availability and quality and an increase in vector and water-borne diseases.

➢ Road network

The trunk roads within the Arusha City include: KIA JCT – USA East – USA West – Philips – Arusha - Ngarenaro. These roads run from East to West serving as the main corridor. The Regional roads which traverse the Arusha region include: Kijenge Road, Tengeru Road, Ngarenanyuki Road and Losinyai Road.

The central urban road network in Arusha is primarily a grid pattern with predominantly cross junctions and roundabout. The road network in Arusha is connected to adjacent regions of Tanzania and to neighboring countries by four key roads:

- Arusha – Moshi Road
- Arusha – Namanga Road
- Arusha – Babati – Singida/Arusha Road
- Arusha – Babati – Kondoa - Dodoma/Arusha Road
- Arusha – Ngorongoro – Musoma Road

These roads link the capital cities of three East African Community member states, namely Tanzania (Dar es Salaam), Kenya (Nairobi) and Uganda (Kampala) through Arusha City.

1.4 Project Scope and Deliverable

1.4.1 Scope of the project

The task of consultancy services has been classified into 6 large categories: Baseline Assessment; Methodology and Outline of Draft DSDP; Validation Workshop and Consultation; Draft DSDP; Consultative Period; and Final DSDP. The consultants will be dedicated to the tasks and related activities for the consultancy services as shown in the table 4.

<Table 4> Scope of Consultancy Services

Tasks	Activities
Baseline Assessment	• Data Collection and Review • City Scale Flood Model • Institutional mapping of storm-water drainage, urban sanitation and resilience, as well as flood management. • Survey and Mapping • Urban Development • Wastewater and Fecal Sludge • Storm Water Drainage and Flood Control Planning and Design • Green Growth, Climate Change, Urban Resilience and Sustainability
Methodology and Outline of Draft DSDP	• Proposing a methodology to develop the DSDP • Proposing an outline of the resultant DSDP structure
Validation Workshop and Consultation	•Validation of the methodology and outline of the DSDP • Focus Group Discussion • Incorporation of the feedback into the draft DSDP
Draft Drainage and Sanitation Development Plan	• Description of targets and milestones • Full description of selected measures • Financial analysis of CAPEX & OPEX and sustainability consideration • Prioritization and phasing of the projects that require investment • Strengthen the Monitoring and Evaluation systems • Preparation of pre-F/S, conceptual designs and TOR for the priority projects

Tasks	Activities
Consultative Period	• Making the draft DSDP available to the public via the internet • Workshop and focus group meetings to seek additional feedback
Final Drainage and Sanitation Development Plan	• Preparation of final DSDP based on comments from stakeholders • Sharing the final DSDP to the stakeholders for the future use

1.4.2 Deliverables

Pursuant to ToR and Consultants' Proposal, The consultants are supposed to provide the deliverables to the Client and reports as shown in the below table.

<Table 5> Deliverables

Report		Description of Report	Time
Consultancy Service	Inception Report	• Setting out the parameters of the consulting services, Consultant's site organization and schedule. • Project overview, approach and methodology for the Services. • Organization, work plan and project schedule.	Within 4 weeks after the commencement date
	Monthly Progress Report	• All activities and progress of each month. • Problems together with actions or recommendations on remedial measures for correction. • The work plan during the coming month.	

Report		Description of Report	Time
Baseline Assessment and Methodology and Outline of the DSDP	Baseline Assessment and Outline Report	• Introduction and background for Baseline Assessment methodology. • Assessment results about the state of affairs, key baseline indicators, stakeholders mapping and analysis. • Feedback regarding the Technical Assistance	Within 2 months after the commencement date

SECTION 2: ASSESSMENT OF EXISTING SITUATION

2.1 Summary of Baseline Conditions

2.1.1 Climatic Condition

Arusha City is located in the north eastern of Tanzania and is the capital of the Arusha Region, with the population of 416,442 (census 2012). This cities is located below Mount Meru on the Eastern edge of the Eastern branch of the Great Rift Valley. The climate of Arusha City is highly influenced by its proximity to the equator and mount Meru. Cool dry air prevalent for much of the year. The temperature typically ranges between 13 and 30 degree Celsius with an average annual high temperature around 25^0C. The coolest season is between Mid-April and Mid-August while the rest of the year is fairly warm. The City is experiencing a bimodal rainfall pattern, with two rainy seasons in a year, short rains between October and January, and longer rains between March and May. The total rainfall between the two seasons ranges between 500mm to 1200mm per annum with a mean average of 844mm being the wettest and August the driest.

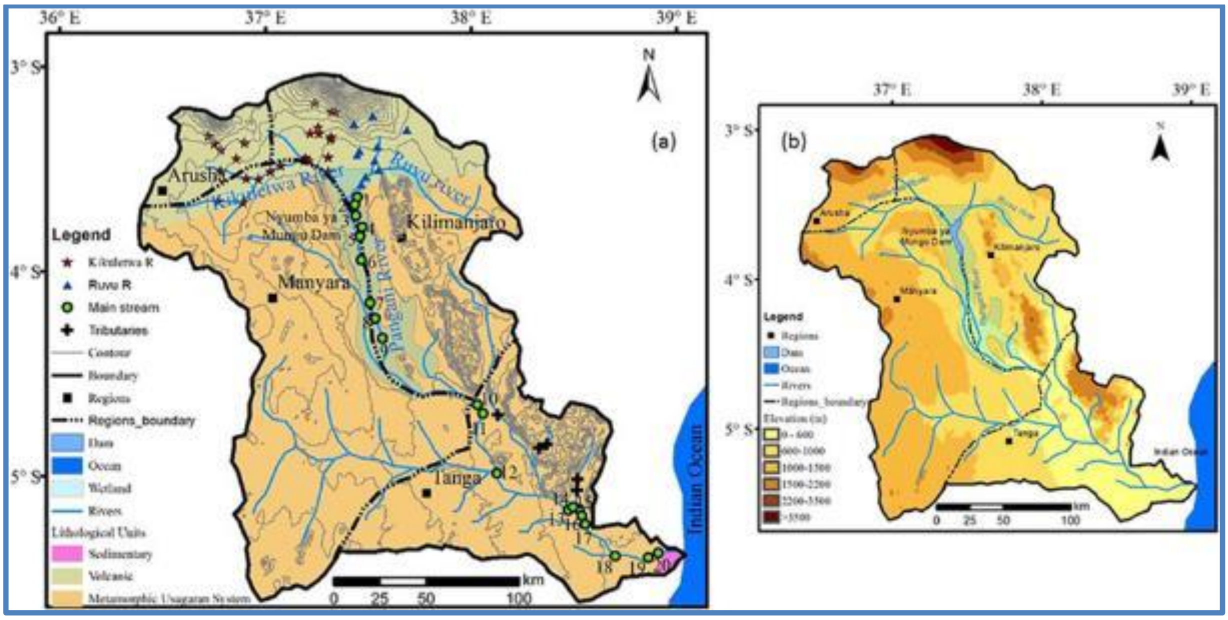
2.1.2 Topography

The topography of Arusha City slopes from an average gradient of 1:40 to gently sloping 1:80 from North to South direction, with an average elevation of the town centre ranging from 1380 to 1390 a.m.s.l.

2.1.3 River Basin

The Pangani Basin is a trans boundary basin shared by Tanzania and Kenya. It covers 56,300 square kilometres and 5% of this area is in Kenya. In the Tanzanian part, there are 18 districts falling within the administrative regions of Manyara, Arusha, Kilimanjaro and Tanga. The Tanzanian part of the basin includes two Cities (Arusha and Tanga) and one Municipality (Moshi). The Basin comprises five sub-basins: Pangani River (43, 650 km^2), Umba River (8, 070km^2), Msangazi River (5, 030 km^2), Zigi (1, 068 km^2) and Mkulumuzi (2, 080 km^2) which all independently drain into the Indian Ocean. The Pangani River has two main tributaries, the Kikuletwa and Ruvu Rivers, which join at Nyumba ya Mungu, a large man-made water body with a surface area of 140 km^2.The highest mountain in Africa is Mt Kilimanjaro (5,985 metres above sea level) which together with Mt Meru (4, 566 metres) provide the source of Kikuletwa river flow, while the Ruvu, Mkomazi and Luengera Rivers drain part of the Kilimanjaro, Pare and Usambara mountains. There are two lakes in the Basin, namely Jipe and Chala which are trans boundary water bodies. The Basin is also endowed with high potential for groundwater use. Currently, only 5% of all the water used in the Basin is derived from groundwater sources. Boreholes yielding more than 100 m^3/h have been drilled in the Kahe plains. The main economic activities in the basin are small-scale fishing, tourism, hydroelectricity power production, mining, industry and irrigation. The Basin also contains National Parks, Game Reserves and controlled areas for wildlife. The Kilimanjaro, Arusha and Mkomazi National Parks, and the Amani Nature Reserve, are major tourist attractions. The Basin is rich in minerals and gemstones. A unique blue diamond (tanzanite) can be found only in Tanzania

Several streams that contribute to Pangani Basin cut across Arusha City. Some of the rivers include; Burka, Ngarenaro, Naura, Themi, Kijenge and Goliondoli which all converge to join the Themi River in the southern part of the Arusha District. These rivers have two extreme flow fluctuations over the period of a year.



<Figure 2> Pangani Catchment

2.1.4 Territory and Climate Description

Arusha City is characterized by the two parallel roads; Nairobi Moshi highway and east west road that runs through the city centre. The city centre lies between these two roads bounded by Nairobi road in the west and Sokoine road in the east. A rail line runs parallel to the east west road stopping at the city centre at Unga Industrial Zone. The rail connects Arusha with Tanga and Dar es Salaam.

The city is bisected by several valleys that make the east west connections very challenging. The principal valleys in the city are formed by Themi, Naura and Goliondoi Rivers. There are several hills in the city that provide good scenic views of Mt. Meru. Most of the hills are inhabitant due to steep slopes and lush forests. The rest of the town consists of relatively gentle sloping terrain dissected by river valleys.

The urban pattern in the City Centre (especially in Central Wards) still echoes the old colonial era architecture with planned low density residential settlements along River Themi. Medium density residential settlements are found in the southern part of the city. In the west close to Unga Industrial area, central market and bus station, the urban density is relatively high. The western wards of kati, levolosi, Sekei and kaloleni are characterized by commercial and institutional developments. The light industrial estate in Themi/Njiro hills corridor attracted international institutions in its surroundings. This area also has some good quality housing and more affluent neighborhoods due to good views and its proximity to the city.

With the city unable to cope with population explosion and lack of housing facilities, unplanned and unauthorized developments have occurred in Sekei, Kimandolu, Ngarenaro, Ungalimited and in the area north of Moshi-Nairobi road. As of today, the high density unplanned settlement expanded beyond Unga Industrial Area into the wards of Sokoni, Lemara, Daraja_mbili, Sombetini and parts of Olasiti. Similar medium to low density informal settlements spread in the east at Baraa, Kimandolu, Olorien and Moshono. As per the recent government report (TACINE2014), around 80% of the residential developments fall under informal housing.

2.1.5 Settlements

➢ **Planned Settlement**

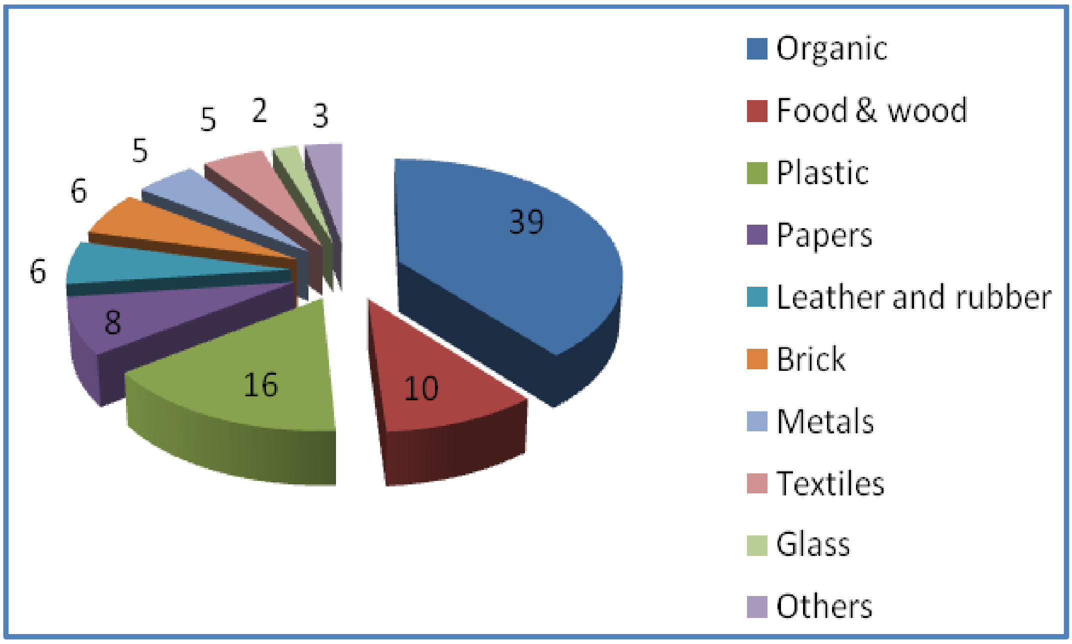
Only 20% of the residents live in Arusha City are following the City Planning drawing and got the building permit during the establishment of their residential/business buildings. Most of these areas are located at the following wards; Sekei, Kati, Themi, Levolosi, Kaloleni, Engutoto and some parts of Ngarenaro, Olasiti and Unga Limited. In most cases, these areas accommodate the medium and high income bracket who can afford to buy or rent higher value properties with a good access to infrastructure and services. According to the housing typology preference survey conducted during the house hold survey, it was observed that the majorities of the local population are still culturally attracted by landed singly family houses and would not easily opt for a multi-storey solution (Arusha Master Plan 2015 -2015). This tendency reduces the market for the apartment typology in the Arusha City area that in the short term mostly attracts a small component of the local population and temporary resident of the city. In the medium and long term however, as observed in similar contexts, young highly educated and higher income home seekers will be open to a different housing solution.

➢ **Unplanned settlement**

Currently 80 percent of the population in Arusha City lives in unplanned area/settlement. Unplanned settlements represent the 80%of the total built up area and accommodate the larger part of the housing stock in the Planning Area. The current expansion trend is predominantly towards the south of the city but it's increasingly spreading towards current farming areas where land values are lower.

➢ **Solid waste production**

Arusha city has a population of 416,442 as per the 2012 national census, distributed through 25 wards and 155 streets. The solid waste generation rate is about 550tonnes/day, with an average generation rate of 1.08 kg/person/day and a collection capacity of about 302 tons/day, which equals 54.8%, with a 16% recycling capacity, according to data collected from four different known recycling groups. Solid wastes include domestic refuse which consists of degradable food wastes, leaves, dead animals, and non-degradable waste such as plastics, bottles, nylon, industries and commercial waste. Estimates are given in the chart below.



<Figure 3> Solid waste composition for Arusha city (*Source: Arusha city council strategic plan and cost recovery for SWM 2012/2013-2017/2018*)

2.1.7 Water Supply, Sanitation and Drainage System in Arusha City

- **Water supply infrastructures**

In ACC 94.6% of residents had access to an improved water sources in 2012 (Tanzanian Bureau of Statistics, 2016). This is in line with other urban areas in the region and significantly higher than the average for rural areas, 68.3%. It is also higher than the national average for urban areas, 78.6% (Tanzanian National Bureau of Statistics, 2015). The estimated water demand is as presented in following table.

<Table 6> Water demand project to the year 2030

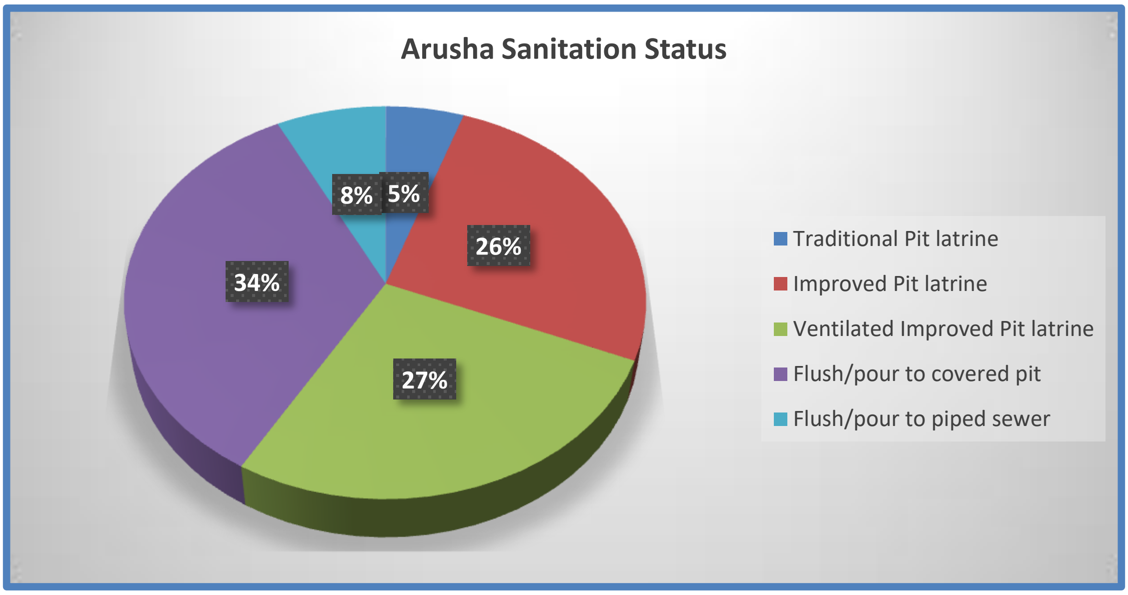
Parameter	Unit	2015	2020	2030
Domestic Demand	m^3/d	52,864.63	60,397.28	78,835.50
Institutional Demand	m^3/d	6,618.15	7,727.98	10,651.23
Commercial/Industrial Demand	m^3/d	19,370.10	20,879.36	30,583.23
Net Demand	m^3/d	78,852.88	89,004.63	120,069.97
Distribution Network Losses	-	20%	20%	20%
Total Demand	**m3/d**	**94,623.45**	**106,805.55**	**144,083.96**

- **Sanitary infrastructures**

The distribution of sanitation provision services in Arusha City Council is generally higher than urban areas nationally and regionally, more than 87.6%. Connection to sewers in ACC, in common like any other urban areas in Tanzanian is low, account only for 7.6%. This means that the vast majorities of residents in ACC are reliant on septic tank (pour flush and cistern flush) / pit latrine (ventilated improved pit, pit latrine and Urinal Diversion toilet) or other onsite containment, storage and treatment. The numbers of sewerage customers/connections are small because the sewerage network only covers the central area, Unga Limited and the areas surrounding the Lemara Waste Water Stabilization Ponds.

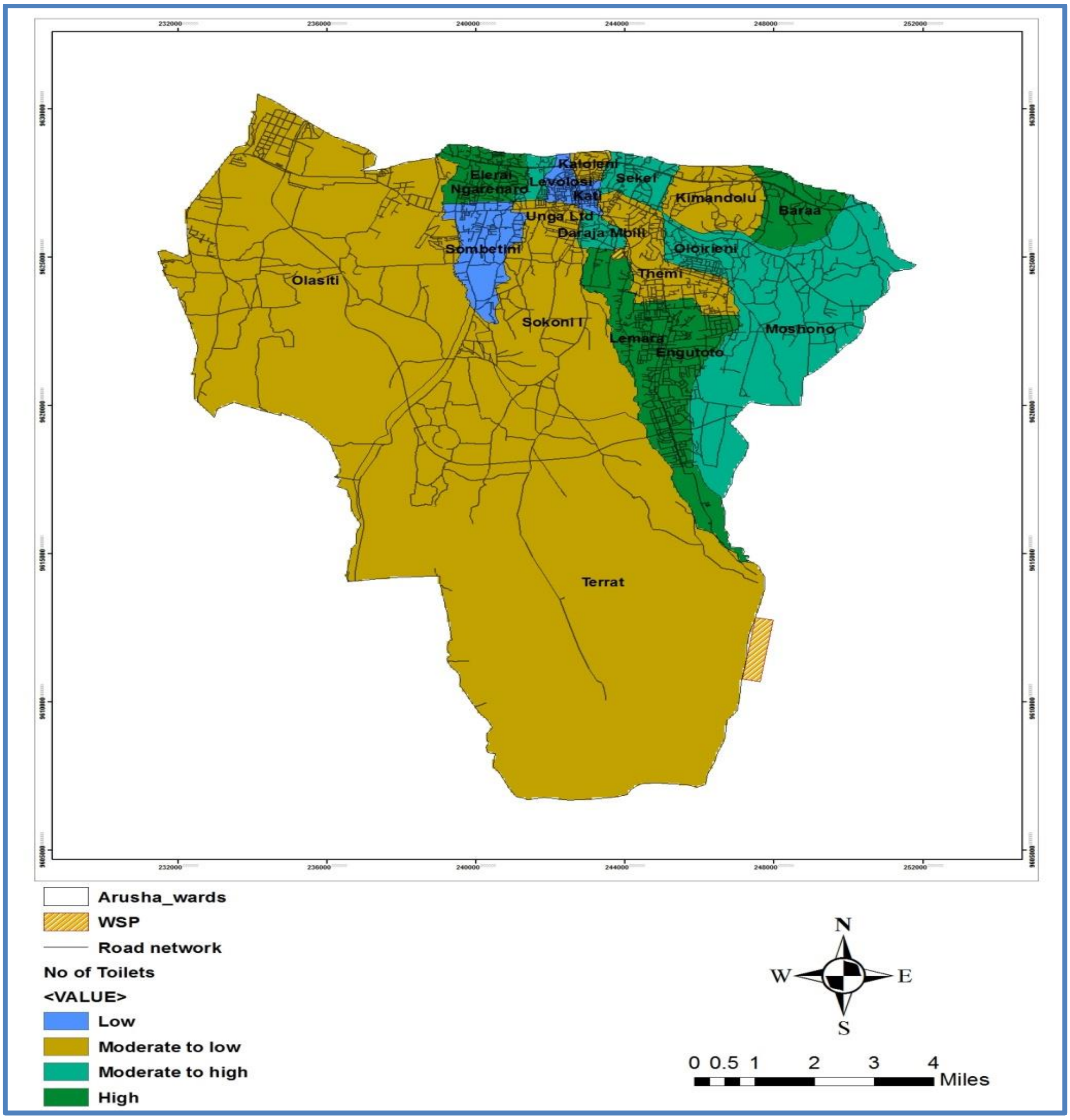
AUWSA's current service coverage challenges are partly the result of Arusha city's upgrading from a municipality to formal city status and the associated increase in population and area that AUWSA was responsible for. As a result of this change, the sewer coverage from 17% to 7.6% and coverage of AUWSA supplied water dropped from 98.5% to less than 44%. This was because the majority the population in the expanded areas were outside of the areas covered by AUWSA sewers or water supply network (AUWSA, 2014).

The wastewater treatment is carried out using waste stabilization ponds at the Lemara treatment facility. This is the responsibility of AUWSA. There are five ponds working in parallel and series. The first pond is anaerobic, followed by two facultative ponds working in parallel and finally two maturation ponds working in series. There are two sludge ponds within the pond area to treat sludge brought by cesspit emptier facilities (AUWSA, 2014). The effluent is ultimately discharged into Themi River which is mainly used for irrigation downstream. Monitoring of the ponds performance is done on a weekly basis by taking samples of incoming and outgoing waste water and analysing them to check the treatment efficiency of the ponds.



<Figure 4> Sanitation Status (Source; NSC, 2017)

AUWSA is responsible for treatment of all of excreta that is collected from onsite latrines a nd from the sewer network. This includes ensuring that treatment facilities have sufficient c apacity. The National Environment Management Council (NEMC) and Pangani Basin Wat er Board (PBWB) have responsibility for inspection of the quality of discharges from the tr *eatment plant.*



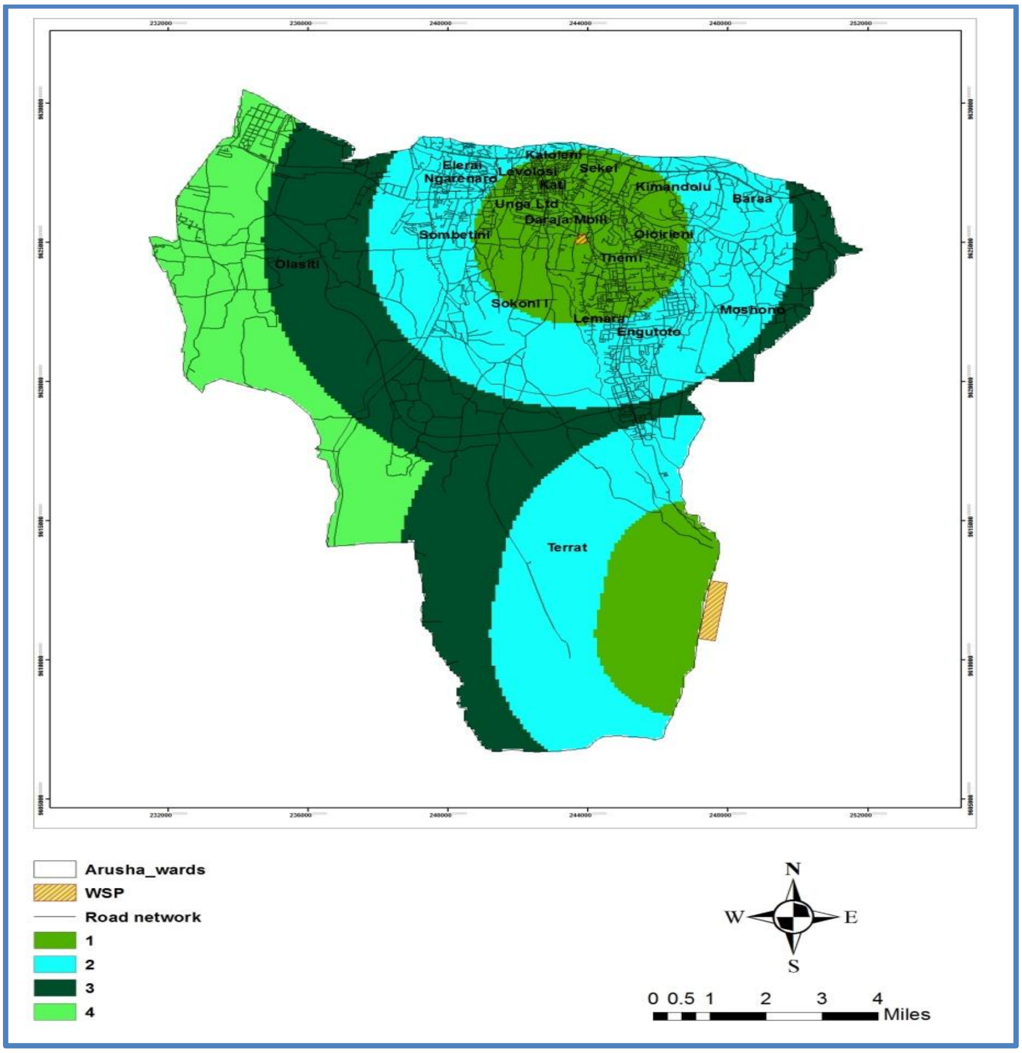
<Figure 5> Arusha City Sanitation status Map

The National Sanitation Campaigns report of 2017, depicts that approximately 5% Arusha city had no access to toilets or have the toilets in their premises traditional pit latrines (or toilets that discharge directly into the environment) or practicing open defecation which we describe as a low sanitation status and its within Sombetini, Ngarenaro, Olmoti and Ungalimited wards.

Furthermore, 26% of households only have a basic improved pit latrine and 27% have ventilated improved pit latrine access to sanitation facilities which is termed as moderate to low and it's found within Terrat, Olasiti, Kimandolu wards.

Conversely 34% of respondents have access to an improved or environmentally safe sanitation facility of which they use Flush/pour covered pit latrine found within Moshono, Elerai, Sekei, Kaloleni and Sakina wards.

And the areas with high sanitation status which are close to sewer for almost 7.6% found within Engutoto, Lemara, Ungalimited and Kati wards

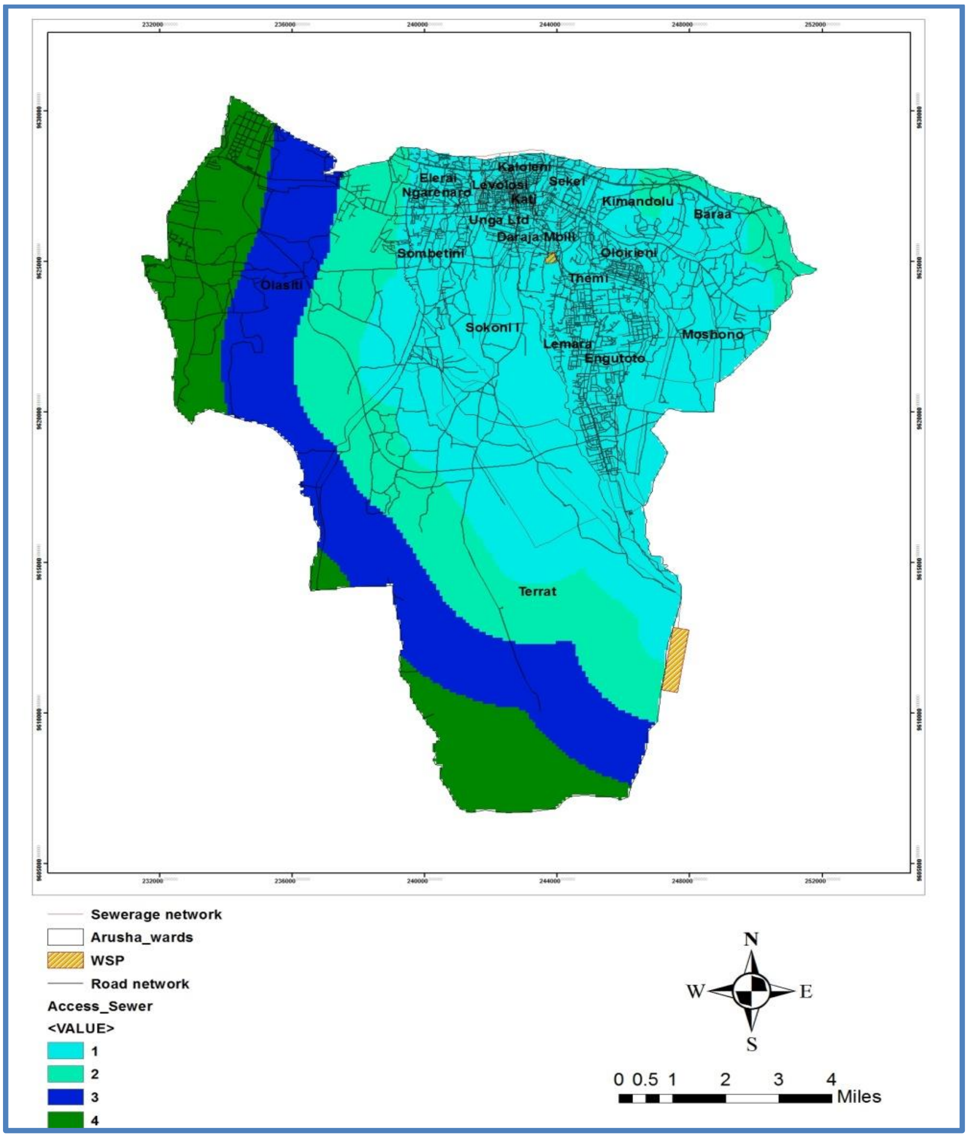


<Figure 6> Access to Waste Stabilazation Pond

The exiting waste water stabilization pond is found at Themi ward and the new one which is underconstuction is at Terrat ward. These are the areas were the sorroundings wards are highl y near to the sewer (1) and hence reduce the disposal of waste water to the sorroundings but t hewards which are found far from the waste treatment pond are highly affected by poor dispo al

of waste water and hence environmental pollution .

The underconstruction waste water pond is located almost 20 kilometeres from the city center which can highly impact by poorly disposal of waste water to the environment due to distanc and cost implication for the services.



<Figure 7> Access to sewer Network

For the existing and undercostruction sewerage sytem it will cover almost 30% percent of th e whole city by 2030 to be connected by sewer networks. Most of the part at Olasiti and Ter rat wards will not be connected to sewer network, due to factthey are far from the ongoing co nstruction infrastructures.

Sanitation issues, gaps and challenges needing upgrading

On-site sanitation is still the most common forms of sanitation system used by most of the resident live in Arusha City Council. In Tanzania, only about 10 percent of the urban inhabitants are connected to sewer networks with the majority relying on diverse types of on-site sanitation systems. The challenge with on-sanitation system is that the generated faecal sludge needs to be emptied and safely transported to treatment plants. However, currently a large fraction of the faecal sludge generated in urban areas of Tanzania are not safely managed or treated. Only a small proportion of the collected faecal sludge gets co-treated in existing City sewage treatment plants. To address this problem, the consultants in collaboration with development partner (SNV) have planned to establish effective faecal sludge management system. This will require characterization of faecal sludge generated and selection of suitable treatment process.

As pointed out above, despite the massive investment and efforts towards solving sanitation issues and challenges, still a large proportion of population, including ACC, lack and don't have access to the environmental safe Sanitation services. A number of tools have been devised to improve the sanitation situation and one of them is sanitation ladder (figure3). The ladder aimed at providing community members and decision making tools with a visual guide to different sanitation options, providing information on a range of factors (e.g. cost, convenience, upgradeability etc.) in order to facilitate household and communal sanitation planning and decision making. This ladder is still in use in some areas of Arusha City Council as the survey provides for all most all levels of the sanitation ladder. The focus is to progressively move people up the ladder to environmentally safe sanitation facilities.

Encouragement to connect to the sewer network

Many wards in Arusha city have traditional pit latrines 3,164, improved pit latrines 15,488, ventilated improved pit latrines 16,278 and few has pour flush with septic tanks 20,343. Unfortunately out of 20,343 only 4,703 have sewage connections including domestic, commercial, institutional and industrial customers. As consultants we are highly advising the authority responsible to increase the number of connections through educating people to improve the existing systems from improved pit latrine and ventilated improved pit latrines to pour flush system. Efforts are also to be made to traditional pit latrines by moving up to improved pit latrine.

Encouragement to connect can also be made by extensions laterals near to the households, constructing condominium inspection chambers etc. Apart from that sewer bills are to be reviewed and see if they are contributing to failure.

AUWSA's plans

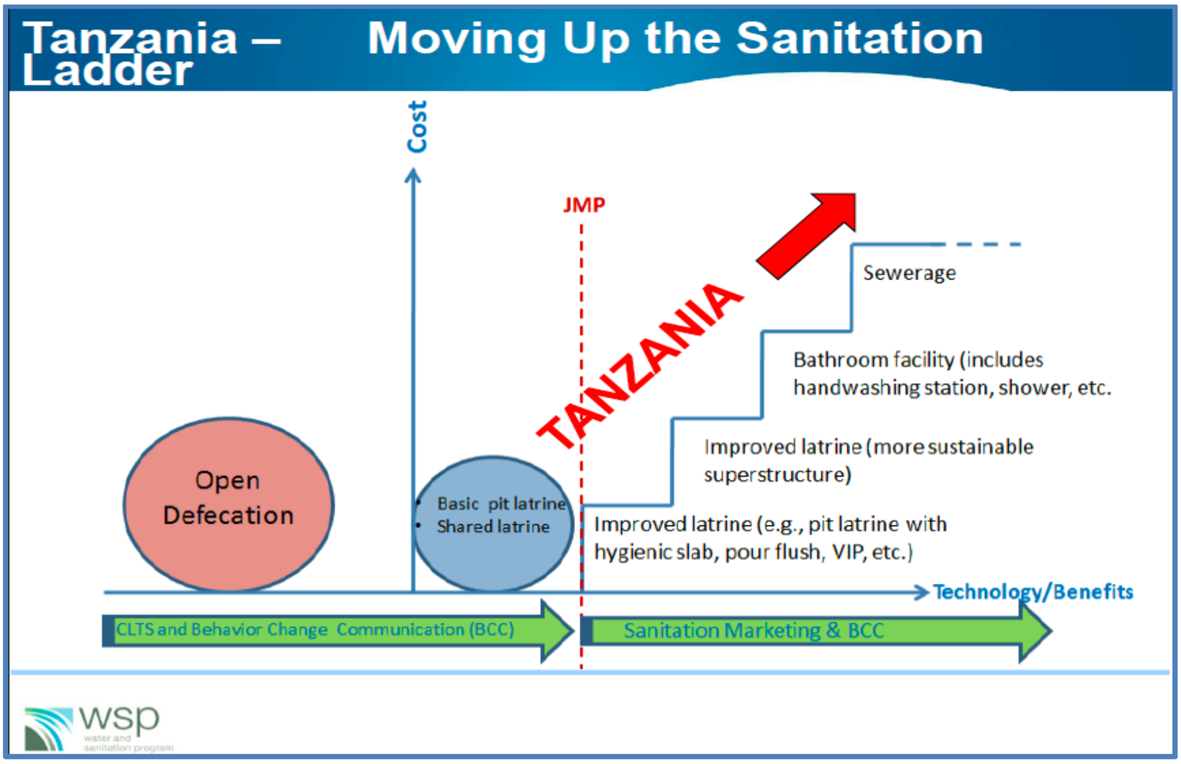
Arusha Urban Water Supply and Sanitation Authority (AUWSA) intended to improve and upgrade the water supply and sanitation system in Arusha city. The proposed project is in line with implementation of the National Urban Water Supply and Sanitation Programme (NUWSSP), which is part of the Water Sector Development Programme (WSDP). The implementations of these programs are based on the principles of the National Water Policy (NAWAPO) formulated in 2002. Ultimately, the intention of these programs is to support the national effort towards improvement of public health and quality of life, hence poverty alleviation among the urban population.

Arusha city is a major international, diplomatic, touristic and regional hub. Its water and sanitation infrastructure is inadequate and requires urgent improvement. The water access coverage in the city is only about 44% in spite of the fact that AUWSA has the highest water connection density per kilometer of water distribution pipeline, among all the regional utilities in the country. The existing sanitation system caters for only about 7.6% of Arusha city, and is concentrated only in the Central Business District (CBD). The existing sewage treatment ponds are critically overloaded. In this regard, AUWSA has been rated as one of the least performer in the provision of sanitation services, among the regional utilities in the country. More over given the fact that Arusha municipality was up-graded to city status in 2010, the AUWSA service area has almost doubled from 93km to 208km. It is in this context that the Government of Tanzania through the Ministry of Water (MoW) submitted a project proposal for consideration by the African Development Bank (AfDB) for funding assistance to support the extension and up-grading of water and sanitation project in Arusha city.

Similar to the problems of blocked sewer, during the site visit it was observed that the treat ment plant is not able to process the wastewater effectively especial the anaerobic ponds ar e not well functioning. The main reasons for this are that the ponds receive 6500m^3 of wast ewater per day while they are designed for only 3500m^3 per day and the excess sludge with in the anaerobic pond

Tanzania Sanitation Ladder

The tool used for the monitoring and assessment of the achievement of the MDG's based on t he functions of the sanitation systems. This tool provides for illustration on how people can m ove from simpler sanitation solutions to more advanced ones by moving up rung by rung on t he ladder <figure 5>. It is used in a variety of situations, generally as a tool to choose latrine t ype in community based sanitation projects.



<Figure 8> Tanzania sanitation ladder

<Table 7> Sanitation ladder on access to toilet

	Sanitation ladder on access to Sanitation facilities	% in Arusha CC
0	**No toilet/Open Defecation** - There is no toilet used within the premises. The disposal of hu man faeces in field, forest, bushes, open water bodies, and othe r open spaces or with solid wastes	5%
1	**Unimproved sanitation facility** - The uses of pit latrines without slab or platform, hanging latrin es or bucket latrines	27%
2	**limited** - Use of improved facilities shared between two or more househ	5%

	Sanitation ladder on access to Sanitation facilities	% in Arusha CC
	olds	
3	**Basic sanitation facility** - Uses of the improved facilities which are not shared with other household	**6%**
4	**Environmentally safe sanitation facility** - Environmentally Safe Toilet: Improved toilet preventing acces s to faeces by any animals or insects (flies/rodents) - ***AND*** Use of improved facilities which are not shared with othe r households and where excreta are safely disposed in situ or tr ansported and treated off-site	**57%**

Excreta Flow Analysis

In Arusha City Council, it was estimated that 99% of excreta is managed safely, of which faecal sludge being contained and not emptied in areas with low risk of groundwater pollution. However, the SFD reflects the current status of excreta, which does not translate to future recommendations.

The following below shit flow diagram designated to provide for excreta flow analysis to inform urban/city sanitation programming. The Shit Flow Diagram (SFD) was created through field-based research and interview from the indigenous community within the vicinity of the ARUSHA City council's wards. More than 90% of the population relies on onsite sanitation technologies for containment of the excreta. However one third of these onsite technologies are not contained for example pit latrines with outlets that discharge directly into open drains or water bodies and partially lined pits and septic tanks soak pit in areas low ground water table. The wastewater and faecal sludge that is delivered to treatment sites is treated in waste stabilization ponds. It is estimated that 90% of the wastewater and faecal sludge delivered to treatment is effectively treated.

Empting

A) Percent Safe sewage empting by means of protective equipment's etc. with public and private cesspit emptier truck is 7.6%

B) Percent Unsafe sewage empting without protective equipment's from septic tanks with public and private cesspit emptier trucks is 87.5%

C) Percent Safe manually empting by protective equipment's 12.5%

D) Percent closed when full and dig another pit is 31%

Transportation

a) Percent safe transport the sewage using other means like buckets with wheel barrow 0%

b) Percent safe transported by public and private cesspit emptier truck 7.6%

c) Percent unsafe transported the sewage manually 0%

Treatment and Disposal

i. Percent sewage is disposed into the well designed and constructed sludge ponds 7.6%

ii. Percent sewage is disposed into unsafe open land 1%

iii. Percent sewage is disposed near receiving water bodies 7%

iv. Percent sewage is treated to meet the standards 7%

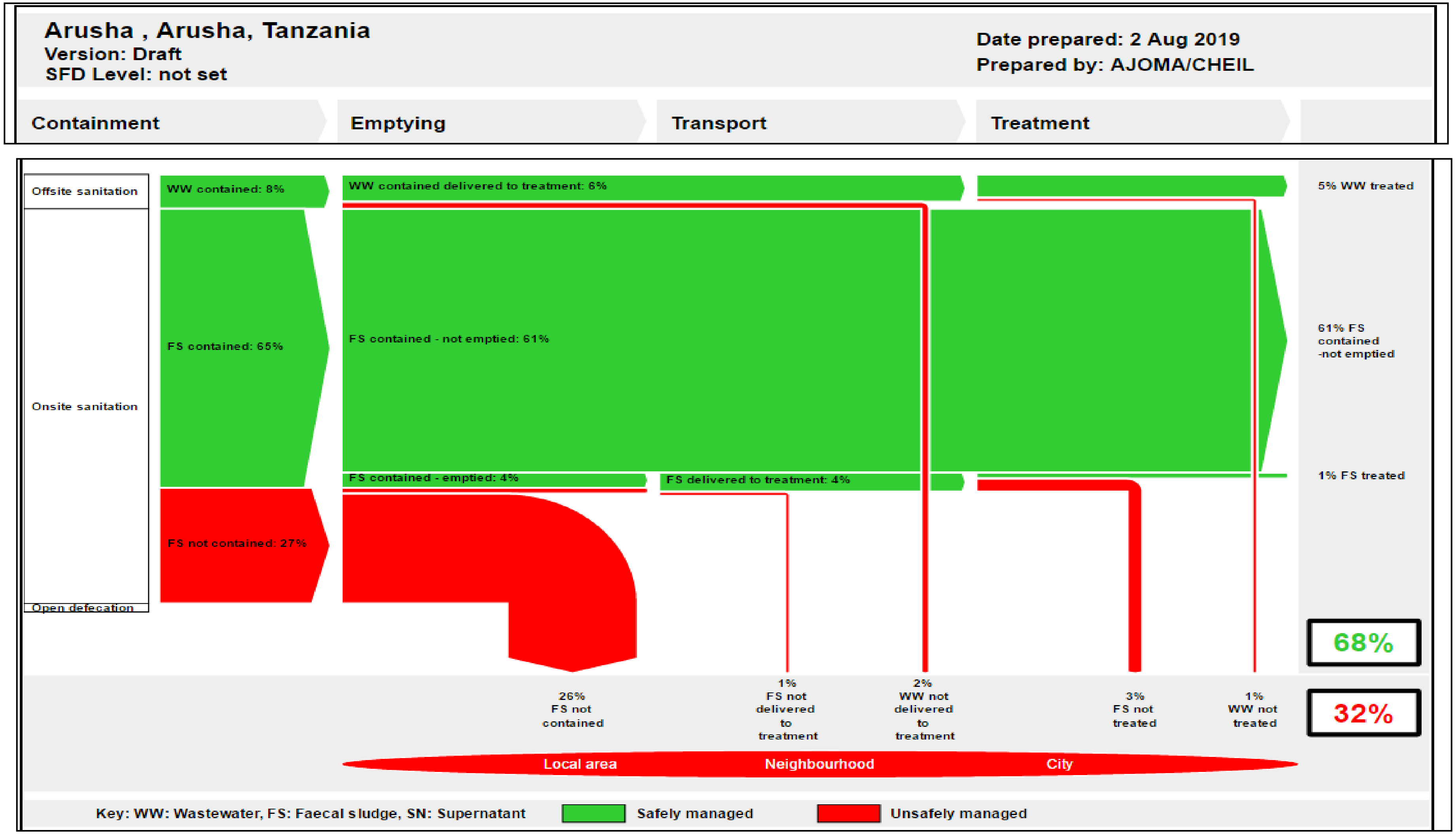
v. Percent the disposal is environmentally friendly 7%

Reuse

A. Percent is the final effluent safe for use 7%

B. Percent is the final effluent not safe for use 1%

<Figure 9> Shit Flow Diagram for Arusha City Council



Cost implications

The charges to customers for emptying on-site facilities vary depending on the household location. Private sector operators interviewed and stated they charge approximately TZS 70,000 - 80,000 per trip for empting household latrines or septic tanks within the city and up to TZS 150,000 per trip outside the city. The charges for emptying the onsite facility from the authority (AUWSA) is TZS 73,000 per trip for the cesspit emptier truck with the capacity of 5000m^3 and 89,000 per trip for the cesspit emptier truck with the capacity of 10,0000 m^3. The ACC charges up to TZS 65,000 per trip. The charges for disposal of waste at the Lemara waste stabilization ponds are TZS 2,000 per trip for each truck with capacity of 5m^3; TZS 5,000 per trip for trucks with capacity of more than 5m^3 to 10m^3, TZS 10,000 per trip for trucks with capacity of more than 10m^3 to 15m^3 and TZS 12,000 per trip for each truck of capacity exceeding 15m^3. The sludge discharge fees generate about TZS 3m monthly on average while the charges from customers connected to sewerage system is between TZS 350m to 400m monthly.

Sanitation challenges in Arusha CC

There are deficiencies throughout the sanitation service chain in Arusha. These deficiencies are having a direct impact on residents' lives. Interviewed ward environmental and health officers explained that diseases linked to poor sanitation practices in Arusha city include diarrhoea, typhoid, dysentery, worm infections and cholera outbreaks. **The last cholera outbreak, in which 856 cases were recorded, was from October 2015 to April 2016**.

The first major sanitation challenge is the lack of effective containment of excreta at the household level. According to multiple interviewees, this is largely due to poorly constructed latrines and Septic Tanks overflowing. There is also still a small percentage of the population that practice open defecation, adding to the problem. The impacts of this challenge are magnified when houses in an area are not connected to the AUWSA water system and so obtain water from shallow wells. These can be contaminated from shallow pit latrines and overflowing latrines and septic tanks. This risk is heightened further when there are water shortages which prompt more people to use shallow wells. The second challenge is blocked sewers. This was identified by residents and AUWSA's sewerage Engineer during the validation workshop. The reasons behind these are; the existing sewer system is old, does not have sufficient capacity and is misused by some residents (disposing of solid waste). This results in a significant number of blockages and subsequent spillage of wastewater. It is approximated that there are over 1300 blockages in the sewer system annually. The third major challenge observed during the site visit at the waste water treatment plant – (WSP) is an ineffective treatment of wastewater. The outflow from the wastewater treatment plant does not meet the required Tanzania standards or ISO standards of treated water quality.

- **Drainage systems for storm water**

Drainage systems, particularly in the Arusha City Council, include but not limited to pipelines, o pen channels, natural surface channels and canals. The major drainage systems are almost certain ly include open channels and natural watercourses within urbanized (or urbanizing) catchment/ar eas. Urban and rural development changes the pre-existing natural drainage conditions. Agricultu ral development involves the clearing of the natural vegetation and replacement with pasture and harvested crops as observed in the upstream side of the Arusha City Council – adjacent to Arush a District. This process usually increases surface water run-off, increases the rate of run-off and r educes the opportunities for infiltration, evaporation and transpiration which are critical compone nts of the overall hydrological cycle. The methods of agricultural improvements to land include p loughing and grazing which can cause erosion, soil loss and sedimentation in streams thus furthe r altering the natural environmental conditions.

Urban development has an even more marked effect than does agricultural development. By its very nature it covers a large proportion of the developed area with impervious surfaces including roads, footpaths, driveways, houses and outbuildings, commercial and industrial buildings and parking areas. Even parks and garden areas and sports fields are designed to be free-draining and avoid ponding and to shed the majority of storm rainfall by surface drainage and sub-surface pipe systems more quickly than the natural rate of infiltration will permit.

Obstruction of drainage systems, ditches, culverts and streams by solid waste and refuse can b e a considerable obstacle to the efficient conveyance of storm water within the City Areas. Ref use (or flood debris) can block channels, causing the water to back up and spread laterally int o business and residential areas.

➢ Existing drainage system

Based on the existing topography, Arusha City is divided into 3 main drainage catchment areas as depicted in figure 6 .The storm water runoff originates from Mount Meru, flowing mostly southward through Arusha City. Catchments C1 up to C3 drain to Themi River which joins the Pangani River about 20 km from the Arusha City boundary. Human settlement and industrial development are extending from the many hills within Arusha City to the low lying areas on the banks of the drainage channels which are part of wetlands and floodplains.

The existing storm water drainage structures in Arusha City are characterized by buried conduits along Sokoine road, market streets and Arusha International Conference Centre – AICC area. Open road side drainages are usually found in densely developed areas. Storm water conduits eventually connect with natural streams (*flowing water bodies*) namely Themi, Naura, Kijenge, Ngarenaro, Burka and Goliondoi Rivers which originate from the Catchment forest on the slope of the Mount Meru and flow through the Arusha City Areas. However, some of the existing drainages channeled their discharge through the resident of the communities.

Storm water drainages in Arusha City are connected to the road network, which is the responsibility of two authorities: Arusha City Council is in charge of local roads in peri-urban and rural through the TARURA agency, while the Ministry of Infrastructure, through the Tanzanian National Road Agency (*TANROADS, established in 2000*), and is responsible for regional and main trunk roads.

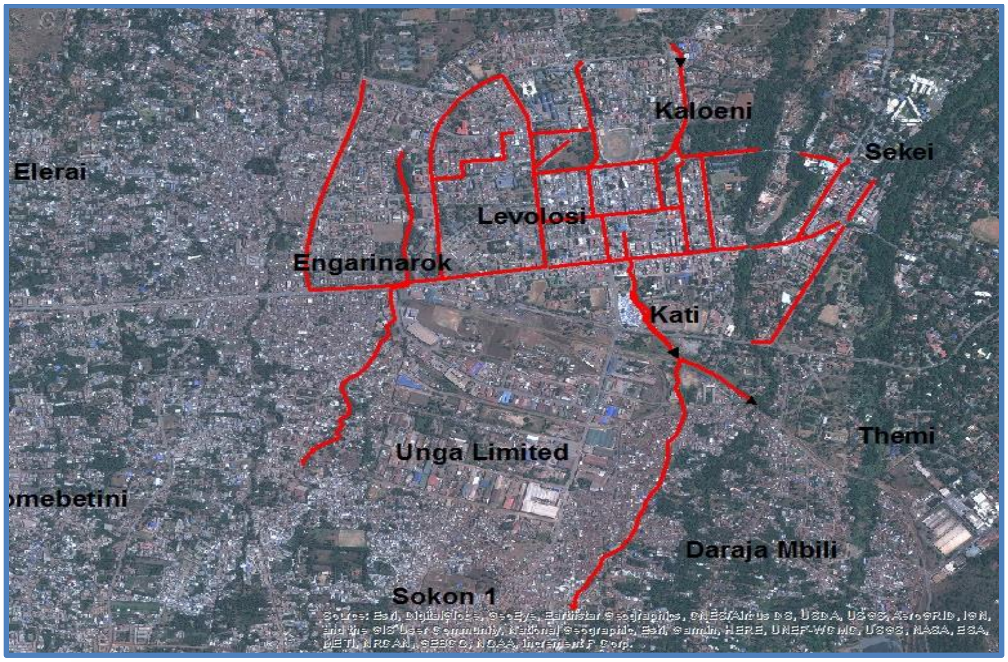
The storm water drainage system available observed to serves part of the city as drainage systems for the rainfall run off and also used for domestic sewage or informal garbage disposal. They are either full of grass and weeds, littered with garbage or the stone/concrete lining has been damaged, old drains and they have small diameters that can support the water flow. This causes erosion on higher elevated areas of town and flooding and sedimentation in lower downstream areas of the towns.

The natural and constructed drainage channels along the floodplains and low-lying areas are regularly overtopped by floodwaters, causing damage to people’s homes and industrial properties, disruption of traffic flow and economic activity in the City and increasing water pollution. The frequency of flooding has increased in recent years.

This is attributed to:

- Increased runoff caused by climate-related and land use changes in the catchments;
- Reduction of the buffer capacity of wetlands due to encroachment;
- Frequent disposal of solid was in open storm water channels leading to blockage;
- Inadequately design and constructed road side drainage channels and culverts among others

These challenges have increased the frequency and magnitude of flooding which has led to negative impacts and consequences that include high property damages, traffic disruption, loss of lives, destruction of livelihoods, and recurring costs to Arusha's socio-economy. Investment in upgrading drainage infrastructure is therefore of critical importance so as to protect people and their property and also spurring economic development**.**



<Figure 10> Existing drainage structures (source: Master plan 2015-20135)

➢ Flood prone areas

As a general definition "flood plains" or a "flood-prone areas" represent those areas adjacent to rivers and streams that are subjected to the recurring inundation. Owing to their continually changing nature, flood prone areas need to be examined in the light of how they might affect or be affected by development. With the context of design the storm water drainage infrastructures as per contract the study and identification of the flood prone areas in Arusha City Council are of more important to provide the planners, disaster management institutions and decision making bodies with practical and cost effective way to improve the drainage systems within the areas.

The information gathered from the field visit in Arusha City Council's wards shown the Storm water and grey water drainage are a further another challenge that contribute mostly to environmental degradation. Currently most of the surveyed area have unimproved drainage systems that collect the storm water during the rain seasons to the nearby water bodies or low laying area. The absence of the improved drainage channel also constitutes a major health risk as uncontrolled storm water spreads the content of poorly constructed latrines around the low lying areas. During the site survey the wards representative and streets leaders in collaboration with the consultant team were managed to identify areas that mostly affected during the rainy season as shown in the table 6~~(8)?~~ below.

<Table 8> Identified flood prone areas in each ward

No.	Ward Name	Type of Flood	Causes	Effect
1	Kaloleni	- Urban flooding - Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Outflow from the road - Unplanned Settlements that block water ways	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Deterioration of quality of surface water
2	Ngarenaro	- Urban flooding - Surface flooding - River flooding (Ngarenaro River)	- Low laying areas - Insufficient drainage infrastructures - Unplanned Settlements that block water ways	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Deterioration of quality of surface water - Deposition and obstruction of canals by refuse and sediments e.g. White rose road
3	Elerai	- Surface flooding - Stream flooding	- Insufficient drainage infrastructures - Poor drainage infrastructures - Silting, sedimentation and garbage/rubbish in the storm water drainage infrastructures - Unplanned Settlements that block water ways	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Deterioration of quality of surface water - Destruction of roads and culverts
4	Ungalimited	-Urban flooding -Surface flooding -Flash flooding	- Insufficient drainage infrastructures - Poor drainage	- Inundation of buildings and residences - Destruction of public infrastructures/institutions

No.	Ward Name	Type of Flood	Causes	Effect
			infrastructures - Silting, sedimentation and garbage/rubbish in the storm water drainage infrastructures - Unplanned Settlements that block water ways	- Deterioration of quality of surface water mud and mold in some residences – not to mention the injuries and loss of life domestic animals
5	Muriet	- Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage outflow from the road	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Deterioration of quality of surface water - Destruction of roads and culverts
6	Osunyai	- Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage outflow from the road	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Deterioration of quality of surface water - Destruction of roads and culverts
7	Sombetini	- Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage - Outflow from the road Arusha- Dodoma road - Unplanned Settlements that block water ways	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Deterioration of quality of surface water - Mud and mold in some residences not to mention the injuries and loss of life domestic animals
8	Themi	- Urban flooding - Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage - Old storm water management structures	- Inundation of buildings and residences - Destruction of public infrastructures/institutions
9	Kimandolu	- Urban flooding - Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage - Outflow from the road Sakina-Tengeru road	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Mud and mold in some residences – not to mention the injuries and loss of life domestic animals
10	Moshono	- Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage - Wetland areas	- Inundation of buildings and residences - Destruction of public infrastructures/institutions e.g. Ward office - Deterioration of quality of surface water - Mud and mold in some residences – not to mention the injuries and loss of life domestic animals
11	Olorieni	- Urban flooding - Surface flooding - Flash flooding - River flooding	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage	- Inundation of buildings and residences - Mud and mold in some residences – not to mention the injuries and loss of life domestic animals

No.	Ward Name	Type of Flood	Causes	Effect
		(Kijenge River)		
12	Sokoni 1	- Urban flooding - Surface flooding - Flash flooding - River flooding (Ngarenaro River)	- Low laying areas - Insufficient drainage infrastructures - Lack of drainage - Outflow from the road Arusha-Dodoma road	- Inundation of buildings and residences e.g. settlement near River Ngarenaro - Destruction of public infrastructures/institutions - Deterioration of quality of surface water - Mud and mold in some residences – not to mention the injuries and loss of life domestic animals - Increment of channel section e.g. destruction of River Banks
13	Sakina	- Urban flooding - Surface flooding	- Insufficient drainage infrastructures - Poor drainage infrastructures - Silting, sedimentation and garbage/rubbish in the storm water drainage infrastructures	- Inundation of buildings and residences - Mud and mold in some residences – not to mention the injuries and loss of life domestic animals
14	Levolosi	- Urban flooding - Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Poor drainage infrastructures - Silting, sedimentation and garbage/rubbish in the storm water drainage infrastructures - Unplanned Settlements that block water ways	- Inundation of buildings and residences - Inundation of buildings and residences - Destruction of public infrastructures e.g. culverts, conduits and canals by refuse and sediments
15	Moivaro	- Surface flooding - Flash flooding - Stream flooding (Baraa Stream)	- High laying and low laying areas - Lack drainage infrastructures - Wet land	- Inundation of buildings and residences e.g. settlement around baraa stream and other low laying areas - Destruction of public infrastructures/institutions - Destruction of public infrastructures e.g. culverts, conduits and canals by refuse and sediments
16	Olmot	- Urban flooding - Surface flooding	- Low laying areas - Lack of drainage infrastructures	- Inundation of buildings and residences - Destruction of public infrastructures/institutions - Mud and mold in some residences – not to mention the injuries and loss of life domestic animals - Increment of channel section e.g. destruction of streams bank
17	Sinoni	- Urban flooding - Surface flooding	- Low laying areas - Lack of drainage infrastructures	- Inundation of buildings and residences within low laying areas - Destruction of public

No.	Ward Name	Type of Flood	Causes	Effect
			- Construction of TSCP roads - Change in climate increase of population	infrastructures/institutions (e.g. Sinoni Secondary school)
18	Terrati	- Urban flooding - Surface flooding	- Low laying areas - Lack of drainage infrastructures - Construction of East African road - Change in climate increase of population	- Inundation of buildings and residences within low laying areas - Destruction of public infrastructures/institutions.
19	Lemara	- Urban flooding - Surface flooding	- Low laying areas - Lack of drainage infrastructures - Construction of AUWSA Sewer pipeline - Change in climate increase of population	- Inundation of buildings and residences within low laying areas - Destruction of public infrastructures/institutions.
20	Olasit	- Urban flooding - Surface flooding	Low laying areas Lack of drainage infrastructures Construction of East African road Change in climate increase of population	Inundation of buildings and residences within low laying areas Destruction of public infrastructures/institutions e.g. Olasit Secondary School
21	Kati	- Urban flooding - Surface flooding	- Low laying areas - Insufficient drainage infrastructures - Poor drainage infrastructures - Silting, sedimentation and garbage/rubbish in the storm water drainage infrastructures	- Inundation of buildings and residences within low laying areas - Destruction of public infrastructures/institutions. - Damage of commercial business centres/areas
22	Sekei	- Urban flooding - Surface flooding - River flooding (Naura River)	- Insufficient drainage Infrastructures - Poor drainage infrastructures	- Inundation of buildings and residences within low laying areas e.g. settlements near Naura river - Destruction of public infrastructures/institutions. Bridge at Naura river which connect to Arusha- Himo Road - In accessibility of AICC road
23	Engutoto	- Urban flooding - Surface flooding	- Low laying areas - lack of drainage infrastructures - Poor drainage infrastructures	- Inundation of buildings and residences within low laying areas - Destruction of public institutions. e.g. Engutoto Primry and Secondary Schools

SECTION 3. STORM WATER MANAGEMENT MEASURES

3.1 Flood Control and Storm Water Drainage

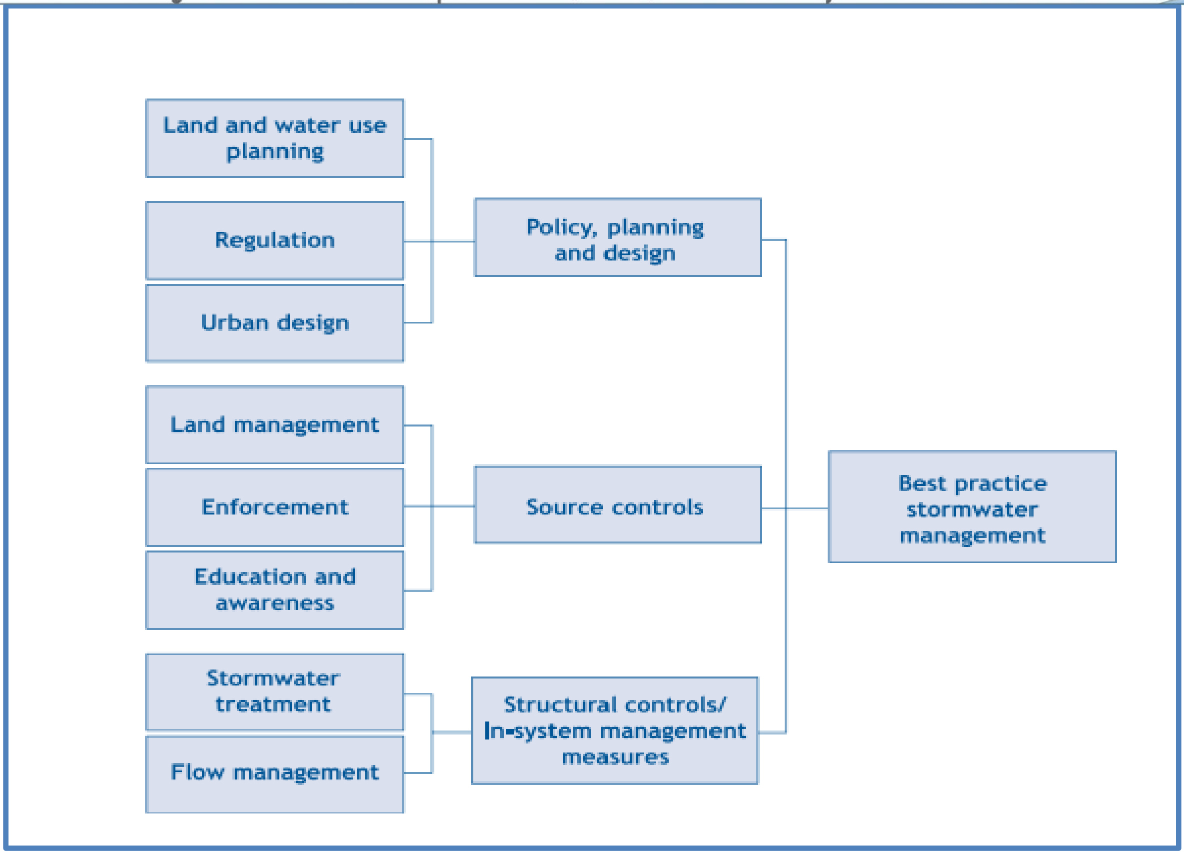
Flooding is controlled by a combination of structural and non-structural measures enabling the riverside population to minimize its losses and continue to live in harmony with the river/water bodies. These include engineering and social, economic and administrative measures. Planning of protection against flooding and its effects involves research into the ideal combination of these measures.

City flood management plans and approaches should share a common feature: a focus and concentration solely on the technical (hydraulic and engineering) aspects of flood management. Storms, heavy rainfall events and a higher frequency of flood events require protection of drainage systems, sewer systems and treatment plants against high peaks of hydraulic load; additional storm water storage in retention structures; treatment of the "first flush" storm water containing high concentrations of pollutants.

Additionally the operations and maintenance of drainage systems are important, especially when these systems intersect or overlap with other infrastructure elements and operations. Poor maintenance of roads and culverts can negatively affect the effectiveness of flood control measures; lack of an effective solid waste disposal system can increase the amount of trash and debris clogging drainage channels, reducing the carrying capacity. However, maintenance of the drainage infrastructure necessarily involves remove of blockages, repair leaks and breaks.

Long-lasting rainfall events can lead to water logging of the soil, leading to increased surface flow, destabilization of slopes, and landslides – all of which can damage infrastructure elements, whether installed above ground or below the surface.

Up-to-date only mapping and modeling of the system will help to identify potential problem areas and choke points and to predict how the system will operate under conditions of higher flow volume and intensity.



< Figure 11> Methodology of storm water Management

3.2 Flooding Control Measures

The hazard-based approach concentrates on the physical characteristics and capacities of structural, technical flood controls. Climate change adaptation under this approach consists of matching the design features and capacities to the projected precipitation and water levels. Structures may be strengthened or improved to meet these new requirements, or if physical improvements are not possible or cost-effective, non-structural adaptive elements may be explored as a means of reducing residual risk.

3.2.1 Storm water Drainage Design Strategy

Only 20% of the residents live in Arusha City are following the City Planning drawing and got the building permit during the establishment of their residential/business buildings. Most of these areas are located at the following wards; Sekei, Kati, Themi, Levolosi, Kaloleni, Engutoto and some parts of Ngarenaro, Olasiti and Unga Limited. In most cases, these areas accommodate the medium and high income bracket who can afford to buy or rent higher value properties with a good access to infrastructure and services. Currently 80 percent of the population in Arusha City lives in unplanned area/settlement. Unplanned settlements represent the 80% of the total built up area and accommodate the larger part of the housing stock in the Planning Area. These areas are at the risk of flash flooding. Therefore, this particular configuration requires a special attention on the choice of the structural solutions in the flood-prone areas

Moreover, as paving and drainage system are improved as part of urban upgrading, runoff inevitably increases, which may exacerbate downstream drainage problems and lead to increased flooding.

3.2.2 Hydrological Design Criteria

Flood Return Period. The return period of flooding is the most important parameter used for design of urban drainage systems for flood protection. It determines both the hydraulic grade line for operation and the size of drains, and subsequently the costs of infrastructure. The choice of return period depends upon the land use and the potential consequences of flooding. In theory, designs should take into consideration that the frequency of flooding and based upon perceptions of local communities to flood risks, but in practice although some projects consult community remembers to help understand problems and find out where the serious problems are, there is generally little attempt to change the recommended return period. As many communities are accustomed to flooding as a part of daily life during the season, they may have lower expectations of return period and may accept flooding on the streets, as long time as it does not create serious damage. **The key point is that removing flooding completely may be impossible without high expenditure and demolition of properties, neither of which may be possible.**

Therefore, drainage planning in informal settlements is often **the 'art of the possible'**. Another important consideration for the capacity of drainage conduits is the build-up of sediment and solid waste. The concept of self-cleansing velocity, which is commonly used in engineering designs for channels and pipes, is used to reduce sedimentation in the drainage system. However, in reality very few drains are self-cleansing due to the excessive solids loading and long dry periods – especially in developing countries. Because of this, many cities clean up the drainage systems just before the onset of the wet season.

- *Drainage System Typology*. Storm water drains may be 'open' or 'closed' and closed systems may consist of pipes or drains with/out cover slabs. The majority of existing drains in informal areas are open, but some drains are covered or installed with piped systems. Upgrading projects will provide drains, storm structures or, in some cases, both. Thus, in reality, systems are often a combination of both and - even in one street, some sections of drain will be covered, while other sections will remain open. Surface drains are generally easier and cheaper to construct compared to buried pipe systems. This is particularly the case when dealing with large storm water discharges and in cases where land subsidence is a problem. **Open drains are less prone to blockages than pipes because the flow can flow over the top of the obstruction and are easier to inspect and access for removal of debris. Furthermore, when drainage problems occur, it is easier to identify and rectify the location of the problem in an open drainage system.** However, if the surface drains are open, they often act as recipients of solid waste dumped by local residents, which may reduce the flow capacity. In addition:

- They are not as hygienic as closed drains and may smell.
- Children may fall into them or play next to or in them.
- They may provide breeding grounds for mosquitoes

➢ *Roads and paving*. Traditionally, the tendency has been to pave/rebuild roads by building on top of the previous road surface. This tends to create a situation in which road surfaces are above house plinth levels, so that any flooding affects houses rather than public rights of way. Raised streets may also obstruct runoff and impound floodwater on private property. To overcome this, it is important to design road levels as low as possible. It is important that roads are not constructed in a way that fills in and builds upon existing drainage channels or constructed on elevated embankments, which cause flood waters to be impounded and the road surfacing should be seen as an integral part of the drainage system – especially where the road itself is designed as a drainage conduit.

3.2.3 Considerations from Urban Master Plan - Managing Storm Water by 2035

Flash flooding at the low lying area and lack of proper drainage systems are the main issues of storm water sector in Arusha City, especially in the densely populated Central Zone. Currently, the Eastern Zone is mostly rural with agricultural lands. When it is urbanised in the future, post development runoff volume is expected to increase significantly. Coupled with the fact that there are existing rivers flowing through the existing and future developments, flood risk would be higher if there is no proper storm water management. To address the above issues, the proposed storm water management plan has to focus on the following strategies:

- Identification of the main drainage network along the roads to collect and discharge the storm water runoff into the receiving water bodies;
- Utilization of the existing rivers as final discharge point of the drainage network; and
- Construction of constructed wetland to remove pollutants from polluted land use and provide temporary runoff detention and
- Construction of swales to remove pollutants at source before it is discharged into the main drains;

The proposed drains are divided into two categories, primary and secondary drain. Primary drain will discharge the runoff into the existing rivers while secondary drain will collect the runoff from the swales and the remaining road side drains. As much as possible, the drains are proposed along secondary arterial road and roads of higher hierarchy as they tend to have wider service corridor to cater to the required drain width. However, there are selected collector roads that carry either primary or secondary drains due to their low elevation (Arusha Master Plan, 2035).

3.2.3 Rainfall data

The collection of rainfall data involved extensive consultations with Pangani Basin Water Board, Tanzania Meteorological Agency (TMA) and other sources like researchers from academic and research institutions. For the daily rainfall data, statistic measures such as min, max, standard deviation (SD), Coefficient of variation (CV), Skewness, Kurtosis and the total rainfall for very wet days (RVWD) were calculated. The procedure for calculation RVWD were:

- *Identifying the wet days (daily precipitation > = 1 mm)*
- *Computing the 95th percentile of precipitation on wet days (PRwn 95)*
- *Identifying the very wet days (daily precipitation > = PRwn95)*
- *Computing the total precipitation on the very wet days:*

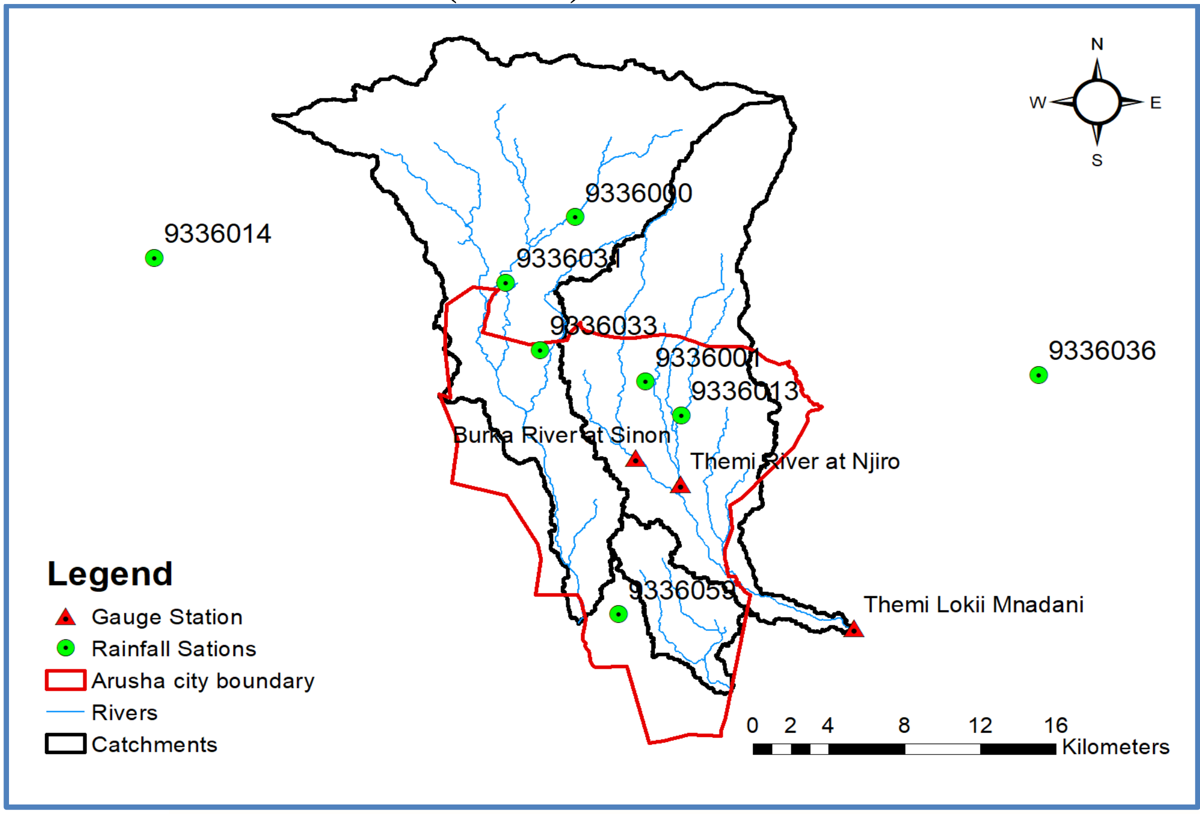
Generally, the main observations are as follows:

- *The rainfall regime is unimodal with one rainy season from November to April.*
- *Dry and wet years are relatively evenly distributed over the long observation period.*
- *The long-term rainfall evolution may be partly described by cycles of dry and wet periods.*
- *The rainfall variability is high especially at the daily time step*

- *Heavy storms tends to occur as a consequence of tropical disturbances prevailing over large areas*
- *The maximum daily rainfall (188.70mm) was observed at Arusha Airport station in year 1990 (Baseline report).*
- *Mean annual rainfall (MAR) ranges 722.35-1119.29.*
- *Minimum rainfall data 0mm*

The rainfall station with long-term daily data around the Arusha City and within the delineated catchment where following

- Minimum rainfall data 0mm (Table 23)



<Figure 12> Distribution of rainfall stations within and around Arusha City

<Table **1**> Inventory of the rainfall stations within and around Arusha City

Station Code	Station Name	Lat	Long	Available Records
9336001	ARUSHA AGRIC. OFFICE	-3.383	36.683	1961-1973
9336059	IMANI ESTATE OLJORO	-3.50	36.67	1978-1985
9336000	OLMOTONYI FOREST	-3.30	36.65	1960-1976/1980-1985

Station Code	Station Name	Lat	Long	Available Records
	STATION			
9336013	THEMI ESTATE	-3.40	36.70	1960-1985
9336031	ARUSHA T.P.R.I.	-3.333	36.617	1960-1985
9336033	ARUSHA AIRPORT	-3.367	36.633	1960-2015
9336036	TENGERU MET	-3.38	36.87	1986-2015
9336014	MONDULI	-3.32	36.45	1956-2015

<Table 1> Statistic summary of the analyzed daily rainfall data

Station Name	Min.	Mean	Max.	SD	CV	Skewness	Kurtosis	Rvwd	NA's	n
Arusha Airport	0.00	2.23	188.70	7.65	3.43	6.78	6.78	12079.50	6.78	6.78
Monduli	0.00	2.25	165.90	7.80	3.46	5.83	49.31	10531.90	588.00	21915.00
TPRI	0.00	2.29	126.50	7.37	3.22	5.99	51.41	5519.20	142.00	9497.00
Themi A Estate	0.00	3.17	161.00	9.81	3.10	5.61	45.70	7391.70	306.00	9497.00
Tengeru Mate	0.00	2.92	130.00	3.00	3.00	5.28	38.47	6946.00	1675.00	10957.00
Olomotonyi	0.00	2.45	157.70	7.90	3.22	6.62	69.26	4520.90	1830.00	9497.00
Imam Estate	0.00	2.29	146.00	8.73	3.81	6.44	60.18	1383.60	153.00	2922.00
Agric. Office	0.00	3.20	179.10	10.39	3.25	6.20	54.81	7224.20	1313.00	9906.00

<Table 3> Mean annual rainfall (MAR) for the stations within and around ARUSHA CITY

Station Code	Station Name	Year Selected	Mar
9336001	ARUSHA AGRIC. OFFICE	13	1098.10
9336059	IMANI ESTATE OLJORO	18	793.34
9336000	OLMOTONYI FOREST STATION	23	722.35
9336013	THEMI ESTATE	26	1119.29
9336031	ARUSHA T.P.R.I.	26	823.39
9336033	ARUSHA AIRPORT	56	814.21

Station Code	Station Name	Year Selected	Mar
9336036	TENGERU MET	30	903.50
9336014	MONDULI	60	800.44

<Table 4> Stream Flows

S/N	Station Code No	Station	Location Name	Location		Gauge Range (m)	Recording Period	Station Status
				Easting	Northing			
1	1DE	Themi	Njiro	253561	9612088	0 to 5.0	2003-2008	working
2	New	Themi	Urangini	242011	9621548			
3	New	Burka	Sinoni	244375	9620079			

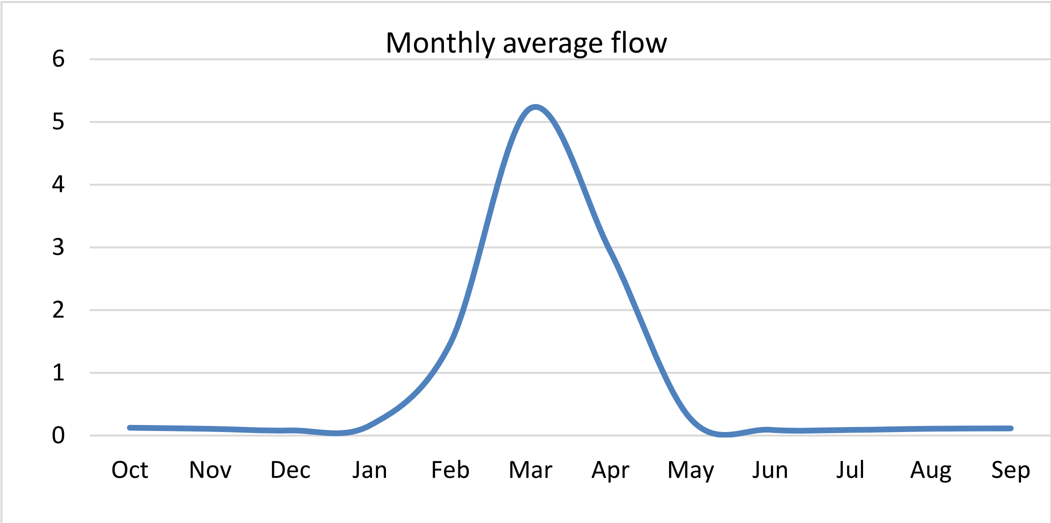
Rating curve equation at Themi Njiro gauge station is

$$Q\left({m^3}/{s}\right) = 17.822(H - 0.046)^{2.8}$$

Valid from 11/09/2003 to 16/04/2008.

<Table 5> Monthly average flow of Themi river at Njiro

Date	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow	0.13	0.11	0.08	0.16	1.47	5.21	2.94	0.27	0.09	0.09	0.11	0.12



3.2.3 Rainfall Runoff Modelling

➢ **Hydro-meteorological Data Acquisition**

Temperature, Related Humidity and Evaporation

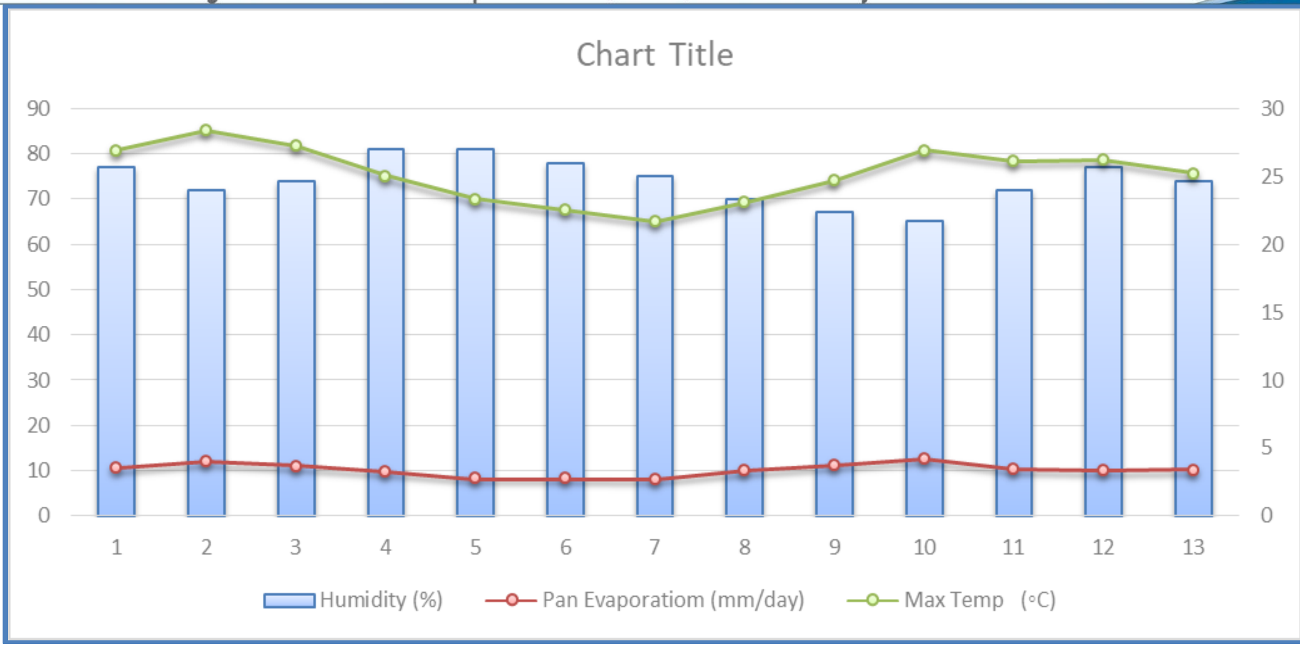
Temperature, related humidity and evaporation data were collected in order to characterize the climate of a region. The analysis results are presented in Table xx and in Figure xx. The main observations are as follows:

- Pan evaporation is maximum between October and March with a peak in October corresponding more or less to the rainy season. Pan evaporation is minimum in April and July
- Annual pan evaporation is big. This can be explained by the lower relative humidity which is a semi-arid region characteristic.

Table 2 Temperature, Relative humidity, pan and potential evaporation at Arusha Airport

<Table 6> Temperature, Relative humidity, pan and potential evaporation at Arusha Airport

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Min Temp (◦C)	13.5	13.4	15.1	15.8	14.9	12.9	12.1	12.5	12.9	14.1	14.5	14.2	13.8
Max Temp (◦C)	26.9	28.4	27.2	25	23.3	22.5	21.7	23.1	24.7	26.9	26.1	26.2	25.2
Humidity (%)	77	72	74	81	81	78	75	70	67	65	72	77	74
Wind (km/day)	78	104	95	104	138	138	147	173	164	173	130	95	128
Sun (Hours)	5.3	6	5	4.8	3.6	4.3	3.8	4.7	5.2	5.8	3.9	4.4	4.7
Rad (Mj/m²/day)	17.4	18.9	17.4	16.3	13.4	13.9	13.4	15.7	17.3	18.5	15.4	16	16.1
Eto (mm/day)	3.48	3.97	3.65	3.26	2.77	2.78	2.72	3.3	3.73	4.21	3.43	3.31	3.38



<Figure 13> Pan Evaporation and relative humidity at Arusha Airport station

3.2.4 New IDF Curve for Arusha City

Daily maximum rainfall data for the eight (8) were used to estimate maximum rainfall intensity for different return periods based on Gumbel distribution which is one of the most widely used probability-distribution functions of extreme values in hydrological and meteorological studies for prediction of flood peaks, maximum rainfalls, maximum wind speed, etc. The probability density function [f(R)] and Cumulative Distribution Function [F(R)] of Gumbel distribution is given by:

$$f(R) = \frac{e^{-(R_i-\alpha)/\beta} e^{-e^{-(R_i-\alpha)/\beta}}}{\beta}, R_i, \beta > 0$$

$$F(R) = e^{-e^{-(R_i-\alpha)/\beta}}$$

Where α and ß are location and scale parameters. The parameters were computed by method of moments (MOM) and used to estimate extreme rainfall (RT) for different return periods using the relation:

$$R_T = \alpha + Y_T\beta$$

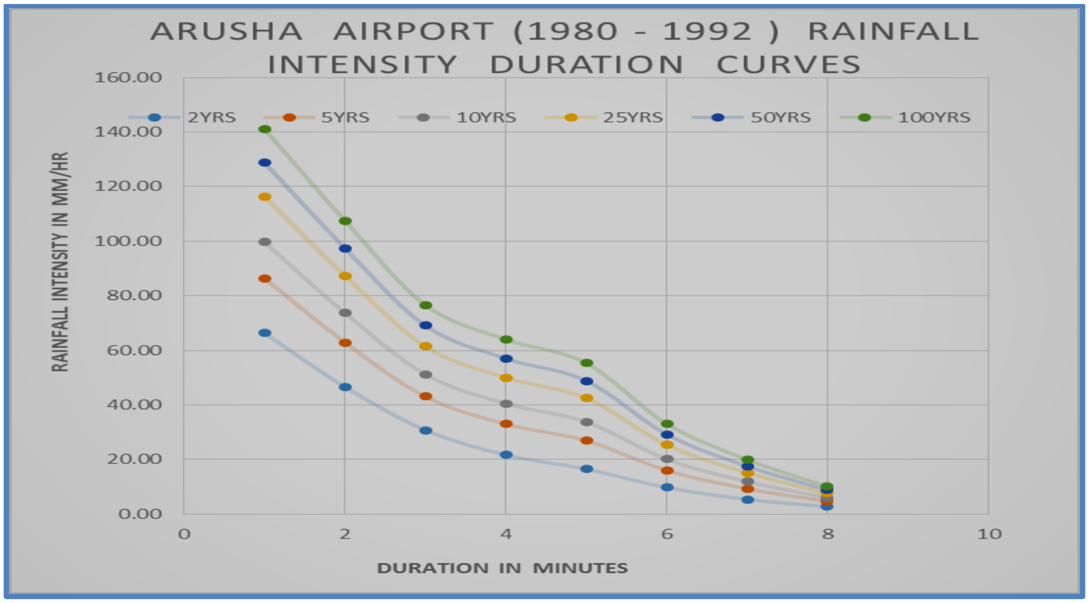
Where

$$\alpha = \overline{R} - 0.5772157\beta$$

$$\beta = \left(\sqrt{6}/\pi\right) S_R$$

$$Y_T = -\mathrm{Ln}(-\mathrm{Ln}(1-(1/T)))$$

Where $\overline{R}$ and SR are the mean and standard deviation of the recorded rainfall data.



<Figure 14> IDF Curve from Arusha Airport Station

3.2.5 Climate Change in Arusha

➢ **Data acquisition**

One of the major impediments to the analysis of climatic trends is the availability of long-term quality climate data. Reliable analysis of climatic trends requires high-quality data for at least 30 years, due to this fact only Arusha Airport rainfall station was selected in trend analysis which have 56 years of precipitation time series data unlike other stations that have less than 30 years' time series precipitation data and Monduli Station which is located outside the boundary despite having 60 years of precipitation data.

- **Trend Detection Using Mann-Kendall Test (M-K Test)**

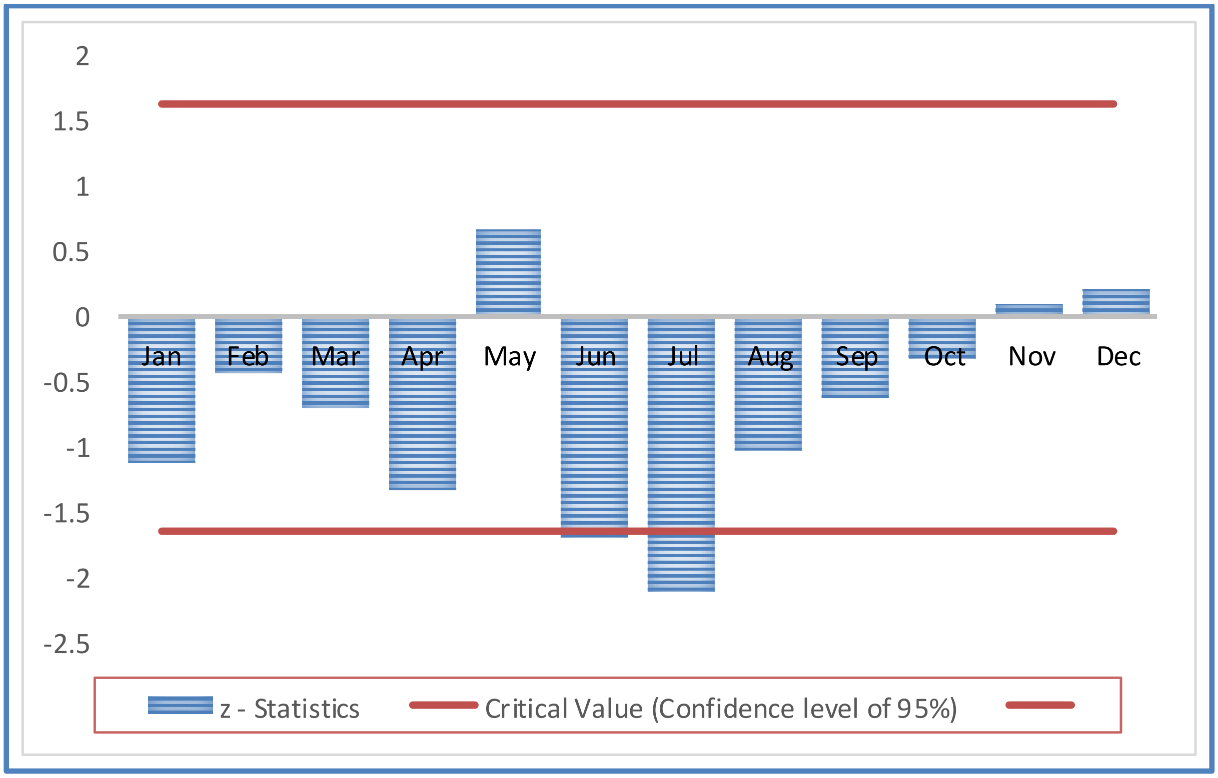
The test is usually known as Kendall tau statistics and has been widely used to test for randomness against trend in hydrology and climatology. It was employed in this rainfall trend analysis because it is a non-parametric ranked based procedure which is robust to the influence of extremes and good for use with Skewed variables.

The analysis was done in each month based on monthly precipitation data of Arusha Airport rainfall station from 1959 to 2015. Trend detection of each month was statistically computed with M-K test in a confidence level of 95% on which computed z-statistics of each month was compared to critical value of ±1.645 in order to determine trend detection. If z-Statistics is higher than the critical value thus means that there is statistically significant trend in our test, otherwise there are no statistically significant trends.

<Table 9> Statistical analysis and Mann-Kendall Trend test results (M-K Test)

Month	Min.	Max.	Mean.	G.Mean.	Median.	S.D	Coeff Variation	M-K Test	S.D of S	Z-Statistics	P-Value
Jan	0.7	225.1	63.22	43.37	46	50.21	0.794	-159	141.5	-1.117	0.132
Feb	8.2	229.6	69.54	51.58	56.05	51.75	0.744	-61	141.5	-0.424	0.336
Mar	2.4	367.1	126.3	99.37	117	78.42	0.621	-100	141.5	-0.7	0.242
Apr	31.8	515.2	211.8	179.8	187.8	115	0.543	-190	141.5	-1.336	0.0908
May	6.1	237	85.48	68.95	76.3	51.51	0.603	97	141.5	0.679	0.249
Jun	0	86.7	12.38	0	7.45	16.01	1.293	-240	141.4	-1.69	0.0455
Jul	0	39.1	6.25	0	2.95	8.44	1.35	-299	141.3	-2.109	0.0175
Aug	0	36.1	6.061	0	1.9	9	1.485	-146	140.9	-1.029	0.152
Sep	0	58.4	7.705	0	2.1	13.69	1.777	-89	141.2	-0.623	0.267
Oct	0	130.7	25.02	0	12.2	32.26	1.289	-46	141.5	-0.318	0.375
Nov	1.4	468.9	102.6	63.62	83.7	91.65	0.894	15	141.5	0.0989	0.461
Dec	6.9	386.6	97.9	74.62	79.4	70.36	0.719	33	141.5	0.226	0.411

With level of confidence of 95% and critical value of ±1.645, trend of rainfall for 56 years from January to December has been calculated for each month individually. The z-Statistics revealed the trend of the series for 56 years for individual 12 months from January to December which are -1.117, -0.424, -0.7, -1.336, 0.679, -1.69, -2.109, -1.029, -0.623, -0.318, 0.0989, 0.226 respectively. For May, November and December there is an evidence of rising trend while z-Statistics value is showing negative trend in January, February, March, April, June, July, August, September and October. But z-Statics values of June and July have exceeded the critical value of ±1.645 and shows that there is significant in negative trend while other months have non-significant trend conditions.



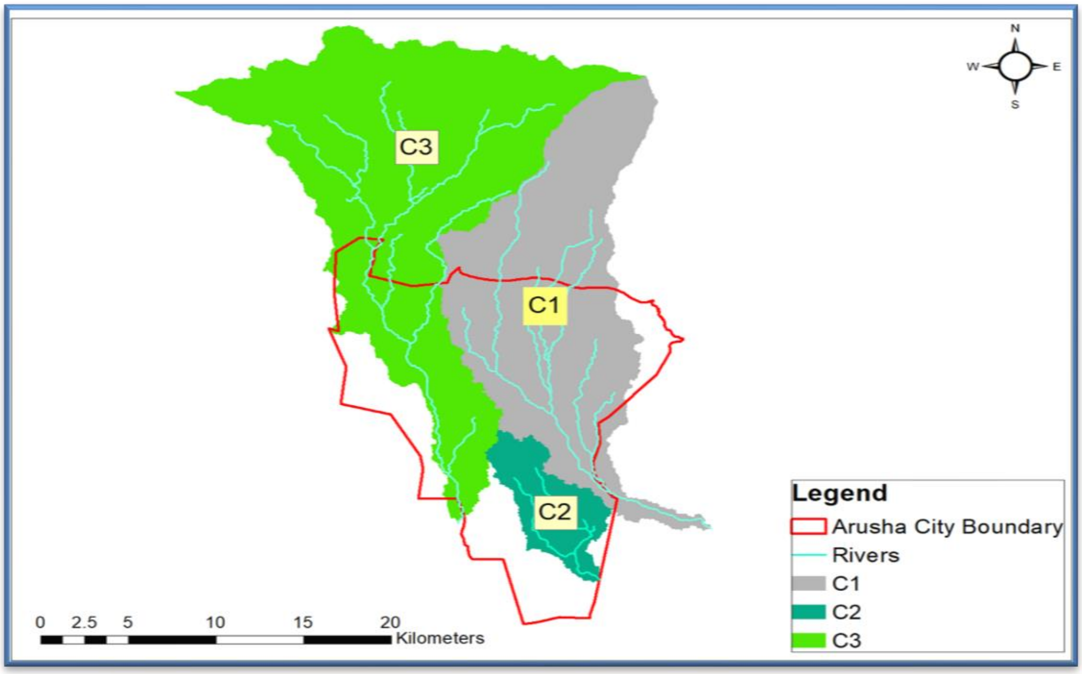
<Figure 15> Statistics distribution with the Critical value

Even though rainfall varies in different months for different years which can be seen in graphs, there are nine months with decreasing in trend or negative z-Statics value and three months of increasing trend and z-Statistics value. Therefore, it can be concluded that there is evidence of decreasing of precipitation of the region with time while months of June and July which are dry season have significant decrease in precipitation with time that can lead to extreme dry season in the future, that means that IDF curves obtained from historical data give as a output the highest rainfall volume. Climate change seems to gain some importance when considering high return periods and duration in the order of magnitude of the day.

Strategies to reduce the risk posed by these disasters are aimed at establishing a disaster planning framework, establishing rural area development plans, relocating vulnerable communities, improving building codes, encouraging terracing and contour farming, and developing an early warning system for flood events (World Bank,2018).

3.2.6 Catchment Delineation

The catchments inside the planning area have been delineated through a geo-processing tool. With the GIS software and by means of a 2 meters grid digital elevation model a total of three (3) catchments draining the ARUSHA CITY have been delineated. Catchments C1 up to C3 drain to Themi River which joins the Pangani River about 20 km from the ARUSHA CITY boundary.



<Figure 16> Delineated catchments in Arusha

Each watershed has been identified with a progressive code for a total of 41catchments. The overall catchments' surface discharging within the planning area is 506.09 km. The main geographical features of the watersheds are showed in the following table.

<Table 10> Geographical features of the watersheds

Catchment	Catchment	Area	River Length	River Slope	Catchment Slope
CODE	Name	(km^2)	(m)	%	%

Catchment	Catchment	Area	River Length	River Slope	Catchment Slope
C1A	W140	*39.88*	12927.10	0.03	24.02
C1B	W150	15.64	10379.02	0.03	24.62
C1C	W160	18.47	6038.04	0.01	22.81
C1D	W170	18.00	17427.06	0.03	10.22
C1E	W180	23.46	9906.85	0.02	6.23
C1F	W190	20.49	2386.56	0.02	8.42
C1G	W200	3.16	4791.59	0.01	5.89
C1H	W210	16.14	1525.02	0.02	4.92
C1I	W220	1.96	9622.72	0.01	5.44
C1J	W230	15.79	5286.13	0.02	5.80
C1K	W240	13.44	6871.54	0.02	6.66
C1L	W250	1.65	3126.78	0.02	7.20
C1M	W260	8.46	7148.82	0.00	5.40
C2A	W80	7.96	6027.25	0.02	4.50
C2B	W90	3.30	710.89	0.04	6.73
C2C	W100	3.43	329.09	0.02	5.96
C2D	W110	0.15	600.16	0.02	5.13
C2E	W120	3.86	1982.01	0.01	5.07
C2F	W130	11.88	7963.59	0.02	5.73
C2G	W140	2.81	2801.44	0.00	4.80
C3A	W220	21.41	1947.39	0.05	14.46
C3B	W230	17.23	5844.16	0.11	30.41
C3C	W240	9.61	5865.55	0.02	30.00
C3D	W250	22.75	3032.59	0.02	18.31
C3E	W260	14.88	7451.23	0.02	21.47

Catchment	Catchment	Area	River Length	River Slope	Catchment Slope
C3F	W270	6.76	7784.70	0.03	11.56
C3G	W280	33.80	976.66	0.02	18.54
C3H	W290	3.27	971.82	0.02	8.23
C3I	W300	1.21	4216.37	0.02	11.50
C3J	W310	9.48	1481.99	0.02	14.01
C3K	W320	25.80	161.89	0.00	10.80
C3L	W330	16.63	7134.48	0.04	8.95
C3M	W340	8.75	4474.00	0.02	12.27
C3N	W350	0.10	4946.90	0.02	4.14
C3O	W360	5.15	5092.90	0.01	5.18
C3P	W370	17.59	6849.51	0.01	5.95
C3Q	W380	9.97	3301.46	0.01	7.39
C3R	W390	8.97	16243.02	0.02	5.03
C3S	W400	20.30	10712.58	0.01	7.84
C3T	W410	15.62	4744.17	0.02	5.31
C3U	W420	6.88	3856.85	0.01	6.95

➢ **Digital Terrain Model**

Two high resolution DTM data have been used:

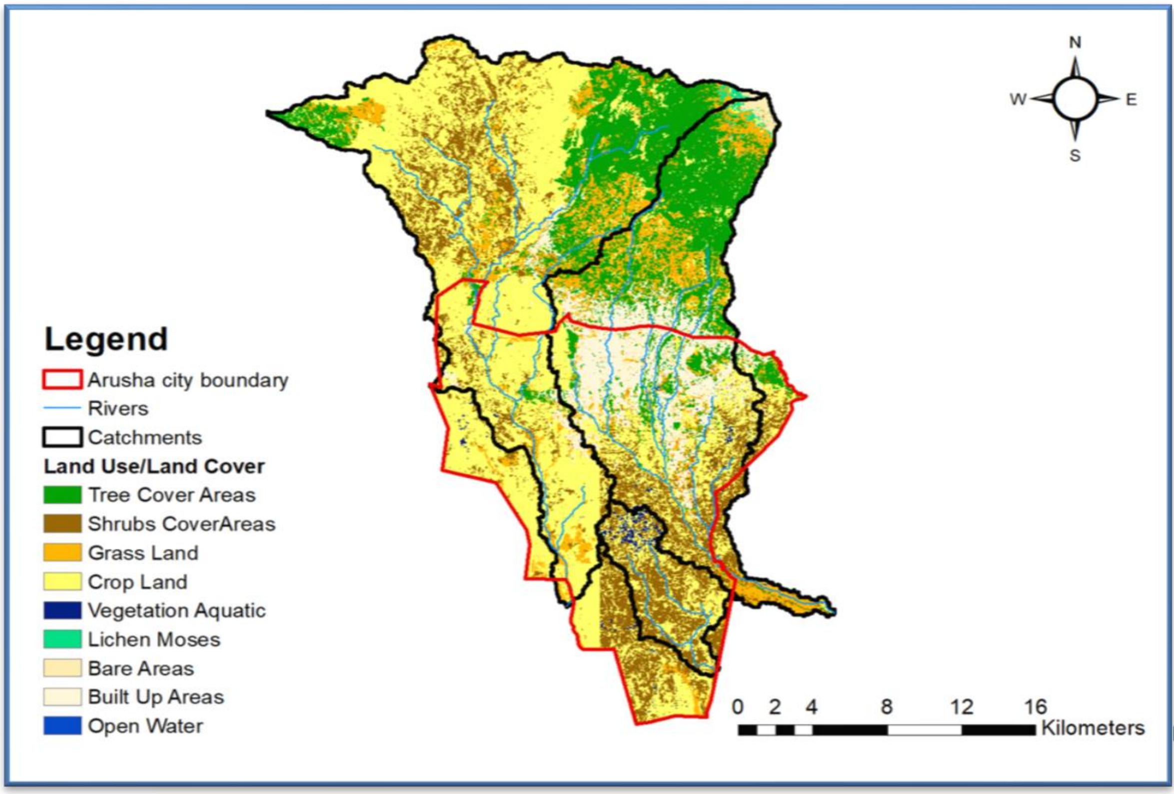
- SRTM 30m resolution
- Topographical Contour data with 2m resolution

The DTM data have been used for:

- Catchment delineation
- Drainage network analysis
- Extracting the river geometry/cross sections
- Extracting the Elevation – storage characteristics of the ponds

- **Land use/cover**

The land use/cover data have been obtained from European Space Agency (ESA) Climate Change Initiative. The dataset has been developed at 20m, based on 1 year of Sentinel-2 A satellite observations from December 2015 to December 2016. Two classification algorithms, the Random Forest (RF) and Machine Learning (ML), were used to transform the cloud-free reflectance composites generated by the pre-processing module into a land cover map. The two maps resulting from both approaches are then combined either to select the best representation of a land cover class which will be part of the final S2 prototype LC 20m map of Africa 2016 or, in case of unreliable LC class delineation, the reference layer is used to consolidate the land cover classification.



<Figure 17> Land use characteristics

From the above map the land use characteristics of Arusha city is distributed as follows in %, see table 9 below.

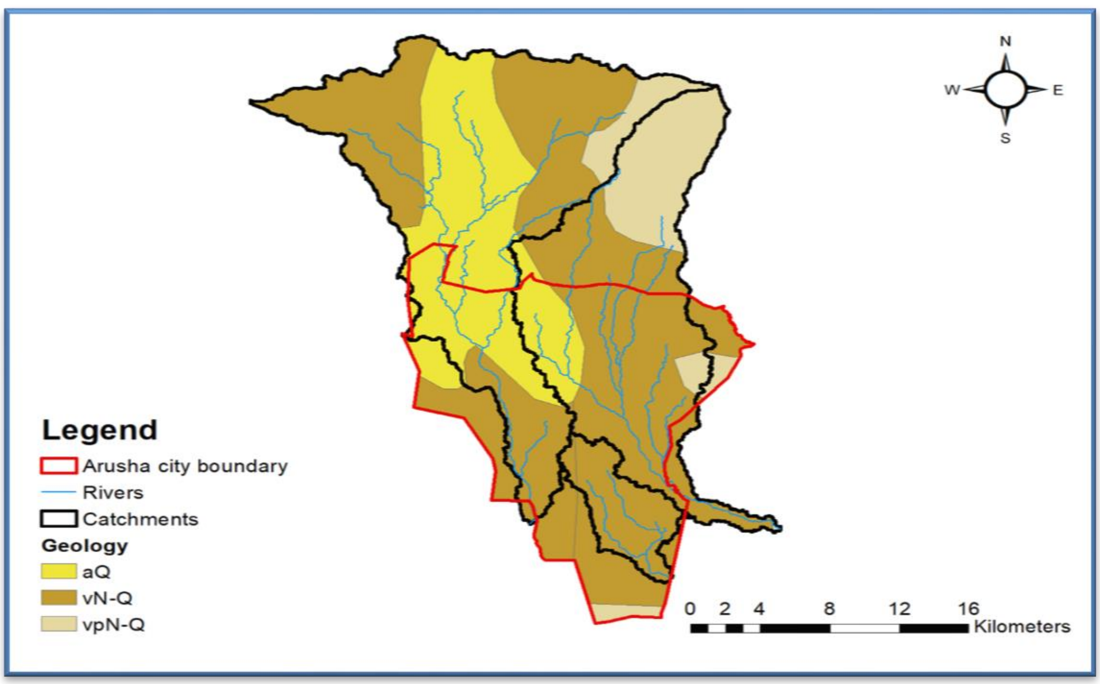
<Table 11> Land Use Distributions

No.	Land Uses	Area(km2)	Coverage (%)
1	Tree cover areas	102.25	17.79

No.	Land Uses	Area(km2)	Coverage (%)
2	Bush land	96.45	16.78
3	Grassland	65.48	11.37
4	Cropland	249.71	43.44
5	Vegetation aquatic or regularly flooded	3.36	0.58
6	Lichens Mosses / Sparse vegetation	1.77	0.31
7	Bare areas	3.03	0.53
8	Built up areas	52.81	9.19
9	Snow and/or Ice	0	0
10	open water	0.03	0.01
Total		**574.89**	**100**

➢ Geological Formation

The geology map produced by the Geological Survey of Tanzania (GST) has been used to



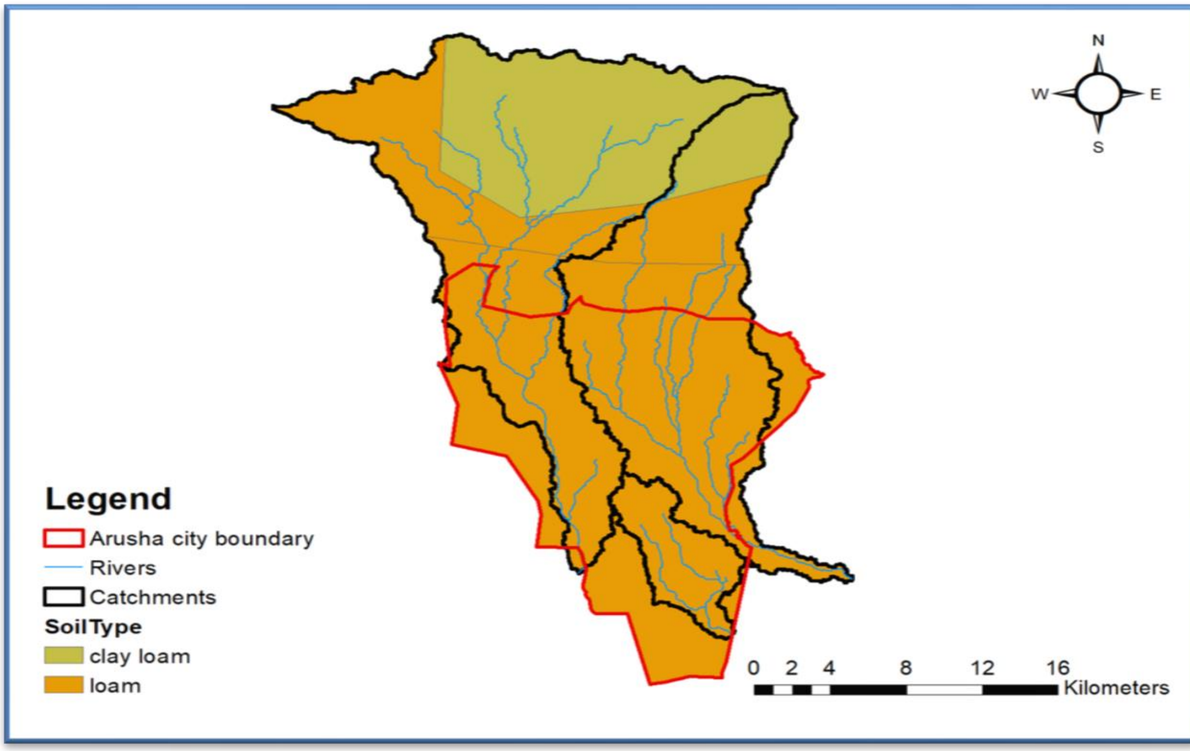
understand the lithology in ARUSHA CITY

Code	Geology	Lithology	Additional info.

Code	Geology	Lithology	Additional info.
aQ	Predominantly alluvial and eluvial sediments	Sandy, gravelly, silty sediments	Quaternary deposits, predominantly alluvial and eluvial sediments
vN-Q	Predominantly volcanic lavas (nephelinite, phonolithe, alkalibasalts)	Volcanic lavas (nephelinite, phonolithe, alkalibasalts)	Neogene-Quaternary volcanic formations
vpN-Q	Predominantly pyroclastics with alkaline volcanic lavas	Pyroclastics, alkaline volcanic lavas	Neogene-Quaternary volcanic formations

➢ **Soil Formation**

The Harmonized World Soil Database (HWSD) has been used to classify soils in the ARUSHA CITY catchments.



<Figure 18> Soil formation and characterization

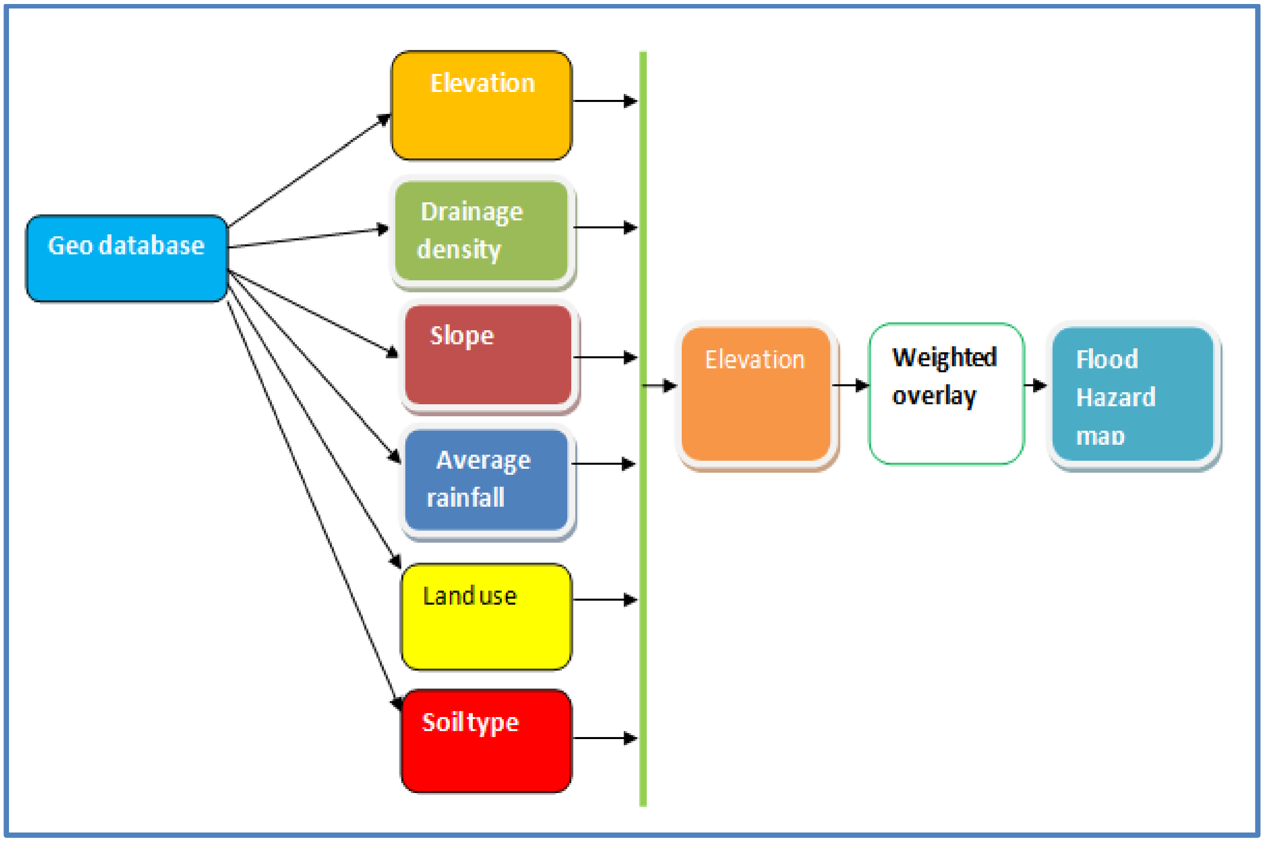
<Table 12> Soil formation and coverage

No.	Soil Name	Soil Type	Area(km2)	Coverage (%)	Hydro Group
1	Leptosols	Clay Loam	147.72	25.69	D
2	Andosols	Loam	95.91	16.68	B
3	Chernozems	Loam	331.27	57.62	B

3.2.7 Flood Risk and Vulnerability Mapping

➢ **Flood hazard zones delineation**

The flood generating factors, such *as slope, elevation, rainfall, drainage density, land use, and soil type in the ARUSHA CITY* were rated and combined to delineate flood hazard zones using multi-criteria AHP techniques in a GIS environment



<Figure 19> Methodology for flood hazard mapping

➢ **Flood hazard factor analysis**

The rasterized and classified flood generating factors have to be weighted. In this study Saaty's approach was used based Analytic Hierarchy Process (AHP), where a pair-wise comparison was prepared for each map using a nine-point importance scale. According to Saaty, (1980) AHP is a multi-criteria decision-making technique, which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent, qualitative as well as quantitative information. It is a methodology to systematically determine the relative importance of a set of activities or criteria by pair wise comparison.

The computed Eigen Vector values Table 3 were used as coefficient for the respective flood factors that is elevation, land use, rainfall, drainage density, slope and soil type layers to be combined in weighted overlay in ArcGIS to generate the final flood hazard map of Arusha City, using the following equation: Flood hazard = 0.439 × [Elevation] + 0.239 × [Drainage density] + 0.134 × [Slope] + 0.092 × [Rainfall] + 0.059 × [Land use] + 0.038 × [Soil type]

<Table 13> Satty's scale (weight) for pair-wise comparison of flood factors

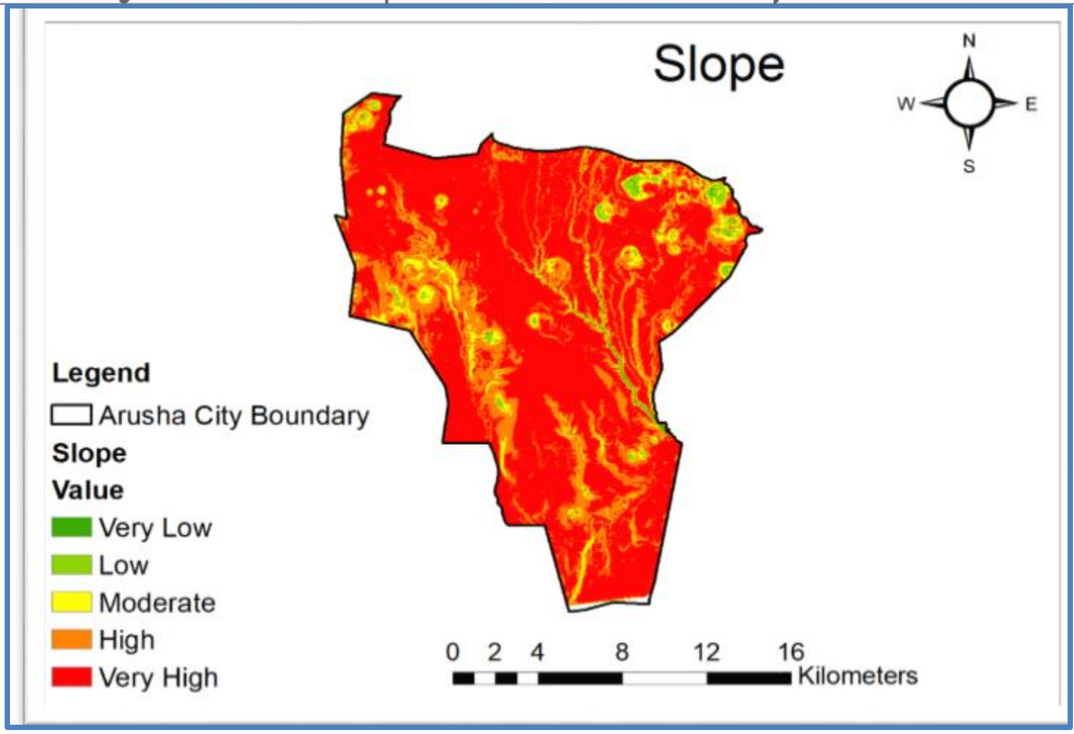
Less Important				Equally important
Extremely	Very Strong	Strongly	Moderately	
1/9	**1/7**	**1/5**	**1/3**	**1**

<Table 14> The weights for the pair-wise comparison matrix of flood generating factors in the Arusha City

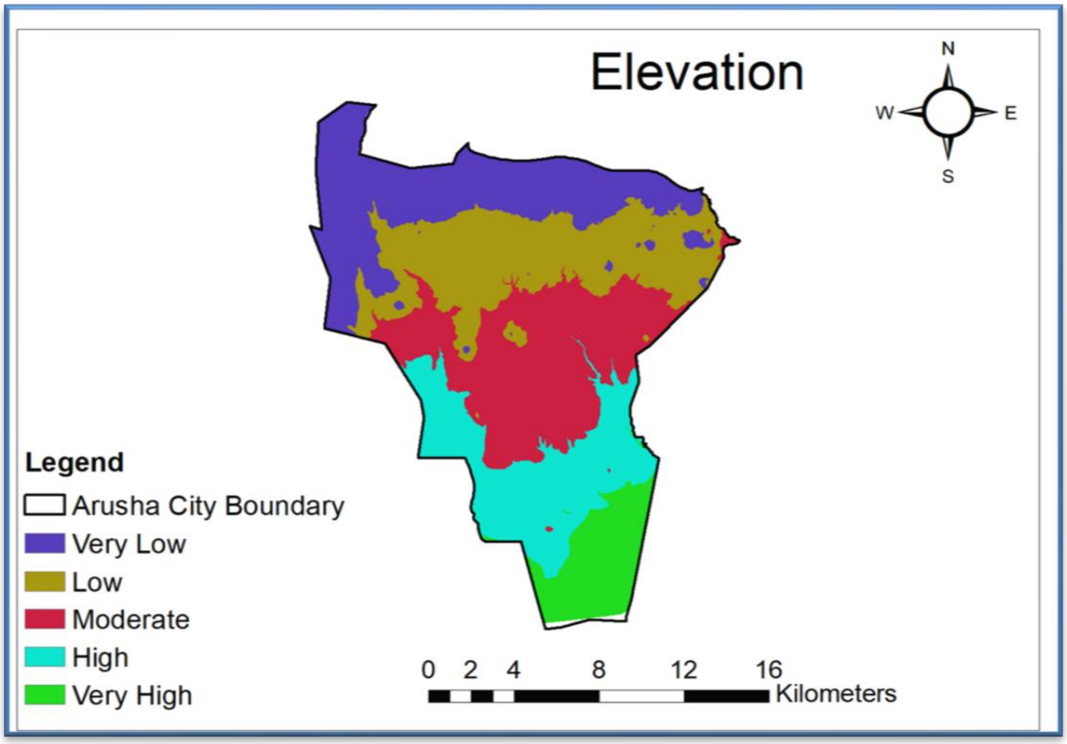
No.	Elevation	Drainage	Slope	Rainfall	Land use	Soil type
Elevation	1	-	-	-	-	-
Drainage density	1/5	1	-	-	-	-
Slope	1/3	1/3	1	-	-	-
Rainfall	1/5	1/5	1/3	1	-	-
Land use	1/5	1/7	1/5	1/3	1	-
Soil type	1/7	1/7	1/5	1/3	1/3	1

<Table 15> The Eigen Vector weights of each flood factor obtained after the pair-wise comparison

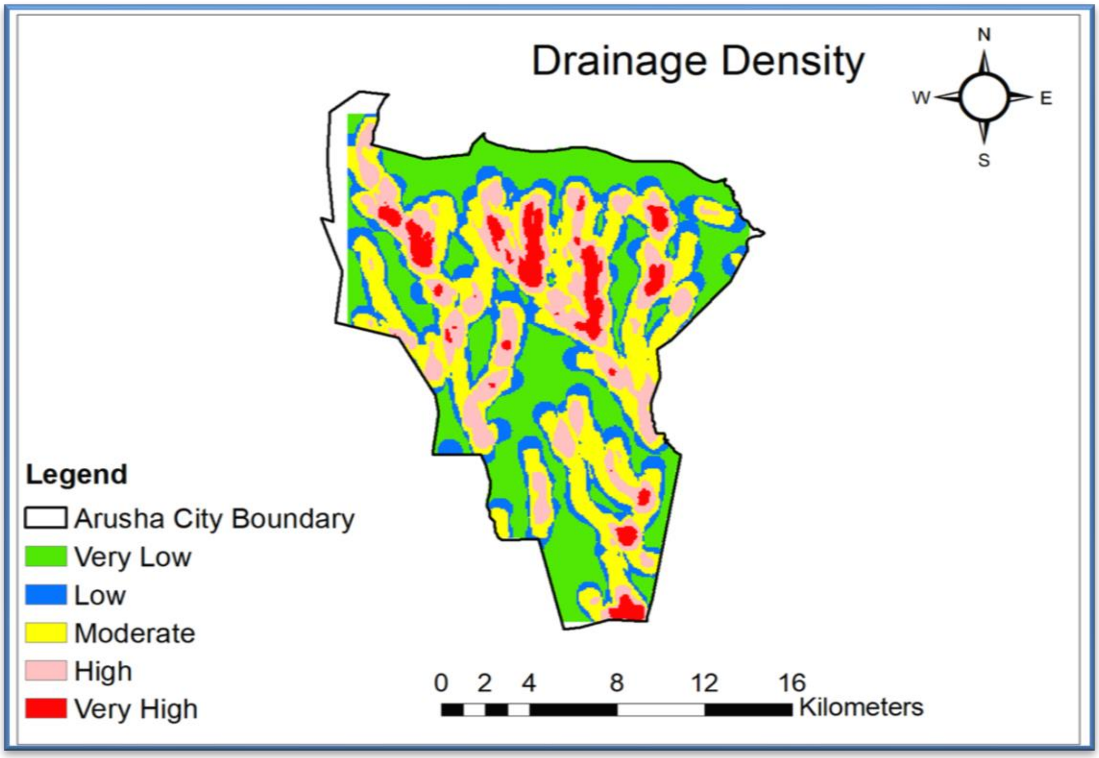
Elevation	0.439
Drainage density	0.239
Slope	0.134
Rainfall	0.092
Land use	0.059
Soil type	0.038



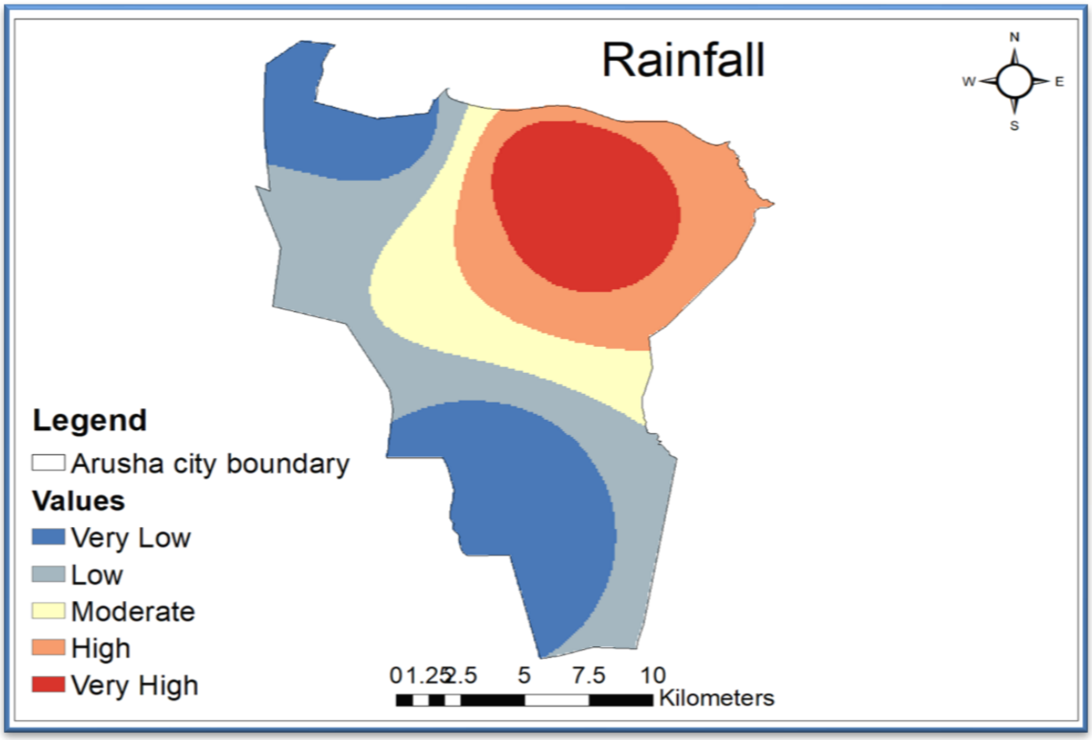
<Figure 20> Susceptibility to flooding: rating of slope.



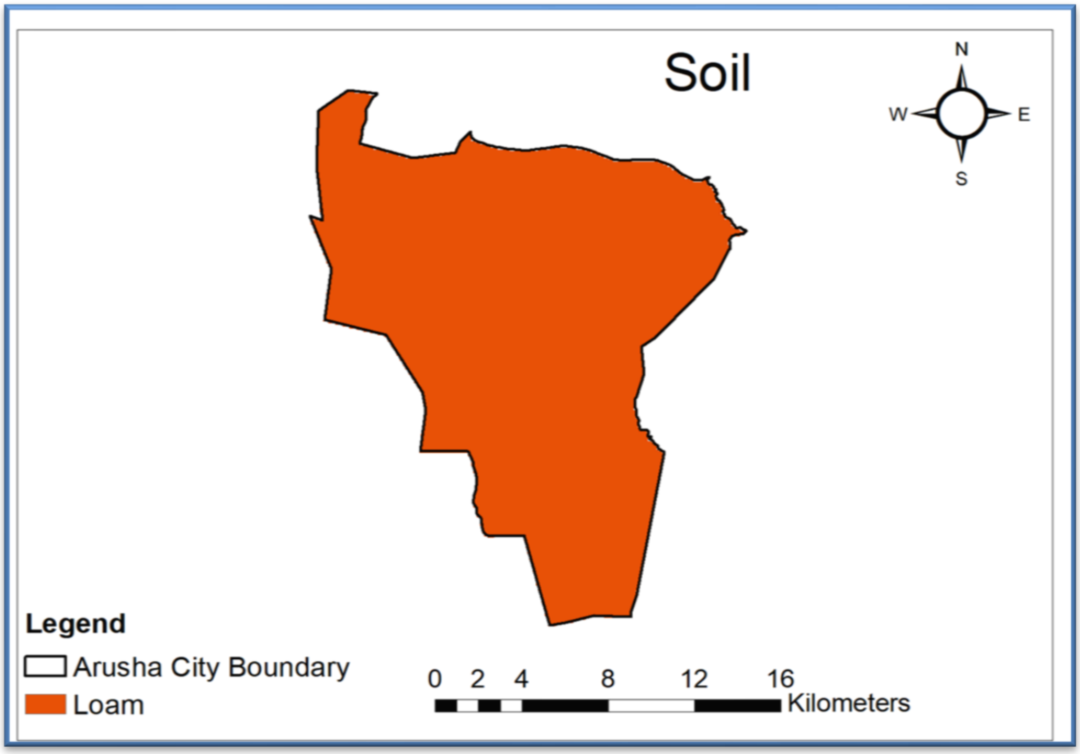
<Figure 21> Susceptibility to flooding: rating of elevation.



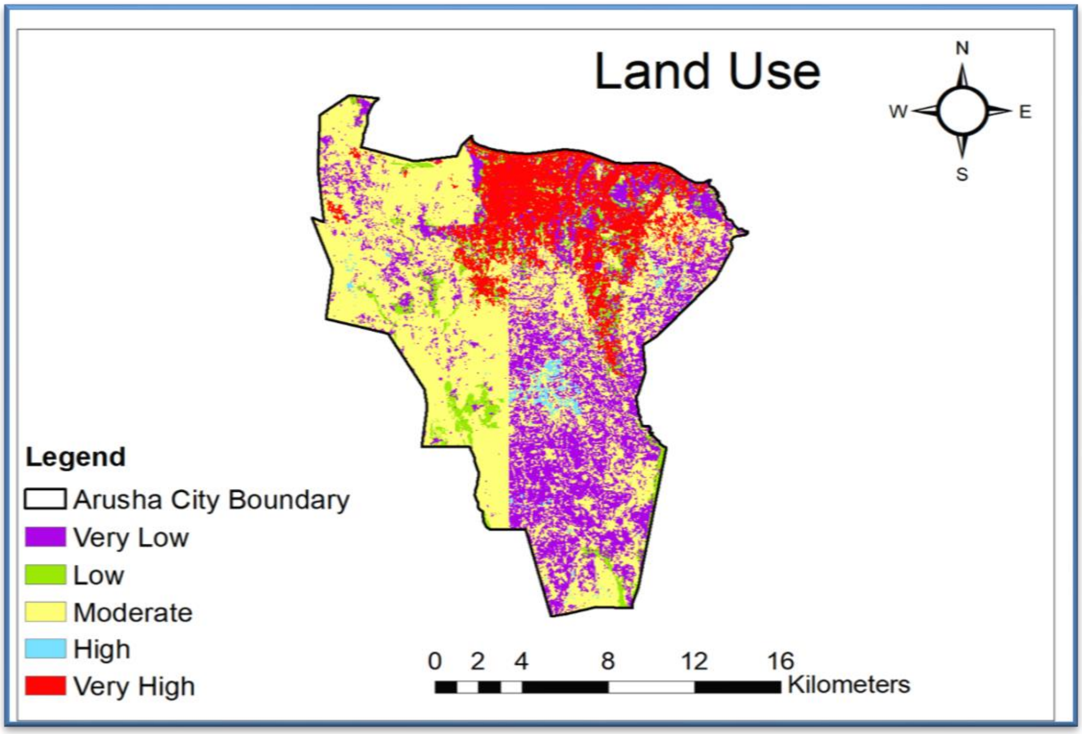
<Figure 22> Susceptibility to flooding: rating of drainage density.



<Figure 23> Susceptibility to flooding: rating of drainage rainfall.

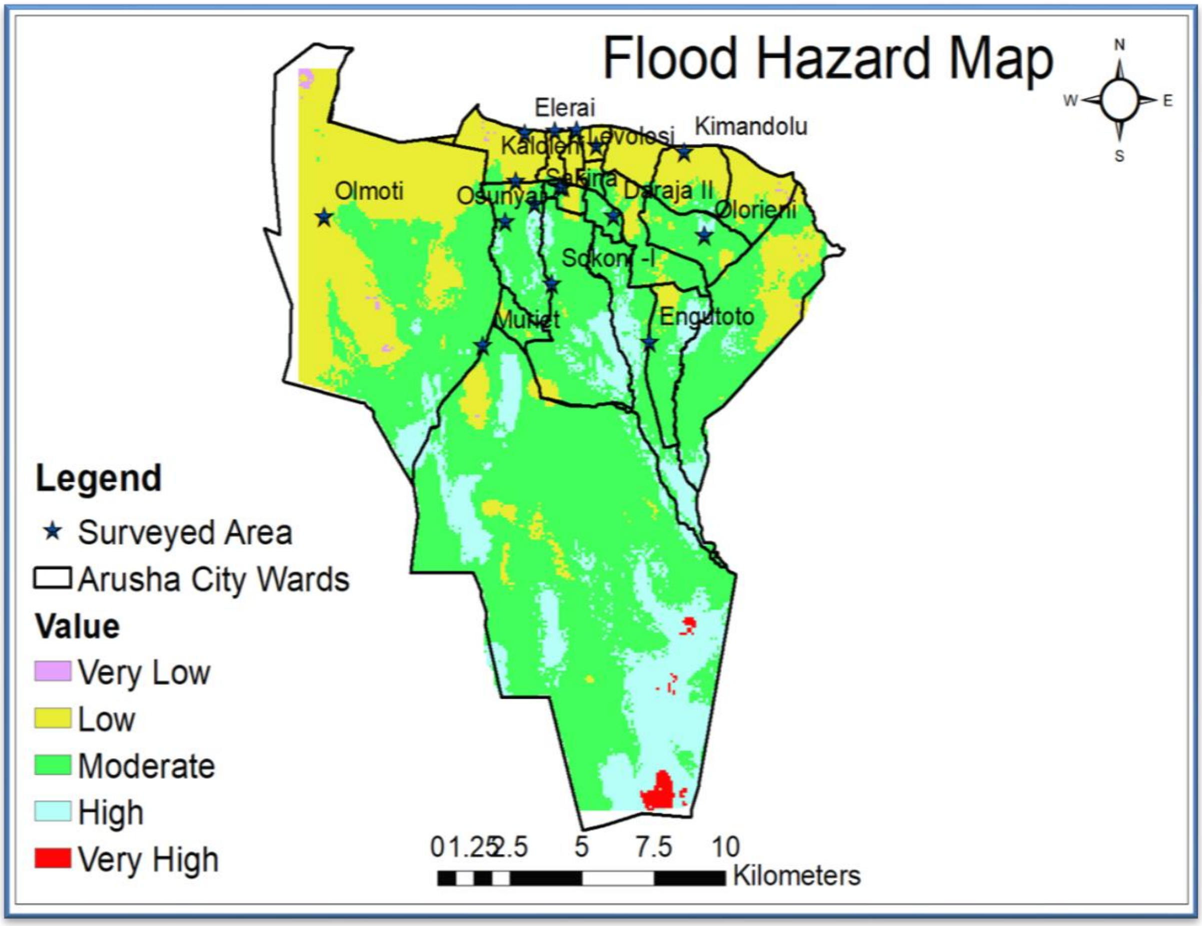


<Figure 24> Susceptibility to flooding: rating of soil type.



<Figure 25> Susceptibility to flooding: rating of land use.

Flood hazard map



<Figure 26> Flood Hazard Map of Arusha City

3.2.8 Hydraulic Analysis

➢ **Design Return Period**

Hydrologic Modeling System (HEC-HMS) was used to obtain synthetic hydrographs. HECHMS is designed to simulate the complete hydrologic processes of dendritic watershed systems. The software includes many traditional hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing. HEC-HMS also includes procedures necessary for continuous simulation including evapo-transpiration, snowmelt, and soil moisture accounting.

The HEC HMS model has four components to simulate the basic hydrologic processes of runoff generation from rainfall, its transformation and combination with base flow and it's routing towards the outlet. These four components are (i) infiltration loss, (ii) direct runoff, (iii) base flow, (IV) Channel routing.

- **Transform method**

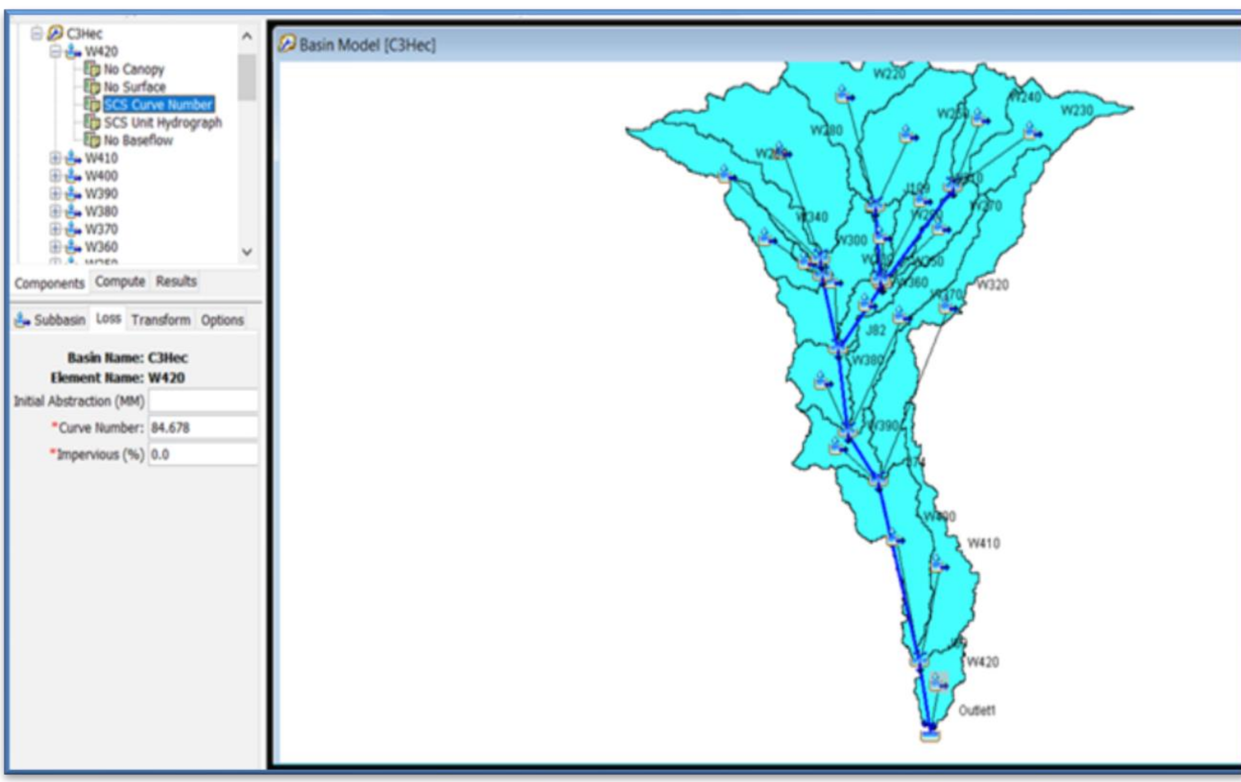
SCS UH unit hydrograph procedure is adopted to simulate a natural hydrograph. This procedure assumes that discharge at any time is proportional to the volume of runoff and that time factors affecting hydrograph shape are constant.

The standard lag is defined as the length of time between the centroid of precipitation mass and the peak flow of the resulting hydrograph:

$$t_L = 0.342\frac{L^{0.8}}{s^{0.5}}(\frac{1000}{CN} - 9)^{0.7}$$

Where

- tL lag (h);
- L Longest flow path (km);
- s Average watershed land slope (%);
- CN Curve Number.



<Figure 27> HEC-HMS SCS unit hydrograph transform method in ARUSHA CITY Catchment

- **Loss Method**

The Soil Conservation Service (SCS) curve number (CN) method is selected for computing the runoff volume. The soil and land-cover maps are used to compute for the Curve Number (CN) parameter of the SCS-CN infiltration loss component. The CN parameter is dependent on land cover, hydrologic soil group based on the soil texture, and antecedent moisture condition. The higher the CN, the higher the runoff potential.

In assigning a curve number to a hydrologic soil-cover complex, it is necessary to consider first the antecedent moisture condition (AMC) of the watershed (Table 20). AMC is the total rainfall in the five-day period preceding a storm or rainfall event under consideration.

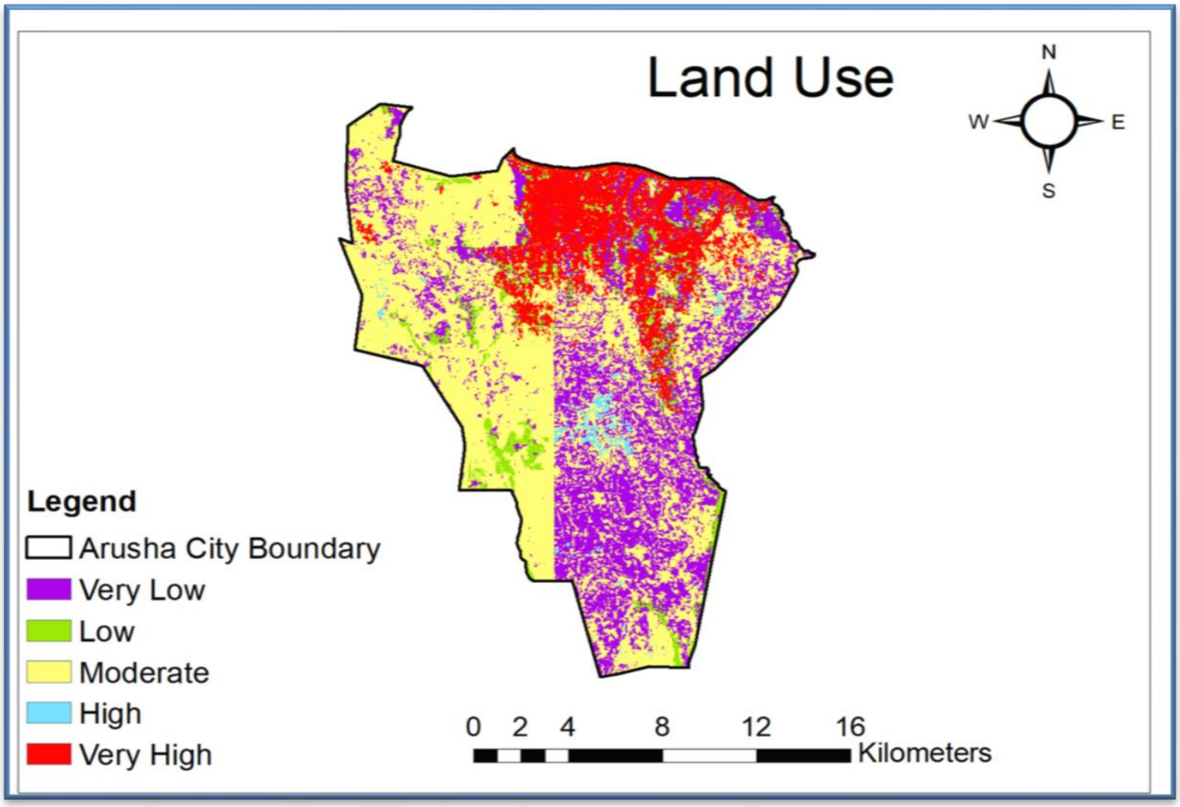
AMCI is basically a "dry" condition, while AMCII connotes a "normal" moisture condition of the watershed. AMCIII refers to a "wet" condition of the watershed. In this assignment, CN (II) values were initially used and later transformed to CN (III) using the equation:

$$CNIII = 23 \times (10 + (0.13 \times CNII))$$

The first step in this analysis is to delineate the basin and sub-basin using geoprocessing tool GIS. Data needed in this step is DTM data. The next step is to define the basin land use maps by intersecting the basin maps with the land use map and then is to estimate the CN for each land use class.

Land use map legend

Value	Label
0	No data
1	Trees cover areas
2	Shrubs cover areas
3	Grassland
4	Cropland
5	Vegetation aquatic or regularly flooded
6	Lichen Mosses / Sparse vegetation
7	Bare areas
8	Built up areas
9	Snow and/or Ice
10	Open water



<Figure 33> Arusha City Land Use Map

The final step is to calculate the CN for each drainage basin by area-weighting the land use-soil group polygons within the drainage basin boundaries.

The basic equation for CN calculation is:

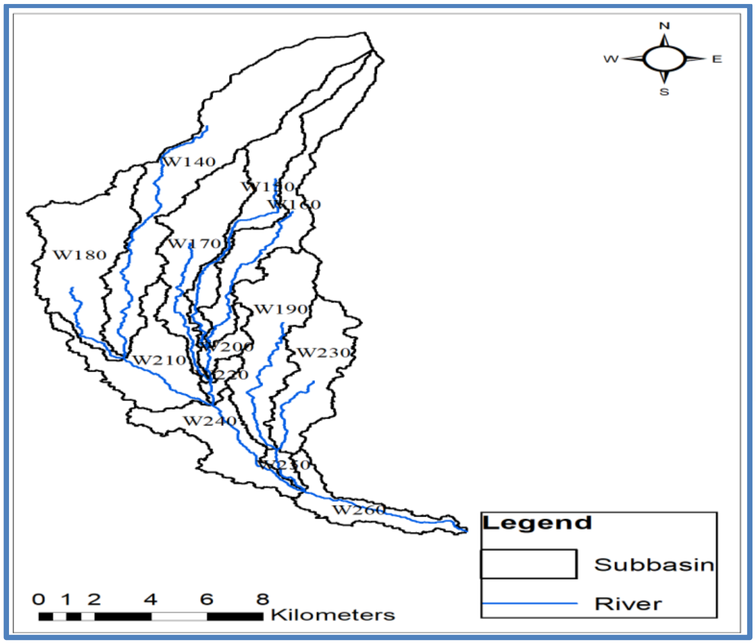
$$CN_{aw} = \frac{\sum_{i=1}^{n}(CN_i \times A_i)}{\sum_{i=1}^{n} A_i}$$

Where:

- CN_{aw} is the area-weighted CN for the drainage basin;
- CN_i and Ai are CN and area respectively for each land use-soil group polygon, and n is the number of polygons in each drainage basin.

<Table 9> Peak Flow Analysis Results

Catchment Code	Catchment Name	CN	TC (hrs)	Lag Time (hrs)	Q5-yr	Q10-yr	Q25-yr	Q50-yr	Q100-yr
					Current Conditions				
C1a	W140	89.71	2.77	1.66	40.67	49.56	56.34	62.83	69.26
C1b	W150	87.01	2.63	1.58	17.24	21.01	23.88	26.63	29.36
C1c	W160	87.75	2.6	1.56	20.39	24.84	28.24	31.49	34.72
C1d	W170	86.7	3.34	2	16.54	20.15	22.91	25.55	28.16
C1e	W180	86.81	4.03	2.42	20.54	25.03	28.45	31.73	34.98
C1f	W190	86.98	3.39	2.04	21.50	26.20	29.78	33.22	36.62
C1g	W200	88.16	1.89	1.14	4.09	4.98	5.66	6.31	6.96
C1h	W210	85.82	3.26	1.96	17.68	21.54	24.49	27.31	30.10
C1i	W220	87.92	1.35	0.81	2.32	2.83	3.22	3.59	3.95
C1j	W230	83.57	3.69	2.21	15.45	18.83	21.41	23.87	26.32
C1k	W240	82.74	3.17	1.9	13.95	17.00	19.33	21.55	23.76
C1l	W250	82.49	1.28	0.77	2.69	3.28	3.73	4.16	4.59
C1m	W260	82.05	3.5	2.1	8.02	9.77	11.10	12.38	13.65



<Figure 28> Main Catchment Peak flow analysis

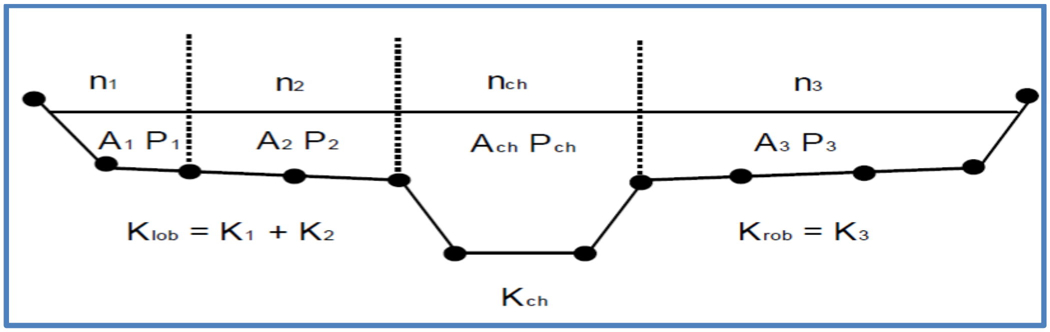
3.2.9 Hydraulic Modeling

- **HEC-RAS Model**

Hydrologic Engineering Center-River Analysis System (HEC-RAS), a renowned hydrodynamic model for natural channel networks has been used as a modeling framework. HEC-RAS is designed to perform 1D/2D hydraulic calculations for a full network of natural and constructed channels. The HEC-RAS system contains four components for

- Steady flow water surface profile computations;
- Unsteady flow simulation;
- Movable boundary sediment transport computations; and
- Water quality analysis.

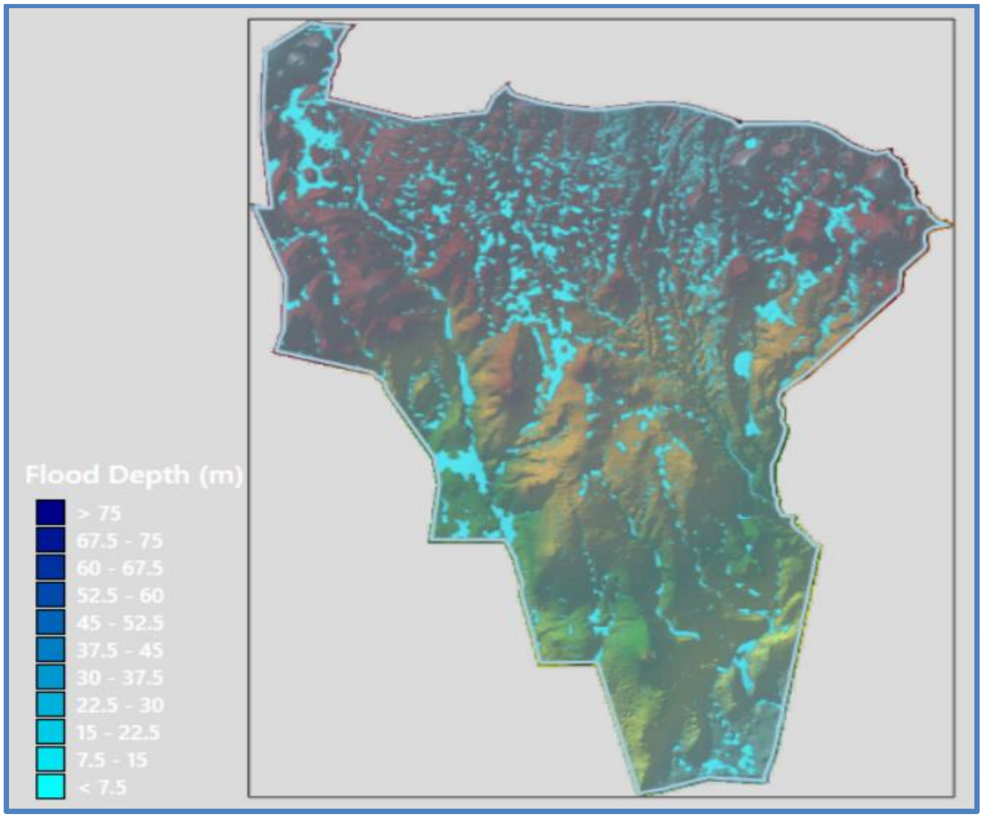
A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In steady flow water surface profiles component, water surface profiles are calculated for steady gradually varied flow. The system can handle a single river reach, a dendritic system, or a full network of channels. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. In model set up, it is necessary to divide the cross sections into parts that have homogeneous hydraulic properties; in the direction of the flow .These are usually the left/right overbanks and the main channel. It is assumed that there is no exchange of energy across the boundaries. Both the water Surface elevation and the total energy head are assumed to be constant at the whole cross section. Such an assumption partly helps to reduce data requirements on observed water surface for calibration. Besides, in the field practice, it is difficult to capture the small changes in water surface elevation between the inner and out banks at the meander as theoretically idealized.



<Figure 29> HEC-RAS Model Cross section subdivided into parts that have homogeneous hydraulic properties

Note: K_i is conveyance factor; n_i is Manning's roughness number; P_i is wetted perimeter; A_i is flow area; lob, ch, and rob signify left overbank, main channel, and right over bank, respectively.

The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning Equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions). The effects of various obstructions such as bridges, levees, culverts, weirs, spillways and other structures in the flood plain may be considered in the computations.

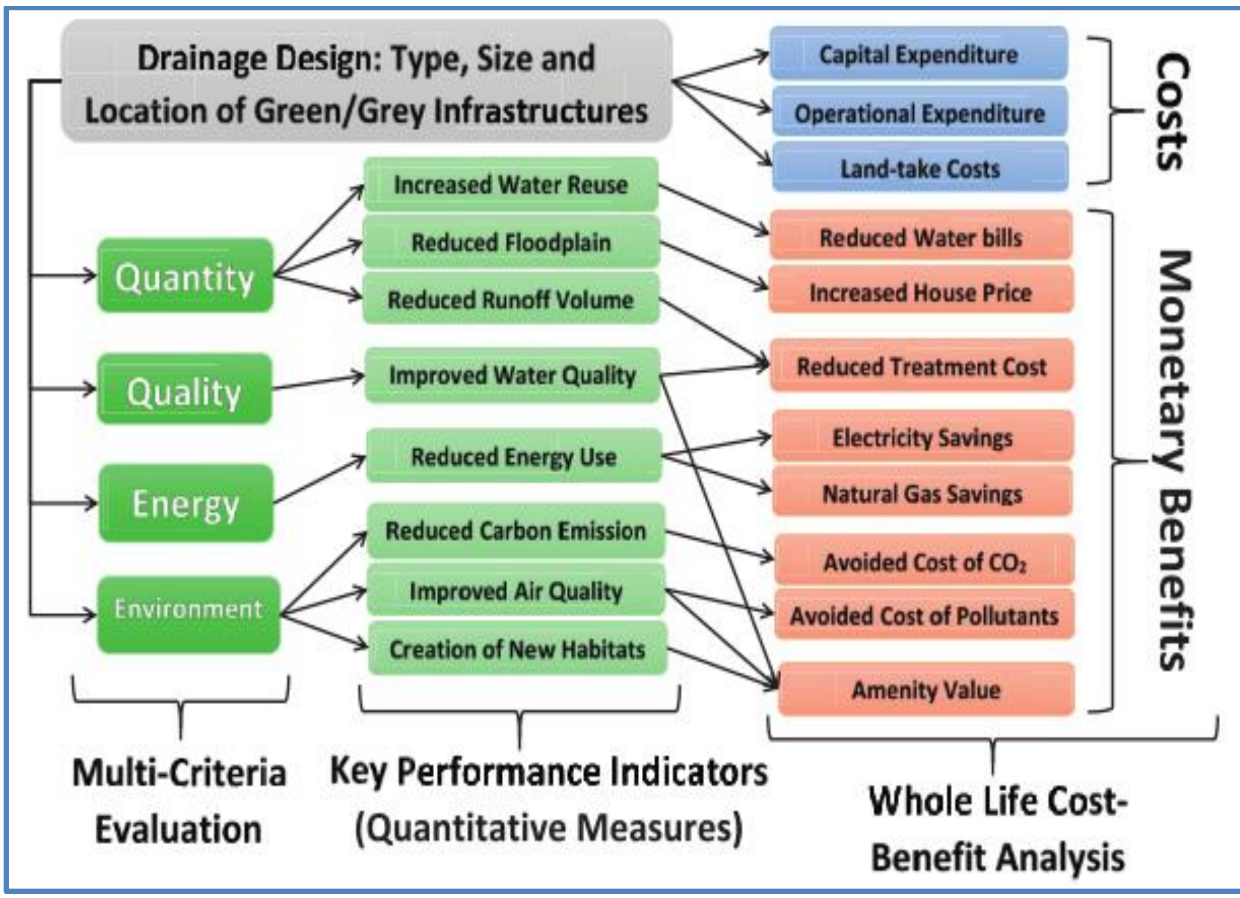


<Figure 30> Flood depth 2-yr ARI

3.2.10 Multi Criteria Analysis for Drainage Interventions

To assess their effectiveness for rainwater runoff reduction and consequently the reduction of combined sewer overflow (CSO) the software GIS water was employed for development of the urban catchment model. This software couples spatial data from GIS with EPA Storm water management model (SWMM). In accordance with the conditions in the urban catchment, five scenarios were developed consisting of following SuDS measures: infiltration basins, infiltration trenches, green roofs and their combinations. These scenarios were evaluated with multi-criteria analysis based on CSO reduction, CAPEX , OPEX , amenity, biodiversity, and feasibility regarding ownership.

After the selection of the interventions described in the previous chapters, given only technical constraints, a ranking to prioritise those alternatives from the screening process must be set.
Multi Criteria Analysis (MCA) is a weighted cost effectiveness techniques usually applied as the basis for the decision regarding if or when to invest in selected projects (i.e. short, medium or long term). Such a ranking process ensures that projects that will be subjected to a more detailed analysis (including cost-benefit analysis) are those that best fit with the objectives of the investment with time (i.e. flood safety, health conditions, etc.).



<Figure 31> Systematic multi-criteria drainage design evaluation framework.

For ranking the projects' priorities the same MCA methodology adopted in the DSDP component (*Flood Control and Storm Water Drainage*) was used.

The identified interventions for the storm water drainage systems have different scales, impacts, results and effects. Thus, when considering an implementation plan for the sub-projects, it is essential to establish a priority action list based on the scale, the importance, the speed, and the wider influence of the intervention in solving the existing problems.

The following subjects constitute the framework of factors to be considered when prioritizing and selecting the interventions to be further developed in the next phases of the "project" and/or to be fully implemented on site:

- The affordability and financial assistance available for carrying them out;
- The impact in improving the lives and welfare of those people in the areas most affected by the floods;
- The impact in reducing the direct loss of public and private property;
- The impact on reducing the cost of rehabilitation/restoration works on other affected infrastructure;
- The impact on the reduction in environmental damages;
- The technical connection between the different types of sectorial interventions to be provided.

Moreover, the DSDP high prioritized projects (rivers: Ngarenaro and Kijenge) However, as for the DSDP strategy, the assumption is still that a priority weighting should be given to small scale, more affordable projects.

The remaining aspects can be classified based on their relative importance in resolving situations that are:

- Threatening the population;
- Threatening property or infrastructure;
- Threatening the environment.

The other specific aspect to be considered in the ranking process is the possibility of achieving multiple benefits through interventions that overlap and help in the delivery of other DMDP projects, or contributes to ongoing improvement works beneficial to the poorer population suffering from lack of infrastructure.

The MCA results obtained allow ranking the various alternatives from best to worst, taking into account the different strategies adopted by the decision-makers involved. The development of a multi criteria approach could, in the future, serve as a supporting decision-aid tool, whose purpose would be to guide users in their choice of storm water source solution.

To determine intervention priorities, Technical (TECH), Economical (ECONOM) and Environmental (ENVI) aspects have been considered with the following sub factors and weights:

<Table 10> Multi-criteria analysis for the drainage structures intervention

CRITERIA (TECH/ECONOM)	SCORE #1	SCORE #2	SCORE #3	SCORE #4	SCORE #5
TECH.01: Type of drainage infrastructure involved	primary (rivers/main streams, detention ponds):3	secondary drain:2	local drainage system:1	-	-
TECH.02: Dimension of catchment/drainage area or class of flow	> 100 m3/s:3	between 20 and 100 m3/s:2	<20 m3/s:1	-	-
TECH.03: Dependence with/from other previewed drainage interventions	high dependence:3	Significant dependence:2	Not significant:1	-	-
TECH.04: Reduction of future maintenance (type of robustness of solution)	High:3	Significant:2	Not identified:1	-	-
ECON.01: Total cost per intervention	less than 5% of total estimated cost for all the drainage interventions:3	Between 5% and10%:2	>10%:1	-	-
ECON.02: Unitary cost per length of intervention (/lm) for linear ones	<750 US$:3	Between 750 US$ and 1,500 US$:2	>1,500 US$:1	-	-
ECON.03: The proposed solution requires the relocation of residents and the concerning resettlement?	no, there is enough space to improve the drainage system without interference with them:4	it is possible to develop a consistent solution without interfere with the residents, but a better solution	only a few houses especially badly located in the river/stream bed are affected:2	yes in a considerable number, to create drainage free corridor for the drainage infrastructure:1	

CRITERIA (TECH/ECONOM)	SCORE #1	SCORE #2	SCORE #3	SCORE #4	SCORE #5
		could be developed:3			
ECON.04: With eventual impact on economic activity operations from interrupting them	intervention located or benefiting the City Center, the Airport or/and Industrial areas:3	if not:1			
ENVI.01: Type of estimated benefits	eventually human lives:5	reducing flooding areas:4	protecting areas with sensible buildings/institutions as schools, fire departments and hospitals:3	protecting other infrastructures:2	preventing traffic interruptions:1
ENVI.02: Beneficiation of low income residents	intervention in unplanned areas with clear improvement on preventing flooding:4	intervention in unplanned areas with improvement on current drainage conditions:3	intervention on the vicinity with some general expectable improvement:2	intervention in planned areas:1	
ENVI.03: Interference with natural areas	exclusively involving urban areas:4	with no significant crossing of natural areas:3	crossing of natural areas including water lines or coastal areas with natural water lines or coastal areas:2	involving protected areas or other:1	-
	more than 80% of catchment in urban areas:4	between 50% and 80% of catchment in urban areas:3	between 30% and 50% of catchment in urban areas:2	less than 30% of catchment in urban areas:1	

3.3 Structural Measures for Stormwater Drainage

Unlike other places, Arusha CC has a number of natural rivers and rivers tributaries almost uniformly distributed across many places within the district. These rivers include Burka, Engarenaro, Naura, Themi and Kijenge. These flow channels play a great role in draining the city when it is storming.

This advantage is also masked by the fact that been on the low lands of Mount Meru, Arusha CC has to possess drainage facilities that will accommodate the water discharged from Arusha DC and pass it through the city without flooding.

The current drainage site condition is characterized with shallow trapezoidal drains, Covered U-drains as well as spoon drains in most parts of the city center, specifically Kati Ward and unpaved silted shallow drains in places outside the city center.

3.3.1 Causes of flooding in Arusha CC.

Based on the findings found after several site visits in all 25 wards of the city, flooding in Arusha is mainly caused by one or more of the following factors

1. Insufficient feeders to tributaries that collects the water towards the major drains
2. Low profiled roads in most of the streets which in turn becomes the water flow channels
3. Lack of road side drains in most of the neighborhoods
4. Siltation of the existing SWD’s with debris and sand from upstream and around the streets
5. Undersized drainage structures and major drains.

- **Scope phasing**

Due to the reasons displayed above, the solutions can be achieved in a number of ways which can be divided in groups as per severity level of flooding in order to simplify implementations and operations of the subprojects

Basing on the hydrological studies, site visits and interviews conducted, several locations have been pointed out to be the most affected areas during the storm. These Locations are shown on UTM coordinates on the table below.

<Table 14> Most affected locations in recent flooding events

S/No.	Ward Name	Easting	Northing
1	Kaloleni	243165	9627685
2	Levolosi	242488	9628189
3	Elerai	240668	9628093
4	Ngarenaro	241718	9628151
5	Sombetini	240376	9626537
6	Ungalimited	242001	9626381
		241898	9626387
		241873	9626389
		242002	9626357
7	Sokoni -I	241615	9623217
8	Kimandolu	246226	9627488
9	Olorieni	246914	9624787
10	Themi	244502	9625195
11	Osunyai	240005	9625245
12	Muriet	239228	9621240
13	Olmoti	233717	9625407
14	Daraja II	243759	9625433
15	Engutoto	245010	9621340
16	Sakina	241025	9625801

The above areas flooding are mainly due to the factors mentioned earlier and the general terrain layout of the areas. Low land areas are mostly affected due to lack of water outlets leading to the tributaries and finally to the main flow channels.

The implementation of the proposed solutions will mainly be done through the following activities depending on the prioritized ones.

- Rehabilitation of the existing sufficient capacity major drains
- Demolition and reconstruction of existing insufficient capacity major drains
- Expansion and banks protection of main flow channels
- Cleaning and repairing of the existing minor drains
- Roads and paving

3.3.2 Demolition and reconstruction of existing insufficient capacity major drains

➢ **Drain Code: KAL 002**

This is the proposed 1.33km major rain which runs through Soweto street playing fields, down along Uchaguzi and Makongoro road and finally in Naura river.

Kaloleni drains its water mainly in Themi river, Kaloleni Mashariki Street which includes both Kaloleni Primary school and Kaloleni Secondary school is one of the most affected areas of the ward.

<Figure 32> Existing side drain at Uchaguzi road.

The side drains (**0.5m bottom width, 1.2m top with, 0.8m depth)** along Uchaguzi road collects water from Mita 200 streets on the north side of Arusha – Moshi road. The capacity of the drain is insufficient hence water overtops and floods to people's residence.

<Figure 33> Satellite map showing (Light blue line) drain along Uchaguzi and Makongo road.

As seen from above, 1.33 km drain is proposed to receive the water from Mita 200 street through Kaloleni ward to final discharge point on river Themi.

Due to sensitivity of the areas in terms of schools, play grounds and health facilities along the way, the consultant is proposing a covered U-Drain Type 1 as seen from the drawings. This will accommodate the water and act as walkways as well.

- **Drain Code: KAL 001**

This drain runs along Colonel Middleton Rd and then turns to Makao Mapya street and finaly along Sokoine and Esso Roads. Having a flow length of 2.55 km through the city this is considered as one of the major insufficient capacity drains.

<Figure 34> Existing drains along the KAL 001 major drain

As seen from the pictures below, the drain has a long run for 2.55km all the way from Mianzini but most sections are insufficient compared to the estimated discharge as per design. Most of crossing structures are blocked hence water overflows on the roads.

<Figure 35> Satellite map showing the 2.55km KAL 001 main drain route

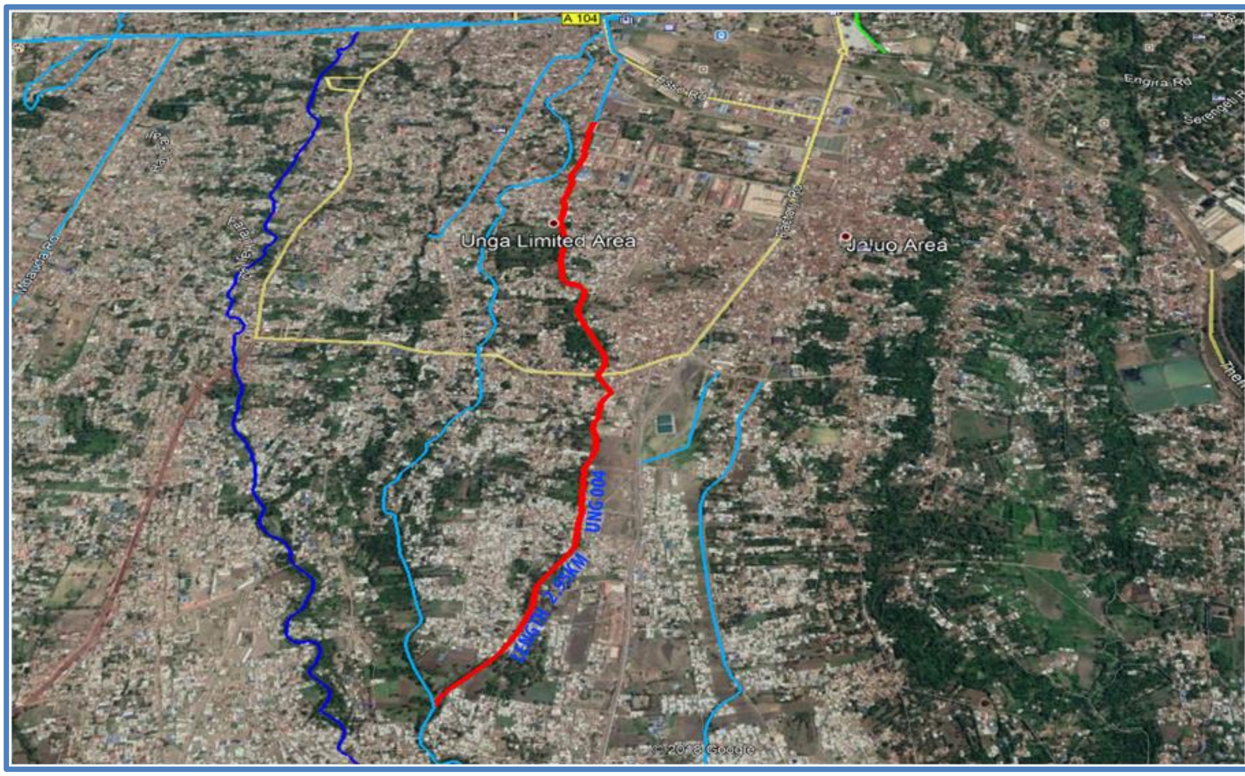
As per hydrology design and the general use of the areas along the route, the consultant has proposed covered U-drain type 2 as seen in the submitted drawings.

- **Drain Code: UNG 004**

This drain receives discharge from KAL 001 drain. It runs right through Ungalimited Ward and Sokon 1 Ward and finally joins river Ngarenaro downstream. It has a total length of 2.95 km.

Unlike other drains, this drain passes through unplanned settlements and sections with limited access.

Currently the drain is characterized be wide and shallow unpaved sections, narrow silted paved sections as well as sections with no defined channel. The existing site condition for this drain is as shown on the following photos.



<Figure 36> Current site condition along UNG 004 drain

<Figure 37> Satellite map showing the 2.95km UNG 004 drain (in red color) route

The consultant has inspected the site and using the hydrological data the SD TYPE 04 (Refer drawings) has been designed as the proper and sufficient drain size for this section.

- **Drain Code: UNG 003**

This is a major drain running from Makaburi Ya Baniani Street in Ungalimited ward, it goes through Sokon 1 road and finally Joins Ngarenaro River downstream. It runs for a distance of 5.42km

Figure 38. Current site condition along UNG 003 drain

As seen above, the drain is mostly characterized by unpaved sections with debris deposits in most parts. Access to most parts of the drain is limited as the drain pass through unplanned neighborhoods.

Through the whole 5.42km some parts will be widened and paved with different section sizes depending on the locations use as well as the design discharge. Gabions protection will be done for 0.62 km and paving of the drain will be done as per SD TYPE 3 (refer drawing) for 1.06km

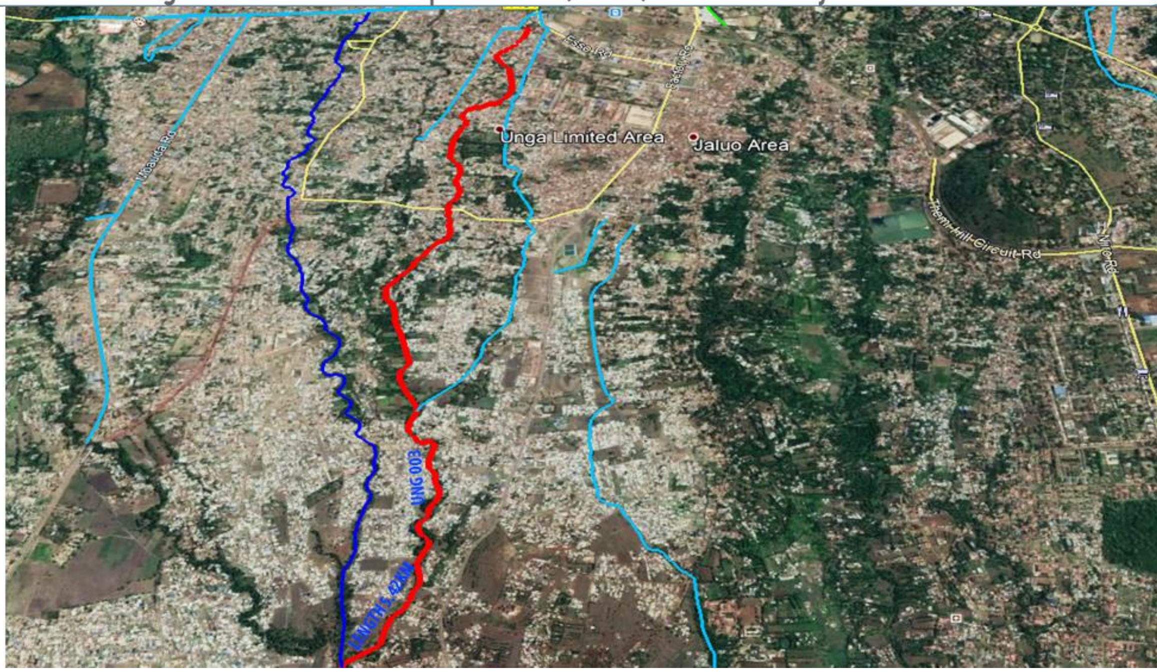


Figure 39. Satellite map showing the 5.42 km UNG 003 drain (in red color) route

- **Drain Code: NGA 002**

This is a drain along Arusha - Dodoma Road running from Ngarenaro river to AIM Mall in Elerai ward. Drain will collect the water from all roads joining Arusha – Dodoma road. The drain will cover a distance of 1.89 km with flow directions towards the lowest point of the section which is at km 1+640.

Like most of road side drains, the existing drains are silted and filled with debris, the capacity of these drains is also small compared to the discharge it is designed to carry. The crossing structures are old and not functioning as of now. More details can be observed from pictures below.

Figure 40. Current site condition along NGA 002 drain

Figure 41. Satellite map showing the 1.89 km NGA 002 drain (in red color) route

This section will be provided with U-Drain type 2. Covered U- drain will accommodate the water and provide walkway platform for pedestrians.

At least 4 crossing structures will be installed to link the minor roads to the main Arusha – Dodoma road.

- **Drain Code: ELE 002**

This is a 1.86 km drain connecting the Arusha- Nairobi road to Arusha – Dodoma road. It advances from Sakina right through Majengo and some parts of Olmate Joo. The drain is characterized by both wide and narrow sections as it passes through unplanned settlements. The route of the drain is as seen from the satellite image below.

Figure 47 Current site condition along ELE 002 drain

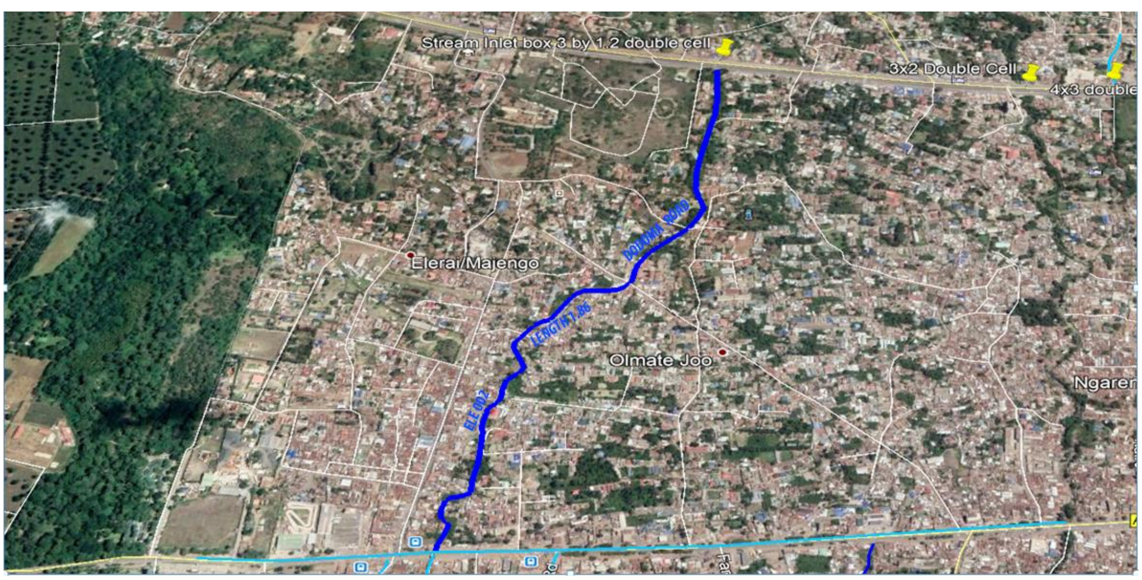


Figure 42. Satellite map showing the 1.86 km ELE 002 drain (in blue color) route

The SD TYPE 03 drain section is proposed for this section as it carried discharge from north side of the town to the Burka River downstream.

- **Drain Code: SIN 002**

This is a 4.25 km drain from Sinoni Primary school passing through Uswahilini Street and discharge at Burka River downstream. As of now, the drain is unpaved, crossing at least 7 road sections which will be provided with crossing structures based on the designated discharge.

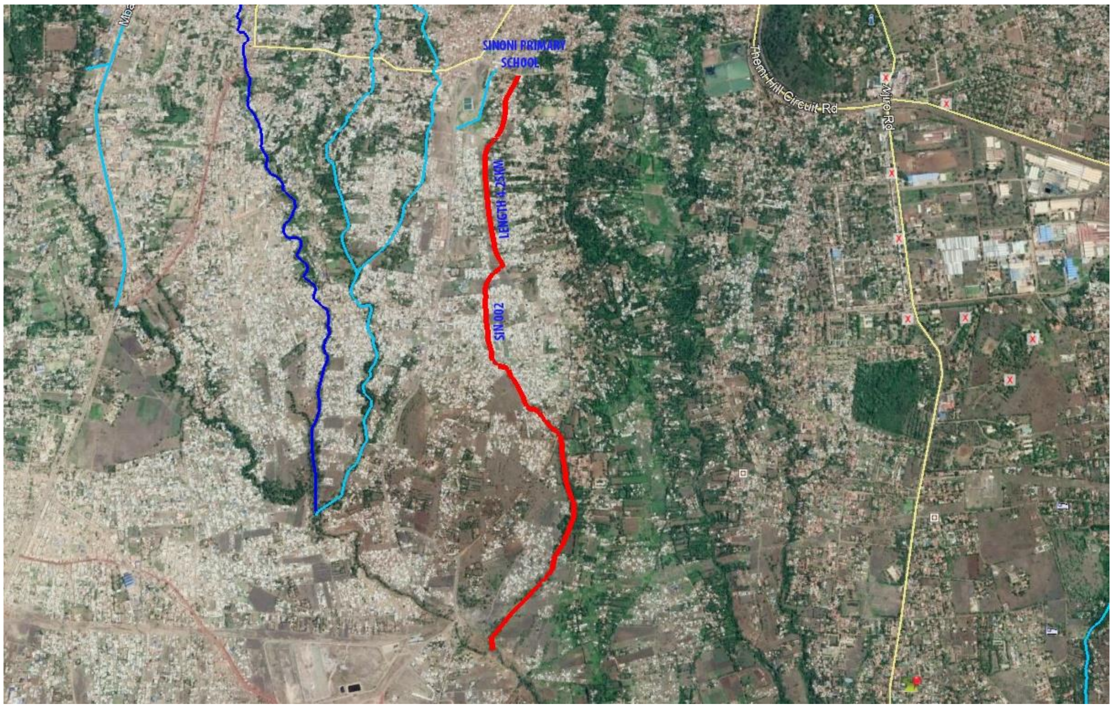


Figure 43. Satellite map showing the 4.25 km SIN 002 drain (in red color) route

Different sections are proposed along the drain depending on the discharge and the primary use of the surrounding areas. It is estimated that 2.74 km will be SD TYPE 02 and 2.88 km SWD TYPE 02. The rest of the sections will be widened to accommodate the discharge and provide barriers and weirs to alter the flow characteristics accordingly and hence eliminate flooding.

3.3.3 Roads and Paving

- **Drain Code: OSU 002**

This is a 2.94 km drain running on the west side of Mbauda road as shown on the satellite map below. The drain is unpaved with different cross sections in different parts depending in where it passes. Average depth from the existing ground is 0.6m. Widening and paving of the drain is recommended here to control the flow from upstream.

Figure 44. Satellite map showing the 2.94 km OSU 002 drain (in red color) route

Figure 45. Current site condition along OSU 002 drain

It is estimated that 1.76 km will be SD TYPE 02, 0.34 km SWD TYPE 02 and 0.82km SWD TYPE 02. The rest of the sections will be widened to accommodate the discharge and provide barriers and weirs to alter the flow characteristics accordingly and hence eliminate flooding

3.3.4 Expansion and banks protection of the main flow channels

In this case, there are rivers flowing within the city. Some parts of the river too narrow compared to the expected flow due to the fact that human activities have been done too close to the river channels. As a result, people in these areas are mostly affected by flooding during the rainy season. In this case widening of the flow channel is inevitable and protection of banks to prevent further erosion is crucial. Some of the identified flow channels are as follows.

- **Drain Code: KIM 005**

This is 11.1 km natural water way (Kijenge River) in which banks protection will be done by provision of gabions. The provision of gabions will be done together with the widening and deepening the water way in order to concentrate the water within a defined route. Protection of the banks will be done on the meandering inner sides of the river without changing the course of the flow.

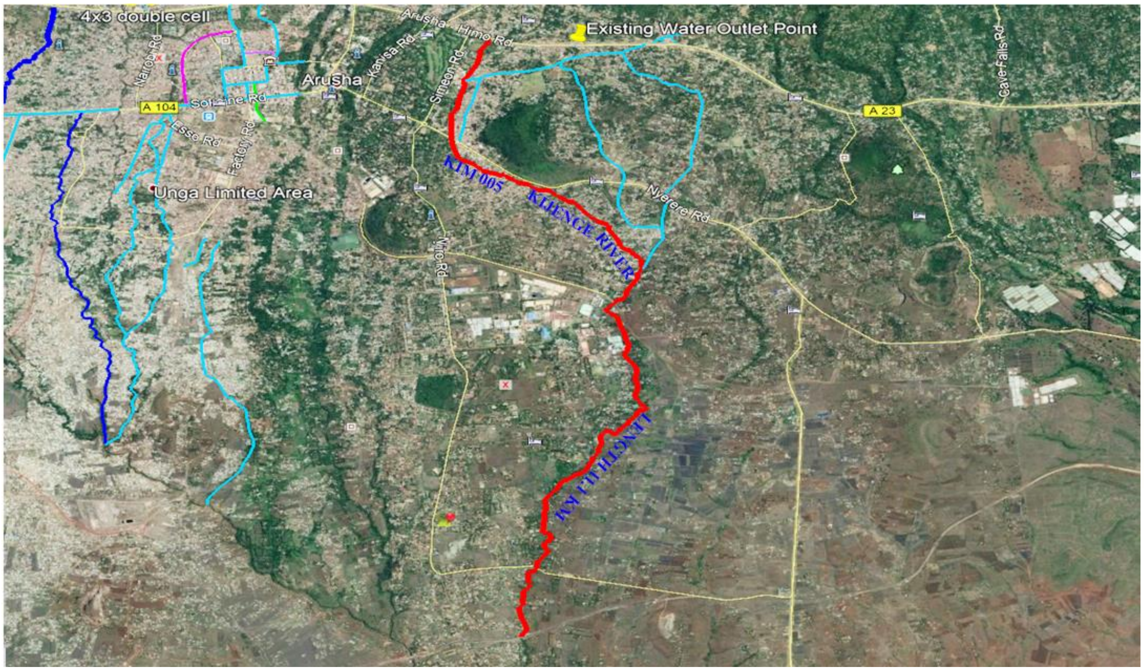


Figure 46. Satellite map showing the 11.1 km KIM 005 drain (in red color) route

For this drain SWD TYPE 2 is proposed in areas identified to be mostly affected by the flooding.

3.3.5 Cleaning and repairing of the existing minor drains

Drain Code: KAT 001

Kati ward has an old existing paved drainage system characterized with both spoon drains and shallow covered and open drains. The covered and open drains are in most cased silted and covered with debris. Crossing structures are also not functioning in most of the junctions due to siltation.

Figure 47. Existing drainage system in some parts of Kati ward

From the below satellite map, the pink color shows the routes consisting of drains that are to be repaired in order to discharge surface runoff water in the main outlets. The total length of these drains is 3.114 km. The rest of the drains are spoon drains which are in good condition.

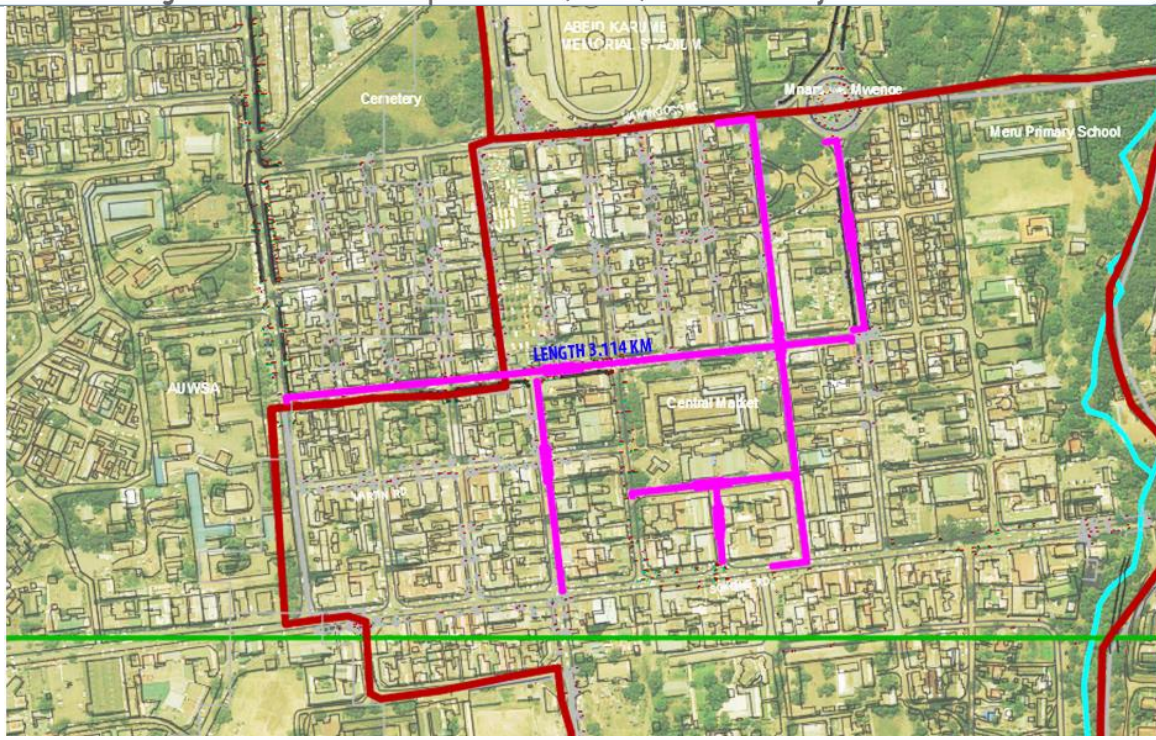


Figure 48. Satellite map showing the 3.114 km drains (in pink color) route to be repaired

3.3.6 Projects implementation – phasing on drainage works

After the field survey was conducted to observe and hydrological assessment and analysis of the locations which had attracted public complaints about poor storm water drainage. These locations were visited and details were collected including discussions with residents and collection of location photographs. Flood problems were cited with local name of the drainage canals and therefore needed comparison with map data for clarification. A detailed drainage line field survey was conducted to assess the field situation of the drainage canals and to capture other relevant details. The project of Short term will be proposed as priority projects.

Table 9Drainage intervention – phasing

Wards	Drain Code	Short term (2020-2025)	Mid term (2026-2035)	Long term (2036-2040)	QUANTITY	
					TYPE	LENGTH (KM)
Kaloleni, Kati, Levelosi	KAL 002, KAL 001,	Rehabilitation of the existing sufficient capacity		Installation of early warning systems	U-DRAIN TYPE 1, U-DRAIN TYPE 2	3.88

		major drains Maintenance practices for storm water Drainage Channels Campaign and Education				
Ungalimited, Sokoni 1, Elerai, Sinoni, Sakina Ngarenaro	UNGA 004, UNGA 003, UNGA 002, NGA 002, ELE 002	Demolition and reconstruction of existing insufficient capacity major drains			U-DRAIN TYPE 02, CONCRETE BOX FRAME TYPE 01, SD TYPE 03, SWD TYPE 02, U-DRAIN TYPE 1,	16.37
Kimandolu, Moshono, Olorieni, Engutoto	KIM 005			Expansion and banks protection of main flow channels	SD TYPE O1, SD TYPE 02, SWD TYPE 02, U DRAIN TYPE 4.	11.1
Kati, Levolosi	KAT 001	Cleaning and repairing of the existing minor drains			U-DRAIN TYPE 3, U-DRAIN TYPE 5.	3.11
Osunyai, Muriet, Sombetini Olasiti	OSU 002	Roads and Paving			SD TYPE 01, SWD TYPE O3, SWD TYPE 03.	2.94
Arusha DC				Retention ponds		

SECTION 4: NON-STRUCTURAL STORM WATER MANAGEMENT

Non-structural storm water quality best management practices (non-structural BMPs) are institutional and pollution-prevention practices designed to prevent or minimize pollutants from entering storm water runoff and/or reduce the volume of storm water requiring management. They do not involve fixed permanent facilities and they usually work by changing behavior through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments.

Examples of non-structural BMPs for managing urban storm water quality include:

• **Town planning controls** (e.g. using town planning instruments to promote Water Sensitive Urban Design [WSUD] principles in new developments, such as decreasing the area of impervious surfaces);

• **City-wide storm water management planning** (e.g. local authorities developing and implementing strategic management plans to improve storm water quality throughout a catchment or city);

• **Controls involving construction and maintenance activities** (e.g. maintenance activities such as regular inspection and clean-out of structural BMPs and manual litter collections);

• **Education and participation programs** (e.g. focused campaigns that aim to change those aspects of behavior that may be damaging the health of local water ways, such as over-applying lawn fertilizer);

• **Enforcement campaigns** (e.g. the use of enforcement to improve erosion and sediment control on construction sites);

• **Economic controls** (e.g. financial incentives to encourage the conversion of lawns and gardens that require large amounts of fertilization and watering to more resource-sensitive alternatives);

• **Regulation and inspection activities involving industrial and commercial premises** (e.g. auditing programs); and

• **Programs to identify and eliminate Arusha City's discharges of pollutants to storm water** (e.g. programs to minimize illegal connections of sewerage to storm water).

4.1. Early Warning Systems

The Disaster Management Act (2015) sets out a comprehensive legal framework for disaster risk management. It provides for the establishment of Tanzania Disaster Management Agency

(TDMA), which is the national focal point for coordination of disaster risk reduction and management in the country. *The Agency shall act as the central planning, coordinating and monitoring institution for the prevention, mitigation, preparedness, response and post disaster recovery, taking into account all potential disaster risks*.

The TDMA will put in place an efficient early warning system at regional and district levels so that local authorities can prepare for and respond to disasters timely and effectively. The aim of any early warning systems (EWS) is to provide warning to people of an impending natural hazard so that those vulnerable are aware of the potential impact of the natural processes in order to respond appropriately and minimise damage.

An efficient EWS should be made of:

- Automatic Weather Stations (AWS)
- Hydrological stations
- Automatic rainfall gauges,
- River staff gauges
- Informatics equipment to data transmission and management
- Capacity building within the government on modern technologies to strengthen the climate data collection and processing
- Private sector engagement and developing sustainable cost recovery strategies for sustaining the meteorological and hydrological services

Moreover, there is need for those issuing warning information to acquire more information themselves about how communities perceive risk, and the reasons that underlie their behaviour when floods threaten them. There is also a need to strengthen local communities' capacity to play a key role in information dissemination before the onset of flood disasters.

A recent project in Tanzania supported by UNDP was launched to strengthen the climate monitoring capabilities, early warning systems and available information for responding to climate shocks and planning adaptation to climate change in Tanzania.

The project aimed to enhance the capacity of Tanzania Meteorological Agency and of two Water Basin Boards, to monitor and forecast droughts and floods, as well as efficient and effective use of hydro-meteorological and environmental information, for developing early warnings and long term growth plans at local level. According to the outputs of the pilot project, by December 2017, 36 new AWS, 15 new Mini Automatic Weather Station, 30 new hydrometric stations and

20 new Automatic Rain gauge and Standard Rain gauge, should be operational and transmitting data accurately toward the data share server, where Tanzania Agencies and Institutions can access data.

4.2. Sustainable Urban Drainage Systems

Green infrastructure (GI)-based approaches to urban drainage such as sustainable urban drainage systems (SUDS) could provide Sub-Saharan cities with an opportunity to address projected climate change impacts and existing deficits in their drainage infrastructure, even more so due to the synergies between an enhanced green infrastructure stock and sustainable urban development.

The conventional approach to storm water control is to directly drain storm water flows as quickly as possible to the nearest receiving watercourse or drainage system to avoid the risk of flooding and to protect human health.

SuDS aim to: handle storm water as close as possible to its source,

It is important to understand that SuDS generally embrace a number of options that are arranged in treatment train. It is thus important that the advantages and limitations of each option should be identified during the planning and design phases. Identified seven basic selection criteria:

i. Current and future land use characteristics;
ii. Site characteristics and Utilisation requirements;
iii. Catchment characteristics;
iv. Storm water runoff quantity (peak flow and flood volume) requirements;
v. Storm water quality requirements;
vi. Amenity requirements; and
vii. Biodiversity requirements.

Table 10. Sustainable Urban Drainage System types.

SuDS Type	Description	General Design Guidelines
Green roofs	A roof that is deliberately covered in vegetation may be described as a 'green roof' (Semple *et al.*, 2004; Stahre, 2006; The use of vegetative roof covers and roof gardens is an important source control for storm water runoff. They provide great benefits in densely urbanised areas where there is less space for other SuDS options.	Post 2000 advances in synthetic drainage materials now allow green roofs to be built on flat and gently sloped roofs, typically between 0° and 20°. On roof slopes greater than 20°, support systems such as horizontal strapping should be used to prevent slipping or slumping of the growing vegetation. The vegetative layer is typically 30-40 mm thick .The drainage layer in

		turn lies on a waterproof membrane to prevent leakage into the building. Green roofs are especially effective when implemented on roofs with large surface areas, such as industrial and commercial buildings, and blocks of flats.
Rainwater harvesting 	Rainwater harvesting is an essential element of effective water conservation where storm water is utilized as a water supply. Conventional storm water Infrastructure results in pollution and the addition of millions of cubic meters of water into watercourses and oceans each year. With minimal treatment this water could be used to supplement the potable water supply for secondary water uses such as toilet flushing and garden irrigation. Storage of runoff from roofs and other elevated impervious surfaces is provided by rainwater tanks barrels and other storage structures until the water is required	The principal element requirements for an effective storm water collection and reuse system are: -The strategic placement of roof gutters; -A first-flush trap and/or filter sock to catch leaves and other debris; -A rainwater storage facility (tank, barrel or sump); -Leaf and organic debris diverters; A means of getting the water to its point of use, preferably by gravity or otherwise a pump and pipeline; -An in-line filter and/or UV disinfection device if there is any risk of human contact; and -An overflow system – preferably linked to another option in a SuDS treatment train
Filter strips 	Filter strips are maintained grassed areas of land that are used to manage shallow overland. Storm water runoff through several filtration processes in a similar manner to buffer strips. They can be as simple as uniformly graded strips of lawn long side a drain They intercept and spread out storm water runoff thus helping to attenuate flood peaks. Filter strips are commonly used along stream banks as vegetated buffer systems but are also used downstream of agricultural land to intercept and infiltrate storm water runoff	Filter strips are generally sized against the 6 or 12 month, 24-hour recurrence interval storm. As with other bio-retention and infiltration options, the pollutant removal characteristics of filter strips are determined by the relationship between their length, width, slope and soil permeability compared to the storm water runoff rate and its associate velocity. 03). Filter strips must be designed to provide sufficient contact time for the adequate functioning of the water quality treatment processes. They normally serve areas smaller than 20,000 m^2 with slopes between 2% and 6%
Swales	Swales are shallow grass-lined channels with flat and sloped sides .Although they are normally lined with grass alternative linings can be used to suit the characteristics of the specified site. They serve as an	Swales are generally suitable for road medians and verges, car parking runoff areas, parks and recreation areas They should be designed to meet two chief storm water management processes,

	alternative option to roadside kerbs and gutters in low density residential areas but because they generally have a larger storm water storage capacity, they help to reduce runoff volumes and peak storm water flows. They require relatively large surface areas to function effectively.	namely, (1) flow conveyance requirements, and (2) effective storm water pre-treatment The grass covering on and around swales should be kept healthy to assist in the removal of pollutants. Grassed swales remove pollutants by binding them to soil particles and other organic matter. The extent to which soluble pollutants are removed depends on the density of the grass and the exposure of the soil to the storm water.
Detention ponds 	Detention ponds or detention basins are temporary storage facilities that are ordinarily dry but are designed in such a manner that they are able to store storm water runoff for short periods of time. The captured storm water runoff either infiltrates into the underlying soil layers or, more usually, is drained into the downstream watercourse at a predetermined rate. This means that detention ponds are particularly effective at regulating the flow in the downstream watercourses and/or supplementary treatment systems. They are usually grass lined, but concrete lined ponds can be used if there are soil stability or land use issues.	In general, detention ponds are designed to temporarily store as much water as possible for 24 to 72 hours whilst aiming to provide a safe and secure public environment. The following four factors should be considered at the planning and design phase: -The local catchment hydraulics and hydrology; -The implementation of appropriate safety structures including pest and vector controls; -The prevention of dangerously steep ground slopes around the pond perimeter; and - Upstream treatment systems and outlet structures.
Retention ponds. 	Retention ponds, also referred to as 'retention basins', have a permanent pool of water in them. They are generally formed through the construction of a dam wall (or walls) equipped with a weir outlet structure. The maximum storage capacity of retention ponds is larger than their permanent pond volume. Storm water coming into the pond is mixed with the permanent pond water and released over the weir at a reduced rate. Retention ponds are usually capable of handling relatively large quantities of storm water runoff. The permanent pond volume can be utilised as a source of water for various non-potable purposes.	The performance of retention ponds is significantly improved with the construction of a sediment fore bay at the inlet. The outlet structure should typically enable the temporary storage of the runoff from the design storm; releasing the volume over a 24-hour period. It should also allow for the complete drainage of the pond for maintenance purposes

4.3. Proposed Non-Structural Drainage Measures for Arusha City

For the case of Arusha city the choice on the type of SuDSs to be applied is limited by the space availability within the dense urban tissue of the informal settlements. There are undoubtedly many other SuDSs measures but not all are suitable for every location.

4.3.1. Early warning system

For the early warning system a good reference is represented by the recent project *Strengthening Climate information and Early Warning Systems in Tanzania for Climate Resilient Development and Adaptation to Climate Change Project*" (UNDP and GoT, August 19, 2016). The DSDP critical flood areas should be considered in the provision of Automatic Weather Stations and Automatic Rain gauge stations, giving TMA and other relevant Authorities operational capability for the forecast of new floods to timely warning the population. Emergency management of the flooding prone area is through warning awareness. During the site visit most of the ward leaders/officers declared that warning was one of the vital function in emergency management of the flooding to the residents live nearby the flood prone areas. Though it was observed that in order to make such warnings credible, it may be necessary to be forecasted before the rainfall hours or even days ahead. The short response time of City flooding between peak rainfall and runoff makes the introduction of warning systems in City areas more difficult. However, the dissemination of flood warnings seemed to be too slow and imprecise useful to those who need it the most. But with the growth and popularity of social media and cell phones these provided an accessible channel for targeted, timely flood warnings.

Early Warning Systems *must be perceived as a major task for all the relevant authorities involved in the flood risk management. The cooperation and coordination of TDMA with the TMA and the Pangani Water Basin should be of the utmost importance. The delineation of the DSDP' inundation areas should also help to set the optimal network of the rain/river automated gauge stations to be used for monitoring the storm water events. Emergency Response and Intervention Plan for the evacuation of people to safe areas upon receiving warning be the consequent step.*

4.3.2. Emergency response Plan

Apart from early warning, emergency response to floods include a number of activities involving different levels of decision making authorities as local, regional, and central government authority as well as the private sectors. Installation and maintenance of flood barriers, channeling flood waters away from certain high-value areas, search and rescue, evacuation of people stranded by flood waters, removal of people and their property from areas potentially threatened by floods are all possible response actions. In addition, accelerated maintenance, strengthening, and expedient repair of drainage infrastructure elements can also be considered as emergency response.

Also emergency response elements include such activities as sheltering and mass care, emergency delivery of food and water, organization of relief supplies and operations – although these efforts often extend well beyond the emergency response period and into the recovery period.

There are four phases of emergency management consist of: mitigation (reducing vulnerability), preparedness (planning, preparation and training), response (limiting damage and protecting people and property) and recovery (restoring and improving what was damaged). The terms are slightly different and in a slightly different configuration, but the principle is the same: an iterative process of identifying hazards and vulnerabilities, acting to prevent or lessen expected damage, preparing ahead for dealing with possible disaster effects, acting to prevent loss of life and damage to property, and rebuilding (perhaps to a higher standard) what is damaged.

4.3.3. Systems in Informal Settlements

As a temporary solution, the informal settlements will be equipped with local drainage and sewerage ecological services, basing on projects proposed in the urban master plan. The DSDP will be implemented also in the informal settlements by means of long-term permanent services such as conventional drainage systems and waste water/sewage treatment plants. A typical intervention proposed in the informal settlements' streets; consist of terrain equalization by using gravel roads with double (symmetric) cross slope. For streets larger than 6 meters, the storm water will be drained to two lateral ditches equipped with a trench-drain made of a perforated pipe laid on the bottom and covered with two layers of gravels separated by a filter cloth used to retain the dissolved solids.

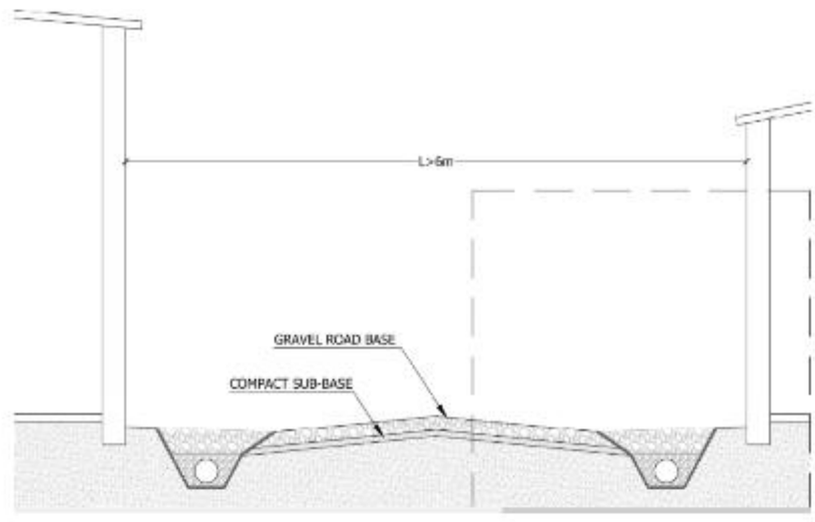
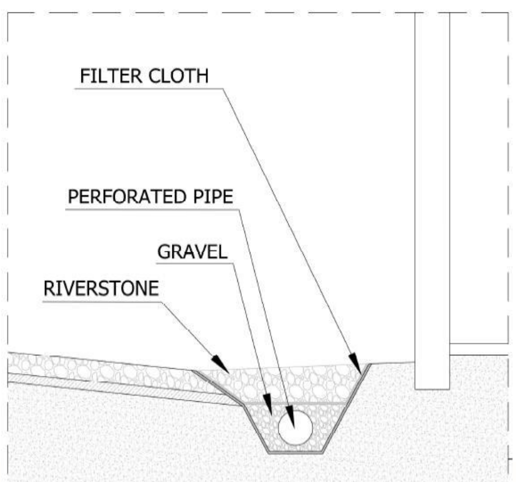


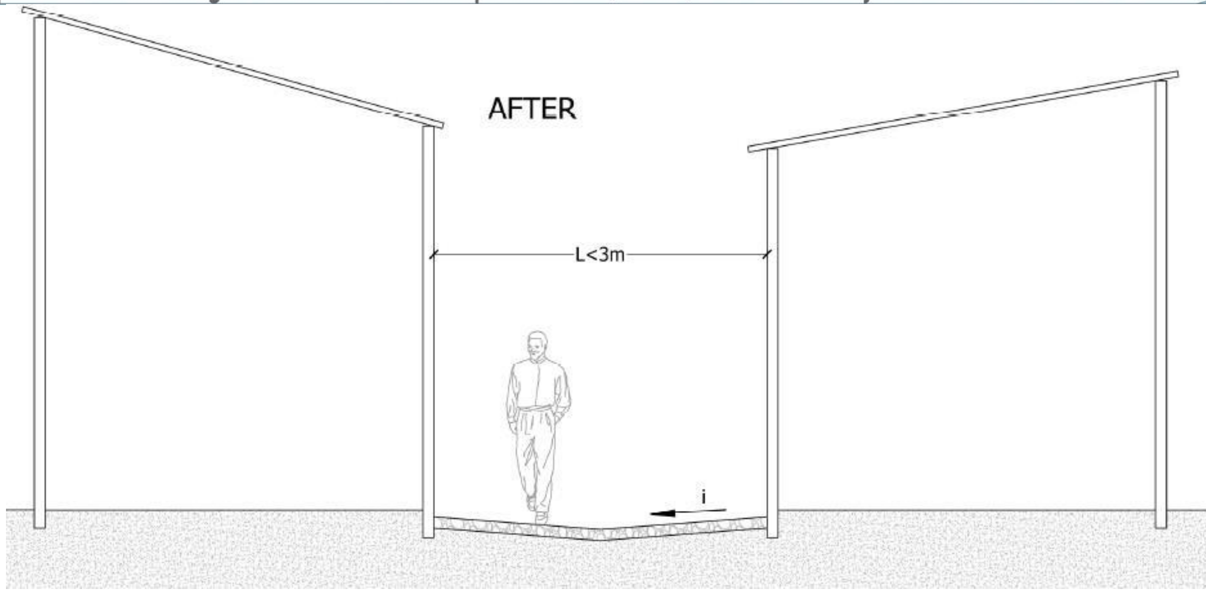
Figure 49. Drainage in gravel roads for informal settlements.

For streets width between 3 and 6 meter only one ditch will be provided. The gravel covered trench-drains will help to avoiding the discharge of solid wastes inside the ditches.



Detail of Trench Drainage in gravel roads

Another typical intervention in small sized streets (less than 3 meters) and alleys is the one with a double convergent slope made of stones and gravels (compacted) to be used both as a lane and a drain (maximum slope 5%).



For all the main natural streams and artificial waterways (ditches, culverts, etc.) crossing the settlements, the cleaning from the solid wastes, the silt and the vegetation will be provided.

4.3.4. Land use management policies and practices

Land-use management policies and processes are a natural companion for urban flood management, and both contribute significantly to Integrated Flood Management and Integrated Water Resources Management. A collaborative approach involving planning at all levels, specialized technical agencies and local governments would maximize the efficient use of flood management resources.

The policy-based approach is structured around four major principles (WMO, 2009b):

— Adaptation to short-term climate variability and extreme events serves as a starting point for reducing vulnerability to longer-term climate change.

— Adaptation policies and measures are best assessed in a developmental context.

— Adaptation occurs at different levels in society, including the local level.

— The adaptation strategy and the process by which it is implemented are equally important.

The adaptive-capacity approach seeks to raise the general capacity of the community to adapt to climate-induced shocks and to remain resilient in the face of both extreme events and longer-lasting adverse trends. It depends heavily on enhancing and sharing knowledge about climate change effects and adaptation, creating better early warning capabilities, and generally improving the socioeconomic level of the populace. Section 5 of this document further explores the concept of adaptive capacity as both a supporting and limiting factor for flood management.

Due to recurring flooding problems the proposed storm water drainage facility for Arusha City Council should be separated from sewerage system, and drained by means of an open system(sometimes closed) or and diverted the inundation toward the existing flowing water bodies. The main intention should be focus to reduce flooding by 70%, both lowering the total volume of storm water and reducing the peak flow rates reaching low laying areas of the Arusha City. (Kazmierczak and Carter, 2010)

4.3.5. The vulnerability-based approach

This approach focuses on reducing the vulnerabilities of the affected population and considers economic activities and degree of development of the area, frequency and intensity of floods, land and land use, anticipated impacts of development activities and demand for resources throughout the community. Circumstances of vulnerability can be improved through economic development and public development policies that are generally beyond the scope of flood management policies and plans.

4.3.6. Enforcement of the existing laws, regulations

It should come as no surprise that most of the physical, social and economic problems associated with Arusha City flooding, stem from inappropriate occupation of the floodplain, poorly-planned land use within the city, insufficient attention to drainage and storm water control facilities and haphazard enforcement of existing regulations. Land-use laws and regulations establish the basis for the kinds of uses permitted in the floodplain, and zoning is essentially the enforcement mechanism. Regulation and zoning may take the form of: restrictions (prohibitions, penalties resettlement); incentives (preferential or punitive taxation); information and education; public investment through purchase of property.

There are three basic types of floodplain development (WMO, 2008a):

— preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural or recreational purpose

— preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial or industrial purpose as long as the encroachment results in only insignificant increase in the water surface elevation

— restricting the use of the flood plain and leaving it in its original unoccupied state

SECTION 5: INSTITUTIONAL STORM WATER MANAGEMENT

5.1. Major Problems in Drainage System Management

Arusha City conditions exacerbate drainage problems; runoff is increased by impermeable urban surfaces and low land areas, due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for storm water drainage.

The following listed factors are directly linked to storm water management in most of African Urban

5.1.1. Lack of knowledge.

Although clearly identified as a major issue in times of flooding, the agencies responsible often lack the knowledge and tools required to deal with storm water management. In Arusha City some of the rainfall data were lacking, obsolete or inaccessible. Furthermore, the quality of any data that is available is compromised by a lack of reliable measuring equipment or data collection tools. Alternative and additional measures (storage /infiltration/delayed surface runoff) remain relatively unknown and rarely used in developing countries.

5.1.2. Lack of coordination between sector stakeholders.

The large number of actors involved in storm water management (ministries of urban planning, the environment, municipalities, operators in charge of sanitation, etc.) renders management and coordination of the sector difficult. There is currently no specific storm water management sector within the public authorities: storm water management is rarely dealt with by a dedicated department, but responsibility for its design, planning and financing is instead usually dispersed among the different development, road or sanitation departments. As there is no clear legal and institutional segmentation, storm water management does not strictly constitute a sector.

5.1.3. Missed storm water management decentralization.

As part of a decentralization process, the management responsibility for different services is progressively transferred to local authorities. However, responsibilities for storm water management lack clarity and the allocation of financial responsibilities between the state and local authorities is not properly defined.

5.1.4. Failure to take the populations' expectations into account.

Although storm water management is considered a priority by the populations of the majority of African towns and cities, this issue is not always prioritised by the public authorities.

5.1.5. Limited local capacities for financing investment.

Most technical solutions developed to address storm water management issues require costly civil engineering infrastructure. The investment costs involved commonly exceed local authorities' investment capacities. The low investment capacity of these local authorities is unlikely to change significantly over the next few years.

5.1.6. Failure to comply with best construction practice.

Failure to comply with equipment design and construction standards increases both the risk of flooding downstream (poor evacuation) and flood damage.

5.2. Review of Institutional Measures for Drainage System Management

Here follows a collection of best practices and policies adopted for drainage systems' management. The City Councils should establish bylaws and/or circulars to promote as many institutional measures as possible.

5.2.1. Existing Situation

Arusha city has no particular institution or department which deals with storm water drainage instead every authority deals with roads constructs the alongside road drain. TARURA with Arusha cities deals with the road within the city and some of the constructed roads has drainage but not sufficient to some areas and TANROAD deals with the roads which get out of the region and city. The lack of particular department which deals with storm water management leads to the following challenges

- Lack of required information about storm water drainage
- Lack of maintenance of the existing storm water drainage
- Insufficient storm water management structures

- Increase of impact which are caused poor storm water management

In order to reduce the mentioned impact the following should be done as monitoring and evaluation

5.2.2. Operation and maintenance for the proposed Drainage System

All drainage systems, irrespective of their design and construction, require attention to O&M, but some require more attention than others. This will depend on the quantity and types of solid waste in the drainage system, combined with climatic factors that affect the duration of the wet season and the accumulation of sediment .O&M strategies for urban drainage systems in developing countries are very different from those in developed countries due to cheaper labour costs. The strategy adopted will also depend on the type of drainage system itself. The majorities of urban drainage systems are designed as gravity flow systems and therefore require little in the way of regular operational activities compared with other urban infrastructure and services. However, those that rely on pumping or operation of sluice gates will require more attention to the operation of the equipment in order to ensure that the drainage system functions. Also, in general, separate surface drains are easier to maintain and clean than combined systems, but it is generally cheaper and easier to implement a maintenance programme for single combined systems. Making a distinction between O&M activities can prove to be difficult, but in general operation deals with the running of a service on a daily basis, whereas maintenance deals with the less frequent activities that are necessary to keep the system in proper working condition.

By the nature of the drainage system, the need for O&M tends to occur during the wet season which is not the best time to carry out these activities, except where the system needs emergency repairs. Although City agencies often make an attempt to clean and improve the operation of the system prior to the onset of the wet season, this tends to be only a partial response to the scale of the problem. Due to the fact that maintenance strategies are not required for everyday operations, they are often not planned or implemented effectively. The practice most commonly adopted by municipal agencies responsible for management of drainage infrastructure is to clean the drains before the rainy season. It may therefore be beneficial to adopt maintenance strategies that remove the waste from the drains more frequently throughout the year rather than a major operation once per year, which requires significant resources in both human and financial terms.

The successful construction of a drainage system in a neighbourhood does not guarantee a successful drainage project. Users need to be aware of operation and maintenance requirements at the neighbourhood level. Often, one of the best solutions for maintenance is for community members to be responsible for the management of the drainage system, as the regular inspection and cleaning of drains is an important task that can be performed without specialized skills. An enhanced management role for user communities is a way of increasing cost-effectiveness, improving reliability and ensuring sustainability, by placing a larger share of the responsibility in the hands of the users themselves.

However, the organization of community members who are ultimately responsible for actually carrying out the cleaning of the drains can be problematic.

This can be achieved most effectively by establishing a special drainage committee in the neighbourhood, or by adding drainage to the list of responsibilities of an already active community committee established for the management of other forms for environmental services (such as water supply and solid waste collection and disposal).

In many situations, it may be more appropriate to contract the services of a member of the local community to be responsible for drain cleaning. This person may be contracted by a management committee, which collects a small fee from community members to pay for the cleaning services. This may overcome problems of reliance on the active participation of all households in drain-cleaning activities, when some may perceive these activities to be degrading or unnecessary – especially where they do not suffer from any of the problems related to poor draining.

5.2.3. The Disaster Management

There is an absence of skilled personnel in disaster management structure, lack of accountability of government officials, poor coordination among the stakeholders at different levels, and weak technical capacity to address Disaster Risk Reduction (DRR). The lack of accountability national wide and preparedness by the government officials, especially disaster management department, poor coordination between inter-ministry levels and Tanzania Meteorological Agency is among the factors that contribute to floods turning into disaster in Arusha. The department of disaster management and government in the lower rank should be trained to mitigate disaster soon before they turn into disasters. Those livings in more risky areas have to be given early warning and be evacuated. Nevertheless, the central government has to improve inter-ministerial coordination in mitigating floods and disasters before they occur.

Urban planning practice in Tanzania has proceeded with little attention on incorporation of disaster issues. Guidelines for the preparation of General Planning Schemes and Detailed

Schemes for New areas, Urban Renewal and Regularization hardly address issues pertinent to Disaster Risk Reduction. This shortcoming has to the larger extent contributed to the accumulation of risks and occurrence of disasters in urban areas.

5.3. Proposed Institutional Measures for Drainage System Management

The City Council should establish bylaws and/or circulars to promote institutional measures regulated by bylaws and included as a condition in building permits. According to the previous collection of best practices and policies adopted for drainage systems' management, the proposed institutional measures for the DSDP can be listed as follows:

• **Building codes.** The purpose of this policy is to define precise building norms to favor a general improvement of the quality of future development and existing constructions.

These building codes have particularly to response to the challenge of establishing better norms in term of safety, water management and land organization. The concept of "hydraulic invariance", namely the condition for peak flow release from transformed areas to remain unvaried before and after land transformation, should be introduced into every urban development plan. The City/Municipal councils should also consider establishing bylaws/circulars to promote the use of permeable pavements against the solid paving blocks which creates massive runoff.

• **Community-based workshops for housing upgrading (governmental assistance).**

Considering that the participation to programs of housing upgrading (retrofitting) is most operative when initiatives are taken at the neighborhood level, it is crucial to develop community-based workshops to promote safer housing in unplanned areas.

These participatory workshops will have to search solutions in term of housing design regarding aspirations of the low income populations. The government has to furnish the necessary assistance including practical means, knowledge resources and technical expertise about sustainable constructions.

• **Building of affordable housing on safe land (urbanization of safe land).** The increase of unplanned settlements in floodplain in Arusha is mostly the result of the non-affordable rents of planned area in safe land. The goal of this policy is to promote construction of high density and affordable settlements on safe lands in order to allow better condition of living for low income populations and to reduce the development of unplanned settlements in hazardous land.

• **Flood Early Warning Systems.** Nowadays, flood forecasting and early warning systems are the most effective non-structural procedures for flood management. Flood warning systems help protect people's lives and prevent property damages by providing sufficient lead time for evacuations. For the prediction of flood inundation, surveyed river survey cross sections are typically needed for the development of hydraulic models. Therefore a well spread network of rain and rivers gauge stations it is needed for the proper functioning of EWSs. Early warning systems (EWS) are an essential component to CBDRM (Community-Based Disaster Risk Management). Early warning systems provide communities with relevant, topical information on environmental conditions so that communities can assess levels of risk and make informed decisions to protect their safety. Furthermore most, if not all, of these EWS are self-monitored by the villagers themselves, which empowers communities and insures that the community itself is a key stakeholder in the EWS initiative.

• **Declaration of hazard land on flood-prone**, by law enforcement to prevent its occupation. The flood-prone zone should be defined beyond the current threshold within 60 meters of the rivers banks (Land Act 1999) and an inundation area of at least 50-year flood Return Period should be accounted for the purpose. All river basin around Arusha City i.e Kijenge and Ngarenarao which has been occupied by settlements

• **Direct involvement of community members** in the implementation of urban drainage maintenance and construction activities, in order to reduce the total cost. This may also stimulate local enterprise initiatives, training and the development of skills. The solid waste management company should also be included in the operations of the removal of solid wastes from the drainage channels.

SECTION 6. PROPOSED STRUCTURAL MEASURES FOR SANITATION

The starting point for developing better sanitation services will base on the analysis of the current problems and their causes. Physical problems often resulted from deeper problems relating to limited institutional capacity and or peoples sanitation related behaviour. There is need to understand these underlying problems if the causes of problems are to be treated and not just their symptoms.

Improved access to sanitation and hence sewerage system under the implementation of this plan to the target communities of Arusha City Council resulting to increase in coverage of household connected to the sewer lines from 7.6% currently to 100% by 2040.

Currently there is poor maintenance of the existing waste stabilisation ponds available that lead to the effluent discharge from the waste water treatment plant (WSP). This plan intended to cover the connections of different users by 100% through which the following intervention has been proposed.

6.1. Construction of waste water treatment plants.

The new ponds which are under construction are expected to serve almost all wards except Olasiti and Olmoti. The work is expected to be complete in the year 2020 as per our site visit assessment. The completion of the ongoing construction waste water treatment plant (WSPs) will solve challenges of wastewater in Arusha City residence. The completion of the above mention stabilization ponds in connection to the extension and rehabilitation of the existing sewer network will be term as the achievement of the medium term goals. The ongoing construction activities involves but not limited to construction of new wastewater treatment plant at Themi Holding ground (2 Anaerobic, 8 Facultative and 8-maturation ponds), Construction of the Trunk main from the existing WSP at Lemara to new site (Themi Holding Ground - Mkonoo), Construction of drying beds at WWTP, Construction of sludge ponds for Cesspit emptier trucks and install digital flow measuring equipment. Also the following structure will be established to facilitate smoothy operational of the treatment plant. These will include the construction of Construction of operator’s house, Construction of wastewater examination laboratory and Fencing the area (100 hectors).

Also apart from the construction of new WWTP the ongoing construction of sewer network will increase the coverage from 7.6% to 30% by the year 2030. These networks will involve the construction of Trunk mains that run through Sombetini, Mbauda, Muriet to WWTP. Additionally there will be a Trunk main that will run through Njiro to WWTP. On the other hand there will be lateral lines that will be installed in various areas and new connection that will connect 5,000 new customers. On the issue of improving the existing and rehabilitation of the existing network the project will upsizing the existing sewer network (20km - CDB), rehabilitate the damaged manholes (250) and improving the customer connections during rehabilitation of the existing sewerage systems.

6.2. Proposed new waste water treatment plants

Based on the fact that the ongoing construction of the new sewerage systems will cater only for 30% of Arusha City residence, this DSDP proposes the additional waste water treatment plants that will accommodate the remaining 70% to ensure 100% coverage of the Arusha City inhabitants. The proposed systems will be design to collect all waste water generated within the city and convey it to sewage treatment works for treatment prior to the discharge into receiving watercourse.

The proposed waste water treatment plants will be designed to services the Arusha City areas based on the average per capital waste water flow rates that has been estimated projected from the percentage of the net water supply (m^3/d).

The new plan takes into account the terrain of Arusha city and plans a new sewage treatment facility that shares the areas of SITE 1(Engutoto, Olorieni_A, Themi, Sekei, Kaloleni, Kati), SITE 2(Olasiti) and SITE 3(Daraja II, Levolosi, Ngarenaro, Unga Ltd, Sombetini, Elerai, Lemara, Sokon I, Terrat) as a result of the review of ARUSHA MASTER PLAN 2015-2035. In addition, a Waste Water Treatment Plant was proposed for area (SITE 4, SITE 5, SITE 6, and SITE 7) not established in the previous plan. The tables below show the generation of sewage in each site by 2040.

6.2.1. Waste Water Flow Projection

The prediction of the total sewage generation through the water consumption calculated as of 2040, the target year of the DSDP, and the results are as follows.

Table 11. Projected Waste Water Flow by Norplan

Description	2015	2020	2030
Population	542,794	620,136	809,453
% coverage	7.6%	28%	54%
Population served by sewerage system	41,252	173,638	437,105
Net Water Demand(m^3/d)	78,853	89,005	120,070
(% Coverage x Net water Demand) m^3/d	5,993	24,921	64,438
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	4,794	19,937	51,870

In the target year 2030, the sewage generation rate was calculated based on 80% Net Water Demand. However, in DSDP, AUWSA applied 100% water supply plan in 2030 and applied 100% water usage in 2030 and 2040

Table 12. Proposed Projection Waste Water Flow by DSDP.

Description	2030	2040
Population	672,702	878,065
% coverage	100%	100%
Population served by sewerage system	672,702	878,065
Net Water Demand(m^3/d)	106,490	136,929
(% Coverage x Net water Demand) m^3/d	106,490	136,929
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	85,193	109,544

As of 2040, the target year for the current task, a total of 109,544m3/day sewage generation is predicted, a new waste water pond with capacity of 22,000m3/day is under construction through ARUSHA SUSTAINBLE URBAN WATER AND SANITATION DELIVERY PROJECT (2017) in AUWSA.

Therefore, DSDP proposed additional facility planning for total 87,544m3

/day in addition to sewage generation in Arusha as of 2040

Table 13. Proposed Projection Waste Water Flow at site under construction (Baraa, Kimandolu, Moshono)

Description	**2030**	**2040**
Population	98,287	128,291
% coverage	100%	100%
Population served by sewerage system	98,287	128,291
Net Water Demand(m^3/d)	14,640	18,780
(% Coverage x Net water Demand) m^3/d	14,640	18,780
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	11,712	15,024

Table 14. Proposed Projection Waste Water Flow at site 1 (Engutoto, Oloirieni_A, Themi, Sekei, Kaloleni, Kati)

Description	**2030**	**2040**
Population	92,853	121,199
% coverage	100%	100%
Population served by sewerage system	92,853	121,199
Net Water Demand(m^3/d)	14,538	18,901
(% Coverage x Net water Demand) m^3/d	14,538	18,901
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	11,631	15,121

Underconstruction Site (22,000 m^3/d) at Terrat ward	DSDP Proposed Site 1 (15,121 m^3/d) at terrat ward

Figure 50. Photos show the sites (under construction and proposed) for WWTP at Terrat ward

Table 15. Proposed Projection Waste Water Flow at site 2 (Olasiti)

Description	**2030**	**2040**
Population	58,736	76,667
% coverage	100%	100%
Population served by sewerage system	58,736	76,667
Net Water Demand(m^3/d)	12,534	16,345
(% Coverage x Net water Demand) m^3/d	12,345	16,345
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	10,028	13,077

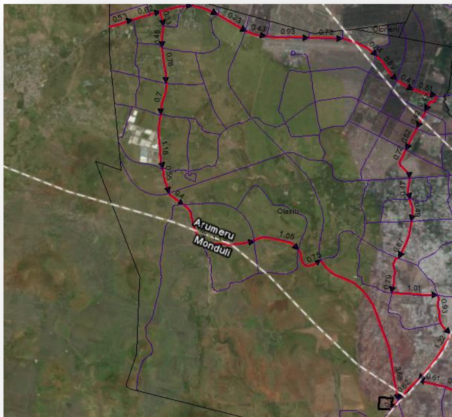
	
Satellite image showing proposed treatment plant 2 at Olasit	DSDP Proposed Site 2 (16,345 m^3/d) at Olasit ward

Figure 51. Satellite image and photo show the proposed site for WWTP at Olasit

Table 16. Proposed Projection Waste Water Flow at site 3 (Terrat)

Description	**2030**	**2040**
Population	417,347	544,757
% coverage	100%	100%
Population served by sewerage system	417,347	544,757
Net Water Demand(m^3/d)	64,208	82,205
(% Coverage x Net water Demand) m^3/d	64,208	82,205
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	51,367	65,765

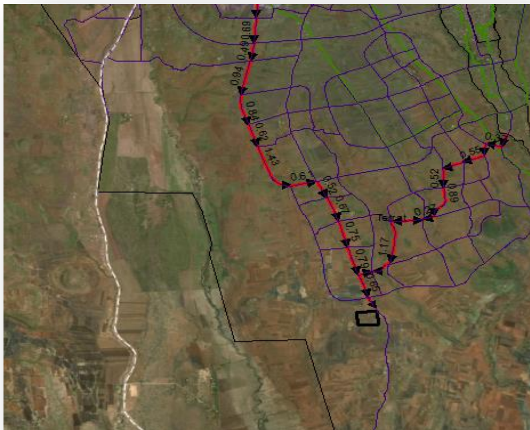
	
Satellite image showing treatment plant 3 at Terrati	DSDP Proposed Site 3 (65,765 m^3/d) at Terrat ward

Figure 52. Satellite image and photo show the proposed site for WWTP at Sokoni_1

Table 17. Proposed Projection Waste Water Flow at site 4 (A part of Sokon_I)

Description	**2030**	**2040**
Population	3,949	5,154
% coverage	100%	100%
Population served by sewerage system	3,949	5,154
Net Water Demand(m^3/d)	487	635
(% Coverage x Net water Demand) m^3/d	487	635
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	390	508

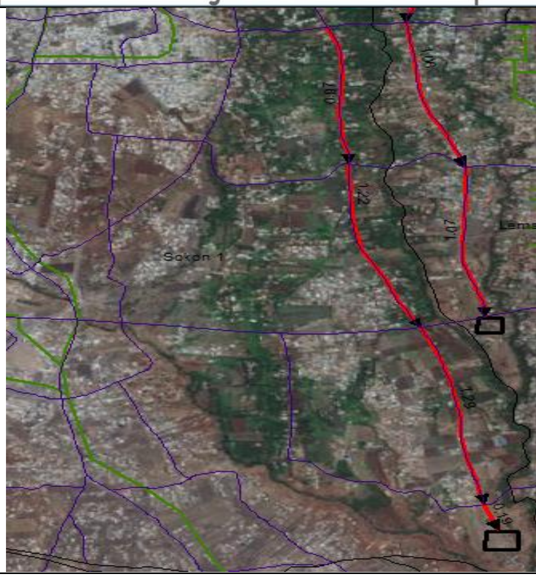
	
Satellite image showing treatment plant 3 at Sokoni 1 ward	DSDP Proposed Site 4 (508 m^3/d) at Sokoni 1 ward

Figure 53. Satellite image and photo show the proposed site for WWTP at Sokoni_1

Table 18. Proposed Projection Waste Water Flow at site 5 (A part of Lemara)

Description	**2030**	**2040**
Population	948	1,238
% coverage	100%	100%
Population served by sewerage system	948	1,238
Net Water Demand(m^3/d)	184	234
(% Coverage x Net water Demand) m^3/d	184	234
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	148	187

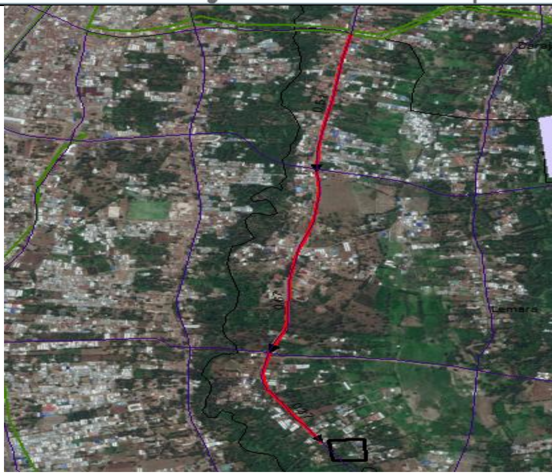
	
Satelite image of Waste Water Flow at site 5 of Lemara)	DSDP Proposed Site 5 (508 m^3/d) at Lemara

Figure 54. Satellite image and photo show the proposed site for WWTP at Lemara ward (site #5)

Table 19. Proposed Projection Waste Water Flow at site 6 (A part of Lemara)

Description	**2030**	**2040**
Population	632	825
% coverage	100%	100%
Population served by sewerage system	632	825
Net Water Demand(m^3/d	123	156
(% Coverage x Net water Demand) m^3/d	123	156
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	99	125

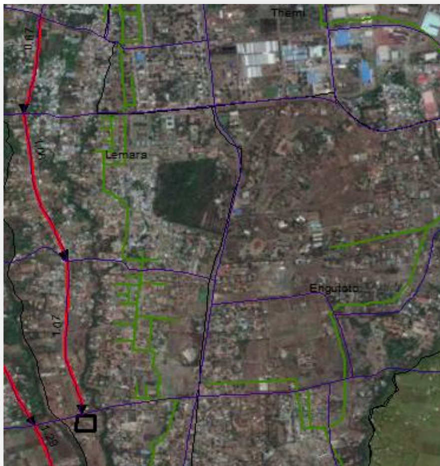
	
Satellite image of Water Flow at site 6 (A part of Lemara)	**Existing situation of proposed site 6 at Lemara** (Q=125m^3/d)

Figure 55. Satellite image and photo show the proposed site for WWTP at Lemara ward (site #6)

Table 20.Proposed Projection Waste Water Flow at site 7 (A part of Sombetini)

Description	**2030**	**2040**
Population	3,899	5,089
% coverage	100%	100%
Population served by sewerage system	3,899	5,089
Net Water Demand(m^3/d)	712	895
(% Coverage x Net water Demand) m^3/d	712	895
Waste water generation (80% of % Coverage x Net water Demand) m^3/d	570	717

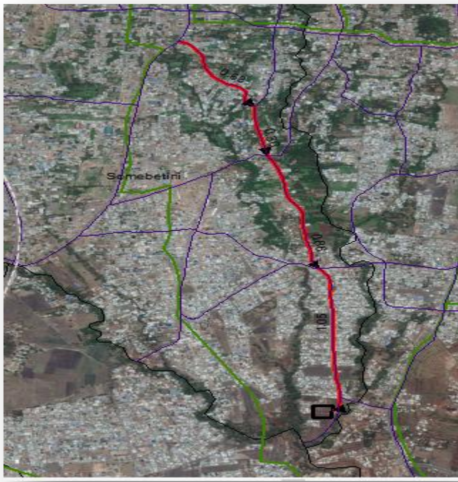
	
Satelite image showing proposed Sombetini waste water treatment	Existing situation of proposed site 7 at Sombetini ($Q=717m^3/d$)

Figure 56. Satellite image and photo show the proposed site for WWTP at Sombetini ward

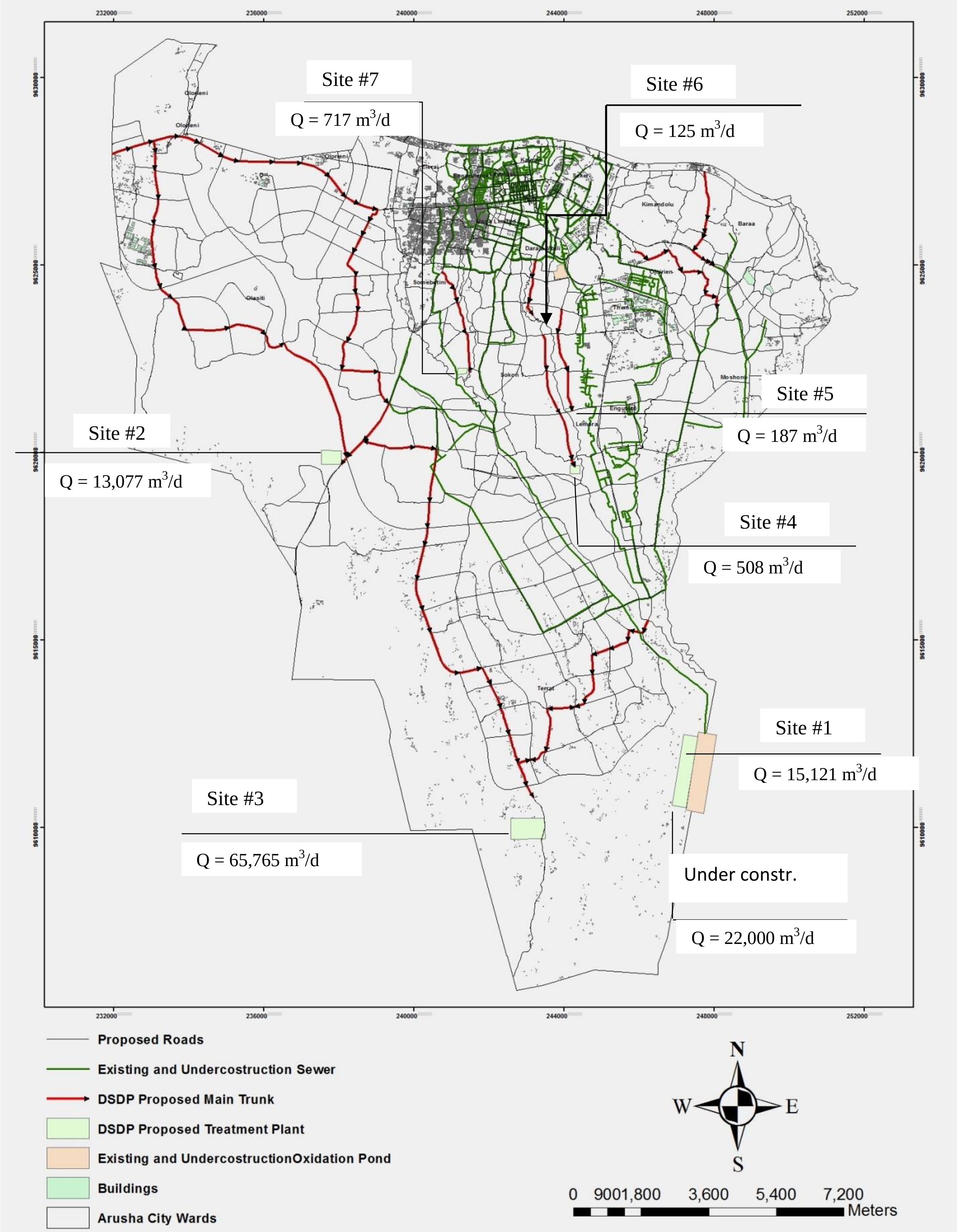


Figure 57.DSDP Proposed New Waste Water Ponds and Sewer Pipe Line

6.2.2. Trunk Main Sewer pipe

Currently, Arusha is working on a pipeline that processes 30% of the sewage generated in 2030 by ARUSHA SUSTAINABLE URBAN WATER AND SANITATION DELIVERY PROJECT (2017). Therefore, for TM – P line, TM – Q line, TM – R line under construction, this time DSDP has secured the capacity of the Trunk Main Pipeline handling 100% as of the target year 2040, so some areas have planned to replace and build new Trunk Main Pipelines.

In addition, TM – T line includes TM – R line and Terrat, and the route change and construction of the pipeline will be planned to allow inflow into the new sewage treatment plant on Site 3

TM – M line planned to construct a new pipe to allow sewage from the Olasiti area to flow into the new sewage treatment plant on Site 2

The total length of the trunk mains is about 74.866km in total and each main was designed for the gravity flow to be available. The materials for trunk mains and laterals are of uPVC, HDPE and Steel. The trunk mains & laterals designed were summarized in Table30 and the details can be seen in the General Design Criteria for Main Trunk of Sewerage System and longitudinal drawing in the Appendix.

Table 21. Quantity of Trunk Main Sewer Pipes

WARD		Number of Lines	Length (m)
TM-P	Baraa, Kimandolu, Moshono	1(TM-P)	12,888
TM-Q	Engutoto, Olorieni_A, Themi, Sekei, Kaloleni, Kati	1(TM-P)	6,414
TM-R~T	Daraja II, Levolosi, Ngarenaro, Unga Ltd, Sombetini, Elerai, Lemara, Sokon I, Terrat	2 (TM-R, TM-T)	24,608
TM-M	Olasiti	2 (TM-M1, M2)	30,962
TOTAL			74,872

Table 22. The length of Trunk Main Sewer Pipes by Sewer Sizes

Trunk	TM-P	TM-Q	TM-R~T	TM-M

D200	-	-	3,505 m	3,170 m
D250	508 m	-	-	-
D300	1,179 m	-	7,650 m	-
D350	639 m	-	-	27,570 m
D400	504 m	-	1,913 m	-
D450	-	-	-	222 m
D500	-	-	100 m	-
D600	370 m	-	1,419 m	-
D700	5,326 m	6,414 m	1,840 m	-
D800	4,362 m	-	-	-
D1000	-	-	8,181 m	-
TOTAL	12,888 m	6,414 m	24,608 m	30,962 m

KEY AND CHALLENGE

- As of 2040 years of calculation, the total sewage generation is 109,544m^3/day. Here, with the exception of 22,000 m^3/day of waste water plant under construction and Site 2 (Q=15,358m^3/d), Site 3(42,128m^3/d), Site 4(508m^3/d as of 2040. Arusha City was considered to require the establishment of a new sewage treatment plant(Site 1) in total 29,550m^3/day

- As reviewed this time, the new capacity(Site 1) required as of 2040 is currently planned around the waste water pond treatment plant under construction and is in the process of discussing it accordingly

Appendices: The General Design Criteria for Main Trunk of Sewerage System

6.2.3. The design of conventional gravity sewers is based on the following design criteria:

(a) *Long-term serviceability*: the design of long-lived sewer infrastructure should consider serviceability factors, such as ease of installation, design period, useful life of the conduit, resistance to infiltration and corrosion and maintenance requirements. The design period should be based on the ultimate tributary population and usually ranges from 25 to 50 years.

(b) *Design flow*: sanitary sewers are designed to carry peak residential, commercial, institutional, and industrial flows, as well as infiltration and inflow. Gravity sewers are designed to flow half full at the design peak flow.

(c) *Minimum pipe diameter*: a minimum pipe size is dictated in gravity sewer design to reduce the possibility of clogging. The minimum pipe diameter recommended by the Tanzania Standards (MoWI Design Manual, 2009) is 200 mm.

(d) *Velocity*: the velocity of wastewater is an important parameter in a sewer design. A minimum velocity must be maintained to reduce solids deposition in the sewer, and most states specify a minimum velocity that must be maintained under low flow conditions. The typical design velocity for low flow conditions is 0.3 m/s. During peak dry weather conditions the sewer lines must attain a velocity greater than 0.6 m/s to ensure that the lines will be self-cleaning (i.e., they will be flushed out once or twice a day by a higher velocity). Velocities higher than 3.0 m/s should be avoided because they may cause erosion and damage to sewers and manholes.

(e) *Slope*: sewer pipes must be adequately sloped to reduce solids deposition and production of hydrogen sulfide and methane.

(f) *Depth of bury*: depth of bury affects many aspects of sewer design. Slope requirements may drive the pipe deep into the ground, increasing the amount of excavation required to install the pipe. Sewer depth averages 1 to 2 m below ground surface. The proper depth of bury depends on the water table, the lowest point to be served (such as a ground floor or basement), the topography of the ground in the service area and the depth of the frost line below grade

6.2.4. The formula of design parameters

The values of four design parameters (i.e. slope, design flow, sewer size and the flow velocity) are calculated as shown in the table below.

Table 23. Design parameters and design formulae

ITEM	FORMULA(COMPUTATIONS)	REMARK

A. Slope(S)	$S = \frac{INV_{up} - INV_{low}}{Pipe\ Length, L}$ Where : INV_{up} = Upper Invert Level (m) INV_{low} = Lower Invert Level (m)	
B. Design Flow(Q_d)	$Q_d = Q_p + Q_{inf} - Q_{seep}$ Where : Q_p = Population Flow(L/s) Q_{inf} = Flow due to Infiltration(L/s) Q_{seep} = Seepage Flow(L/s)	
C. Sewer Size(D)	$D = \left(\frac{3.2084 * n * Q_{full}}{S^{1/2}}\right)^{3/8}$ Where : n = Manning's coefficient (concrete pipe 0.015, uPVC, GRP 0.012) Q_{full} = design flow at full flow conditions which is obtained by the formula Q_{full}= 2*Q_d	
D. Horizontal Flow Velocity(V_H)	$V_H = n^{-1} * R^{\frac{2}{3}} * S^{1/2}$ Where : R= Hydraulic radius, which is given by the formula R=D/4	

※ by MoWI Design Manual, Vol-2 (2009)

3. Manholes

For ease of maintenance and inspection manholes are provided at each intersection and every change in gradient, pipe diameter, direction of flow or level of the sewer and at all junctions. Manholes are usually installed at intervals ranging from 70 to 150m.

For Tanzania where maintenance has traditionally been poor, and blockage problems tend to be frequent, in addition to this usual requirement, the distance between manholes should be restricted to:

Table 24. Manholes spacing along trunk main sewer

Sewer Diameter	Manhole Spacing
Trunk Main Sewers, 100 – 500 mm	30 - 80 m
Trunk Main Sewers, 500 – 700mm	80 - 100 m
Trunk Main Sewers, > 700 mm	100 m

6.3. New faecal sludge treatment plants

As most part of unplanned settlements in Arusha City Council, prefer the use of onsite sanitation system as their mean of excreta storage; the issue of faecal sludge treatment should be set as the short term goal within this DSDP. In this regards, ACC in collaboration with one of the developing partner i.e. SNV have agreed to improve the health and quality of life of people in Arusha City through access to adequate, safe, equitable and sustainable sanitation. The agreed strategy entails the improvement of the quality and quantity of sanitation services provision to the community of Arusha City. Therefore the SNV organization need to establish a faecal sludge treatment plants based on the main concern that the new ongoing construction WSP being farthest from the centre of the City almost 5 times the distance of the current WSP, and therefore bring about impact on environmentally FS collection and disposal (in terms of cost, and increased likelihood of illegal dumping). However, there is some reluctance from the utility (AUWSA) about a treatment option that will once again be close to the city centre, so ongoing discussions around suitable locations and options are taking place with different decision makers including us so as to have a common decision and plan towards the implementation of these faecal sludge treatment plants nearby the City Centre - Arusha City. Based on the above mentioned discussion and agreement between the parties SNV in association with INOSOLT Consulting – from Thailand have come up with the proposal and design of environmental friendly faecal sludge treatment plant that will be installed at Kimandolu and Lemara sites.

Figure 58. Satellite Image of Kimandolu and Lemara Fecal treatment sites

	
Existing situation of proposed Kimandolu Site (Q=120m^3/d)	Existing situation of proposed Lemara Site (Q=120m^3/d)

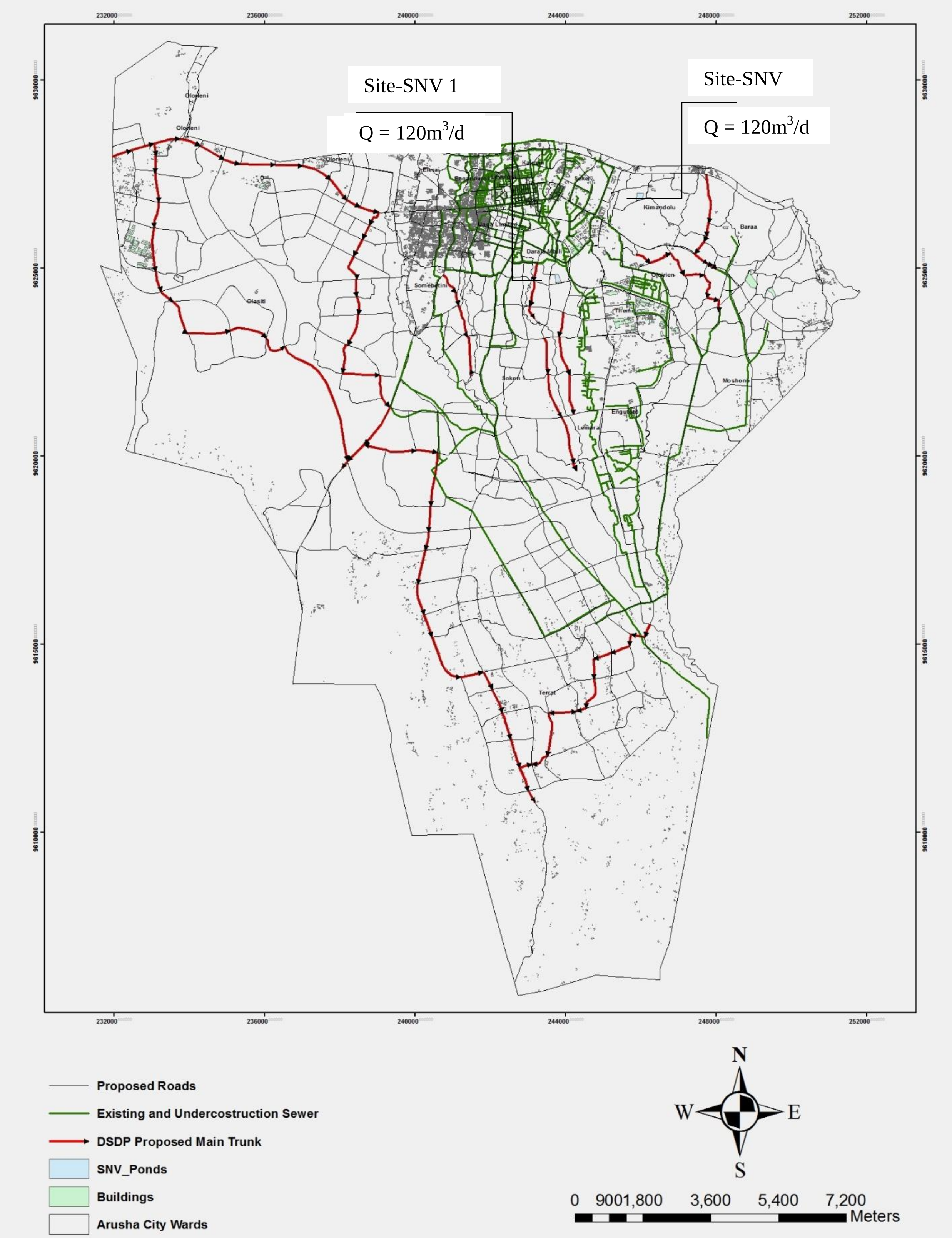


Figure 59. Proposed sites for the treatment of faecal sludge

The first step in designing faecal sludge (FS) treatment technologies, is to quantify and characterize the FS to be treated, this will defined treatment objectives. However the quantities of FS generated and the typical FS characteristics are difficult to determine due the variety of onsite sanitation technologies in use, such as pit latrines, urinal diversion toilet, Ventilated improved pit latrine, pour flush toilet, cistern flush toilet, public ablution blocks and septic tanks. Faecal Sludge characteristics are influenced by a wide range of factors; some of the factors that have been found to influence faecal sludge quality include: containment emptying technologies and patterns, storage duration (months to years), performance of containment (e.g. septic tanks), presence of admixtures (solid wastes, grease), temperature, and groundwater intrusion ((Heinss and Koottatep, 1998). However, selecting the appropriate technology for faecal sludge treatment depends on a particular City's sludge characteristics and on the treatment objectives (e.g. intension for agricultural reuse, regulation of discharge of treated liquids into receiving water bodies etc.) (Koné and Strauss, 2004). Kone and Strauss (2004) provide overview of design criteria and expected removal efficiency of some of the treatment process. Form their analysis, settling and thickening tanks alone can remove about 30 – 50% COD, and 60 – 70% Suspend Solids, when settling tank is used in combination with anaerobic pond it can achieve BOD_5 removal of 60 to 70%. Unplanted drying beds (dewatering/drying beds) can remove more than 60 – 80% of Suspend Solids, 70 – 90% of COD and 40 – 60% of NH4+ - N (see Heinss et al. 1999; Kone and Strauss 2004). Planted drying beds (constructed wetlands) are reported to remove more than 80% of Suspended Solids, while Waster Stabilization Ponds can remove about 60% of BOD_5. A well designed and operated drying/dewatering beds connected to a system of Constructed Wetlands have been reported can remove 100% of parasites (helminthes eggs).

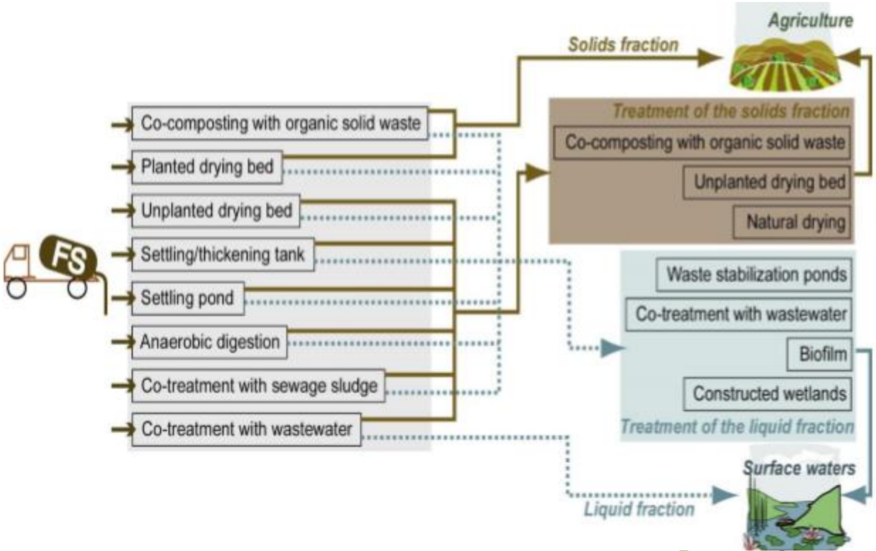


Figure 60. Faecal sludge treatment options (Source: Ingallinella et al., 2001)

In order to cater for the needs of faecal sludge treatment and sustainable sanitation system in Arusha City, the installation of faecal sludge treatment plant is of more important and should be considered in this DSDP as a short term goal. With this regard and in consultation with the Client the proposition of planted drying bed and constructed wetland is of more priority. Furthermore, the existence of these faecal sludge treatment plants will reduce the haulage distance and hence minimize the cost the customer as the treatment plants will be within the city centre. But all the approaches will depend upon the local government preferences in terms of plant management, maintenance and operation attitude on the proposed FS treatment plant.

6.4. Constructed wetlands

A subsurface flow bed filled with gravel and planted with vegetation. Constructed wetlands (CWs) are a natural, low-cost, eco-technological biological wastewater treatment technology, which are designed to replicate the processes found in natural wetland ecosystems. The shape of constructed wetlands may vary based on design. However, it is a shallow basin filled with some sort of filter material known as media, sand or gravel.

A constructed wetland typically comprises following components: a basin, media, vegetation, liner and inlet/outlet arrangement system. During treatment, the wastewater/faecal sludge is fed into the basin filled with media and planted with vegetation. The wastewater/faecal sludge flow over or through the substrate depending upon the type of constructed wetlands. The mechanisms of treatment are subjected to physical, chemical, as well as microbial interactions, where it will be treated. At the early stages of operation, attention is required mainly on the growth of planted vegetation on constructed wetland. The contamination level and organic load will be much higher in faecal sludge and needs to be acclimatized slowly. Therefore, a proper and complete process needs to be carefully followed during the start-up of constructed wetlands for faecal sludge treatment (Ecological treatment system, AIT).The optimum loading rate is considered as 250 kg total solids (TS) per m^2 year or 8 m^3/week, and resulting sludge accumulation is about

10-20 cm per year (AIT, 2001). The series of constructed wetland as vertical flow and horizontal subsurface types are normally applied for treating FS.

6.4.1. Treatment description and criteria

In this DSDP the following has been provided as the descriptive for design and treatment criteria.

Design parameters are loading of 0.1 -0.3 m3/m^2/batch and 6-day of retaining. Liquid will flow down vertically through a filter bed while sludge is left on the surface of bed.

Horizontal subsurface flow CW is the channel of planted bed receiving water flow through horizontally. The pollutants will be trapped in substrata and degraded by microorganisms on the surface or around the materials. HRT of 1-2 days is used as design parameter.

Floating plant pond is a shallow pond which floating plants can uptake nutrients and release O2 through rooting system. The treatment mechanism is similar to maturation pond where applied in the final treatment process. HRT of 1-2 days is used as design parameter.

Table 25. Design parameters for the constructed wetlands

Details	**Arusha (Kimandolu) → CW**
FS Load	75 m^3/day Or Maximum 120 m3/day for the low strength of FS
Design Criteria	0.10 m3/m^2 2 day HRT for Percolate
Unit and Area	6 CW units for FS 2 CW unit for Percolate
Tank	Clay
Expected Effluent Characteristics	BOD <50 mg/L HE < 2 – 5 no./L FC < 104 MPN/100 mL
Life time	7-10 years Plant harvesting in every 3 months, remove sludge after 710 years
Other concern	Garbage, weed

6.5. Planted Drying Beds (PDBs)

These beds (PDBs), also sometimes referred to as planted dewatering beds and sludge drying reed beds, are beds of porous media (e.g. sand and gravel) that are planted with emergent macrophytes. PDBs are loaded with layers of sludge that are subsequently dewatered and stabilised through multiple physical and biological mechanisms (Kadlec and Knight, 1996).

These beds operated in a manner FS is repeatedly loaded onto PDBs, with up to 20 cm of FS per loading (Kadlec and Wallace, 2009), where it accumulates for several years depending on the loading rate, the capacity of the system and mineralisation rates (Nielsen, 2003).

The dewatering, organic stabilisation and mineralisation performance of the PDB depends on a variety of factors such as the media type and size, the type of plants, the maturity of the beds, climatic factors, and the sludge characteristics, as well as operational factors such as the hydraulic loading rate (HLR), the solids loading rate (SLR), and the loading frequency (Breen, 1997; Prochaska et al., 2007; Van Cuyk et al., 2001). As the bed matures, microbial communities become more established and stable.

6.5.1. Design consideration of the planted drying beds

The following table below provides for the general design consideration for the implementation of PDBs as FS treatment option.

Table 26. Design consideration and parameters for PDBs.

Factor	Parameters to consider	Remarks
Site selection	Land use and Access	located centrally to reduce transport distances
	Land availability	Enough area to accommodate current demand and future expansion
	Topography of the site	located centrally to reduce transport distances
Structure	Cells	the cell must have a reasonable depth, either through excavation or build up earth embankment
		Multiple cells (in parallel) are recommended so that the cells can be loaded sequentially and allow for a resting phase

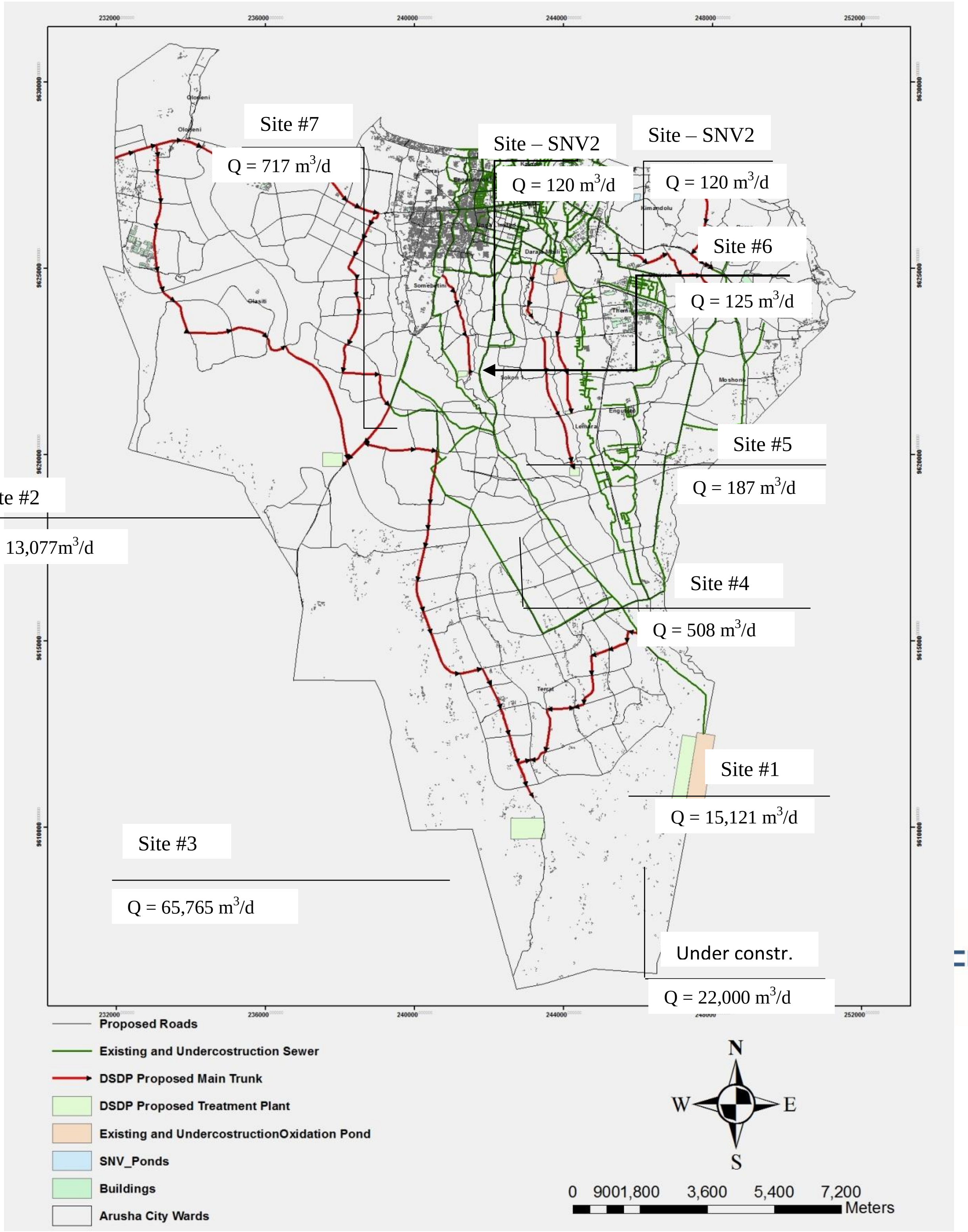
		The bottom should be sloped slightly (1-3%)
	Liners	Synthetic or compacted clay --> to avoid possible contamination of ground water
Flow structures	In let	Flow control structures should be easy to adjust
	Outlet	Should be installed in a manner can control water level if necessary (weir, spillway)
Design Criteria		0.10 m^3/m^2 2 days HRT for Percolate
FS Load		75 m^3/day Or Maximum 120 m^3/day for the low strength of Faecal Sludge.
Units and area		6 CW units for FS 2 CW unit for Percolate
System life		The operation life of the PDBs determined by the loading rate stabilisation rate and the number of beds.
Vegetation		The vegetation should be of indigenous and non-invasive macrophtes that can grow in sludge.

6.5.2. Expected output

Conclusively PDBs are a relatively good technology for treating FS from septic tanks and other onsite sanitation technologies in low- and middle-income countries. Although the macrophytes require some time to acclimatise to the nutrient-rich sludge, the PDB can then operate for up to 10 years without deluding and the macrophytes can be harvested for beneficial use. The stabilised sludge layer can also be used as a soil amendment and organic fertiliser. Table 36 summarises the anticipated out from the plant drying bed suggested to be implemented under this DSDP report for Arusha City.

Table 27. PDBs output:

Output	**Remarks**
Expected Effluent Characteristics	BOD < 50 mg/L HE < 2 – 5 no./L FC < 10^4 MPN/100 mL
Life time	7-10 years, Plant harvesting in every 3 months, remove sludge after 7 - 10 years


Site #7
Q = 717 m3/d
Site – SNV2
Q = 120 m3/d
Site – SNV2
Q = 120 m3/d
Site #6
Q = 125 m3/d
Site #5
Q = 187 m3/d
Site #2
Q = 13,077m3/d
Site #4
Q = 508 m3/d
Site #1
Q = 15,121 m3/d
Site #3
Q = 65,765 m3/d
Under constr.
Q = 22,000 m3/d
Proposed Roads
Existing and Undercostruction Sewer
DSDP Proposed Main Trunk
DSDP Proposed Treatment Plant
Existing and UndercostructionOxidation Pond
SNV_Ponds
Buildings
Arusha City Wards
N
W
E
S
0 9001,800 3,600 5,400 7,200
Meters

6.5.3. Sanitation projects implementation – phasing

These sanitation intervention Projects are demand-driven. The implementation of the sanitation related projects in Arusha City will be implemented in three phases as categorized in the following table below. Phase I (Short terms) project package consist of the following components – i.e construction of the DEWATS 2No. each consist of 120 m^3/d

A Phase 2 (and 3) project package consist of the construction of the waste water treatments plants (sewerage) that will involve the sewer lines and WWTP to be implemented at different seven(7) selected sites/zones.

Table 28 Sanitation intervention – phasing

Project Phasing	Sanitation interventions	Wards	Quantity		
				Dimension	
			Size (m^3/d)	Length x width	Diameter, mm
Short terms 2020 - 2025	Construction of DEWATs (Drying Beds and Constructed Wetlands)	Kimandolu, Olorieni, Sakina, Sekei, Kaloleni, Elerai, Baraa, Sokoni I, Themi, Unga ltd, Sombetini, Engutoto,Moshono, Kaloleni, Kati, Levolosi	2 No @ 120	76 x 200 m^2 @ Kimandolu	N/A
Medium terms.	Construction of the waste water treatment	Part of Lemara, Sombetini, Lemara, Sokoni I	2 No.@508		

2026 - 2035	plants (Sites Nos. 4,5,6 &7)		125 717		Table 31 &32
Long terms 2036 - 2040	Construction of waste water treatment plants (Sites Nos. 1,2&3)	Engutoto, Olorieni, Themi, Sekei, Kaloleni, Kati, Olasiti, Daraja II, Levolosi, Ngarenaro, Unga ltd, Sombetini, Elerai, Lemara, Sokoni I and Terati	15,121 16,345 65,765		

After the successful implementation of the project from phase 1 to 3, a total of .2 DEWATs will be constructed for the handling and treatment of faecal sludge. Also a total of seven WWTPs will be constructed at different zone as selected during the feasibility study of the DSDP and approved in consultation with the Client. The construction of these seven WWTPs will go together with the installation of sewer lines with the total length of 74,872m to be installed at different areas as indicated in figure 62.

6.6. Climate Change On Sanitation Issue

6.6.1. National Climate Change Strategy 2012

This Strategy has been developed in response to growing concerns about the negative impacts of climate change and climate variability on the country's social, economic and physical environment. Its overall aim is to enhance the technical and institutional capacity of the country to address the impacts of climate change. The Strategy covers adaptation, mitigation and intersectoral interventions that will enable Tanzania to benefit from the opportunities available to developing countries in their efforts to tackle climate change.

The goal of the Strategy is to enable Tanzania to effectively adapt to climate change and participate in global efforts to mitigate climate change with a view to achieving sustainable development in line with the nation's Five Year National Development Plan, the Tanzania Development Vision 2025, and national sectorial policies. It is expected that this Strategy will reduce vulnerability and enhance resilience to the impacts of climate change. The implementation of the Strategy will enable the country to put in place measures to adapt to climate change and reduce GHG emissions in order to achieve sustainable national development through climate change-resilient pathways.

The specific objectives of this Strategy are:

a) To build the capacity of Tanzania to adapt to climate change impacts.

b) To enhance resilience of ecosystems to the challenges posed by climate change.

c) To enable accessibility and utilization of the available climate change opportunities through implementation.

d) To enhance participation in climate change mitigation activities that lead to sustainable development.

e) To enhance public awareness on climate change.

f) To enhance information management on climate change.

g) To put in place a better institutional arrangement to adequately address climate change.

h) To mobilize resources including finance to adequately address climate change.

The Strategy aims to create a climate change-resilient society and nation with water and sanitation facilities capable of coping with and resisting climate change-related events.

6.7. Vulnerability and the impact on sanitation systems and adaptive measures

6.7.1. Centralised treatment system

A centralised treatment system is a sewer-based system in which black water is directly connected to a piped conveyance, which is predominantly a conventional sewer. This system does not have an intermediary collection and storage facility. According to information gathered during the baseline research, Arusha city has a sewer network and it is understood that there is a huge programme of sewer extension from the current 7% to about 30% coverage by 2020 and the DSDP is planning to have the achievement from 30% to100% covered up to 2040. Gravity sewers are vulnerable to flooding and inundation, often resulting in the wide spread of contaminants.

The potential for damage is even greater in the case of a combined sewer, as storm water also drains into the same network. Overloading of the sewer network can cause damage to the sewer system and to the treatment facilities, leading to system failure. The only difference in the case of sewerage systems with urine diversion is that urine is separated and collected at source.

6.7.2. Systems with pits

Arusha city is mostly covered by systems with pits as defined, systems with pits are vulnerable to flooding. During floods, pits are inaccessible and after flooding they may be

filled with silt and rendered unusable. Floods can also lead to the overflowing of pits, resulting in significant environmental contamination which may lead to outbreaks of diseases.

Furthermore, pits are prone to collapse, and the superstructure can be damaged during floods.

Projections from Global Circulation Models (GCMs) indicate that due to a doubling in the concentration of CO2 in the atmosphere by 2100 there will be an increase in rainfall in some regions while others will experience decreased rainfall. The areas with two rainfall seasons – that is, the north-eastern highland and Zanzibar, the Lake Victoria basin and the northern coast are likely to experience an increase in rainfall in March to May (long rains) of up to 15 per cent. Southern, south-western, western and central areas are expected to experience a decrease in March to May rainfall of up to 6%. These changes may affect sanitation systems and any decisions made today have to consider such variability and changes in climate.

Table 29 Examples of impacts, potential resulting events of Climate change and impacts on sanitation

Impact of climate system) change relevant in Arusha City	Potential resulting events and changes	Examples of impact on sanitation
Increase in rainfall	• Increased flooding • Increased erosion • Contamination of and damage to surface water and groundwater supplies • Changes to groundwater recharge and groundwater levels	• Destruction and damage to sanitation infrastructure • Damage to other infrastructure/systems on which sanitation systems rely (e.g. electricity networks for pumping; road networks used by FSM vehicles) • Flooding of on-site systems causing spillage and environmental contamination • Flooding of pit latrines, including via groundwater • Overflow and/or obstruction of sewerage and septic systems
Drought	• Longer dry seasons/periods • Reduced surface water flows • Reduced groundwater levels/resources	• Declining water supply impeding the functioning of water-reliant sanitation systems (e.g. flush toilets, sewerage) • Greater distance between pit latrine pollutants and groundwater levels, allowing for pathogen attenuation • Obstruction creating reduced capacity in rivers or ponds that receive wastewater • Malfunction, breakdown or inaccessibility of sanitation systems deterring safe sanitation behaviours
Increased temperatures	• Higher ambient air temperatures in homes or facilities • Higher freshwater temperatures (with increased concentration of nutrients such as phosphorus, and other factors) - Decrease in	• Malfunction, breakdown or inaccessibility of sanitation systems deterring safe sanitation behaviours • Obstruction creating reduced capacity in rivers or ponds that receive

	surface water quality e.g. proliferation of algal blooms or microbes carried by vectors in water	wastewater

Table 30 Table Summary of potential impacts of climate change and adaptation measures in Arusha as per existing and proposed type of sanitation systems

Onsite systems			
Pit latrines (dry and low- flush)	• Reduced soil stability leading to lower pit stability • Environmental contamination from latrine flooding • Groundwater contamination from flooding • Risk of latrine owners using floodwaters to flush out latrine pits • Collapse of latrine due to inundation or erosion	• Lining of pits using local materials (including more permanent linings in high density areas) • Locally adapted pit latrine designs: raised latrines; smaller pits that are emptied more frequently; vault latrines; appropriate separation distances; use of appropriate groundwater technologies; protective infrastructure around system • In highly vulnerable areas: provide low-cost temporary facilities in lieu of permanent ones • Where feasible, site systems in locations less prone	High (Good adaptive capacity through potential design changes)
Septic tanks	• Increased water scarcity reducing water supplies and impeding tank function • Rising groundwater levels, extreme events and/or floods, leading to structural damage to tanks, flooding of drain fields and households, tank	• Installation of sealed covers for septic tanks and non-return valves on pipes to prevent back flows • Insure vents on sewers are above expected flood lines • Community education on tank maintenance, and on hygiene and safe behaviours during/after extreme events	Low to medium (Some adaptive capacity; vulnerable to flooding and drying environments)
Offsite systems			

Conventional sewerage (e.g. combined sewers)	• Extreme rainfall events causing discharge of excess, untreated wastewater into environment	• Use of deep tunnel conveyance and storage systems to intercept/store combined sewer overflow • Re-engineering to separate storm water flows from sewage • Providing additional storage for storm water	Low to medium (Some adaptive capacity; vulnerable to reduced water
Sewage treatment	• Extreme rainfall events causing back- flooding of raw sewage into buildings • Extreme events damaging sewers and causing leakage, resulting in environmental contamination • Sea-level rise raising water levels in coastal sewers, causing back-flooding in infrastructure and buildings • Increased water scarcity reducing water flows in sewers, increasing solid deposits and blockages	• Use of special gratings and restricted outflow pipes • Installation of non-return valves on pipes to prevent back flows • Where appropriate, installation of small-bore or other low-cost options at local level to reduce costs of separate systems • Community education on hygiene and safe behaviours during/after extreme events	availability and flooding of combined sewers)

	• Extreme weather events or floods destroying/damaging wastewater treatment systems, causing discharge of untreated sewage and sewage overflow, creating major environmental contamination • Extreme rainfall events damaging waste stabilization ponds • Extreme events damaging low-lying treatment plants, causing environmental contamination • Increased water scarcity causing obstruction that reduces capacity in rivers or ponds that receive wastewater	• Install flood defences and undertake sound catchment management • Invest in early warning systems and emergency response equipment(e.g. mobile pumps stored off-site) • Prepare a rehabilitation plan for the treatment works • Where feasible, site systems in locations less prone to floods, erosion, etc.	Low to medium (Some adaptive capacity; vulnerable to increases and decreases in water availability; reduced carrying capacity may increase sewage treatment requirements)

Reuse of wastewater for food production	• Increased water scarcity leading to increased reliance on wastewater for irrigation purposes • Without adequate wastewater treatment, increased reuse can expose populations (farmers, their communities and consumers) to health hazards including pathogens, chemicals, etc.	• Include climate change and variability in assessing, monitoring and establishing control measures for wastewater management. • Crop selection, irrigation type, withholding times, vaccination and chemotherapy • Behavioral interventions/ health and hygiene promotion for safe hygiene practices, use of personal protective equipment etc.	

SECTION 7. INSTITUTIONAL SANITATION MANAGEMENT

7.1.Institutional Administrative Framework

7.1.1. Water Supply and Sanitation Sector

According to the Water Supply and Sanitation Act No 5 of 2019 the institutional set-up for water supply and sanitation services and related authorities from national level to village level includes:

- Minister Responsible for Water;
- Minister responsible for Local Government;
- Energy and Water Utilities Regulatory Authority (EWURA);
- Regional Secretariats; and
- Local Government Authorities (City, Municipal, District, Ward and Village).

The functions of each institution are outlined in the Water Supply and Sanitation Act and here presented in brief in the table 41. The following table presents the main institutions involved and their responsibilities.

Table 31 Responsibilities of Institutions related to Water Supply and Sanitation Service

Administrative level	Institution	Responsibility
National	The Minister responsible for Water – Ministry of Water	Determine legislative aspects of the provision of water supply and sanitation services; Determine policy and strategy aspects of the provision of water supply and sanitation services; Coordinate technical and financial support for water supply and sanitation services; Coordinate planning and resource mobilization for water supply and sanitation services through external support, Non-Governmental Organizations and the public; Ensure the provision of the technical guidance to Water Supply and Sanitation Authorities

		and RUWASA; Coordinate and monitor water and sanitation authority strategies and plans; Monitor performance of and regulate community based water supply organizations; Supervise implementation of the provisions of water supply and sanitation service; Cause to be prepared the National Water Sector Master Plan developed under the Water Resources Management Act; and Facilitate provisions of low cost technologies of water supply and sanitation services to communities.
	The Minister responsible for Local Government – PO-RALG	Establish Water and Sanitation Authority; Cluster water authorities in order to achieve commercial viability; Creating a conducive environment for community and private sector participation in development, operation and management of water supply and sanitation services; and Creating a conducive environment for Water and Sanitation Authorities, RUWASA and community organizations in the execution of functions connected with provisions of water supply and sanitation services.
	Energy and Water Utilities Regulatory Authority (EWURA)	Exercise licensing and regulatory functions in respect of water supply and sanitation services; Establish standards relating to equipment attached to the water and sanitation system; Establish guidelines on tariffs chargeable for the

		provisions of water supply and sanitation services; Approve tariffs chargeable for the provision of water supply and sanitation services; Monitor water quality and standards of performance for the provision of water supply and sanitation services; Initiate and conduct investigations in relation to the quality of water and standards of service given to consumers; Conduct studies necessary for administrative or management purposes; Collect and compile data on licensees as it considers necessary for the performance of its functions; Issue orders or give directions to any person granted a license in respect of a regulated activity; Establish or approve standards and codes of conduct in respect of(i) licensees; (ii) consumers; and (iii) public safety; Promote the development of water supply and sanitation services in accordance with recognized international standard practices and public demand.
Regional	Regional Secretariat	Coordinate and follow up status of planning and implementation of water supply and sanitation services in the Region; and Create a conducive environment for water authorities, RUWASA and Community Organizations in the execution of functions connected with provisions of water supply

		and sanitation services in the Region.
District	Urban Authorities – Arusha City Council	Make by-laws in relation to water supply and sanitation to give effect to the efficient and sustainable provision of these services in their areas of jurisdiction by water authorities or community organizations; Coordinate physical planning with the water authorities and community organizations; Set aside funds from own sources for water supply and sanitation project; Facilitate the acquisition by communities desirous of owning and managing their water schemes of certificates of title prior to the communities taking over responsibility; Mobilize communities to take over water supply schemes; Approve by-laws for protection of water sources, operations of community organizations and other service providers; and Promote provision of sanitation facilities in the areas of community based water supply schemes.
	Urban Water Supply and Sanitation Authorities –AUWSA	Responsible for efficient and economical provision of water supply and sanitation services; Secure the continued supply of water for all lawful purposes by continuously treating the water and monitoring the quality of water supplied at such times; Develop and maintain waterworks and sanitation works;

		In consultation with relevant authorities protect and maintain water sources; Advise the Government in the formulation of policies and guidelines relating to potable water standards; Plan and execute new projects for the supply of water and the provision of sanitation; Educate and provide information to persons on public health aspects of water supply, water conservation, sanitation, and similar issues; Liaise with relevant government authorities on matters relating to water supply and sanitation and the preparation and execution of plans relating to the expansion thereof; Collect fees and levies including any regulatory levy for water supply and sanitation services supplied to consumers by the water authority; Provide bulk procurement and distribution of water chemicals and materials to ensure availability of water chemicals and materials which meet required standards; Propose water supply and sanitation tariffs; Provide amenities or facilities which the water authority considers necessary or desirable for persons making use of the services or the facilities provided by the water authority; and Do anything or enter into any transaction which, in the opinion of the Board of the Water Authority, is calculated to facilitate the proper exercise of the functions of the Water Authority.
Community	Ward and Village Councils	Promote the establishment of community

		organizations; Co-ordinate community organization budgets with village council budgets; and Resolve conflicts within community organizations.

7.1.2. Sanitation and Hygiene Sector

In Tanzania, responsibilities for sanitation and hygiene are spread over different sectors, such as water, health and education. The Ministry of Health, Community Development, Gender, Elderly and Children is developing a National Sanitation and Hygiene Policy. Provides guidelines and technical assistance to councils, and prepares acts, regulations and standards for monitoring, regulating and supporting councils and other stakeholders. And, the Ministry of Education, Science, Technology and Vocational Training is responsible for coordinating sanitation and hygiene in schools, while the Prime Minister's Office leads the implementation of school sanitation and hygiene activities. And, PO-LARG is responsible for local government authorities (LGAs), which are in turn responsible for providing onsite sanitation in consultation with .LGAs report to the PO-LARG. And, urban water supply and sewerage authority is responsible for sewerage services but not on-site sanitation, which is found predominantly in rural areas.

Table 42. Roles and Responsibilities of Key Authorities in Sanitaiton and Hygiene Sector

Institutional Roles and Responsibilities	Key Institutions in sanitation and hygiene sector
Planning / Policy Formulation	Ministry of Water Ministry of Health, Community Development, Gender, Seniors and Children Ministry of Education, Science, Technology and Vocational Training National Sanitation and Hygiene Steering Committee
Financing	Ministry of Health, Community Development, Gender, Seniors and Children Ministry of Water Ministry of Education, Science, Technology and Vocational Training PO-LARG
Regulation	Ministry of Water Ministry of Education, Science, Technology and Vocational Training
Implementation	Local government authorities Prime Minister's Office
Operation and Maintenance	Local government authorities

Institutional Roles and Responsibilities	Key Institutions in sanitation and hygiene sector
	Private operators Households/ landlords
Monitoring and Evaluation	Tanzania Water and Sanitation Network (TAWASANET) Annual Joint Water Sector Review (JWSRs)

7.2.Legal framework

7.2.1. Public Health Act No. 1, 2009

This Act provides for the promotion, preservation and maintenance of public health with a view to ensuring the provisions of comprehensive, functional and sustainable public health services to the general public. Public Health Act also addresses the protection of the environmental health and sanitation including healthcare waste management.

The central theme of this act is to provide for the promotion, preservation and maintenance of public health with a view to ensuring the provisions of comprehensive, functional and sustainable public health services to the general public and to provide for other related matters. Major issues addressed in this act include operation of housing & hygiene, human settlements, solid & liquid waste, food & nutrition, control of diseases and workers' health. Relevant sections of this Act related to the implementation of this project include the following:

Section (81) Transportation and Disposal of Liquid Waste:

a) The authority shall ensure that sewage from cesspool and sludge from septic tanks are collected and transported by specified vehicles for liquid waste disposal;

b) Ensure that sewage is appropriately treated prior to its discharge into water bodies or open land; the sewage will not increase the risk of infections or ecological disturbance and environmental degradation;

c) Designate and ensure compliance with designated disposal ponds, sewage treatment facilities and sewer points.

Section 73(1)(c): To collect, transport and dispose of solid and liquid waste from buildings, premises and land.

7.2.2. Water Resources Management Act No. 11, 2009

The Water Resources Management Act (WRMA) repeals the Water Utilisation (Control and Regulation) Act No. 42 of 1974.

This law covers issues of institutional and legal framework, principles for water resources management and prevention and control of water pollution. It established the National Water Board, BWB, catchments and sub-catchments and offences and penalties.

The objective of the WRMA is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled to meet the basic human needs of present and future generations.

7.2.3. Water Supply and Sanitation Act No.5, 2019

The Water Supply and Management Act established the legal framework for sustainable management and transparent regulation for water supply and sanitation services with a view to give effect to the National Water Policy, 2002.

Under the new Water Supply and sanitation Act No. 5 of 2019, in respect of sanitation, Urban Water Supply and Sanitation Authorities they are responsible with the provision of appropriate facilities and services for the collection and disposal of human excreta and waste waters; by means of sanitation works (sewers, drains, pipes, ducts or channels, whether open or closed, used for the drainage of human excreta or waste waters from buildings or land, and on-site systems for the reception of human excreta and waste waters which do not connect to a sewer)

The Act outlines the responsibilities of government authorities involved in the water sector, establishes Water Supply and Sanitation Authorities as commercial entities and allows for their clustering where this leads to improved commercial viability. It also provides for the registration and operation of Community Owned Water Supply Organisations and regulates the appointment of board members.

And, this act has regulated the offences and penalties as following table:

Table 32. Offences and Penalties

1	Any person, who damages, hinders, disrupts, diverts or interferes with water works or sanitation works or other assets owned or vested in a water authority or community organization	500,000Tshs≤Fine≤50millionsTshs or2 yrs ≤Imprisonment≤ 5 yrs
2	Any person who abstract or draws off from water works water using a pipe, drain, pond, pump or other means whereby water may be conveyed or retained	500,000Tshs≤Fine≤50millionsTshs or12months≤Imprisonment≤5yrs or to both In addition to fine or imprisonment the court may issue an order requiring the person to remedy any Damage or loss caused.
3	Any person who misuses or wastes, or causes or allows to be misused or wasted any water passing into, through or upon or near any premises from the waterworks	500,000Tshs≤Fine≤10millionsTshs or 6months≤ Imprisonment≤2yrs or to both
4	Any person who alters or causes or permits to be altered any appurtenances with intent to avoid the accurate measurement or register of water by means of any meter or to obtain a greater supply of water than he is entitled to or to avoid payment for the supply of water or who interferes with or damages any meter.	500,000 Tshs≤Fine≤10millionsTshs or 6 months≤ Imprisonment≤2 yrs. or to both
5	In the case of subsequent	10 millionsTshs≤Fine≤20millionsTshs or 2yrs ≤ Imprisonment≤5yrs or to both In addition to fine or imprisonment under this section, the court shall order the payment of cost incurred to repair or replace an appearance altered or meter damaged or interfered with, and the cost incurred shall be recovered from that person as a civil debt by way of summary suit.
6	Any person who uses any water supplied to him by water authority or community organisation for purposes other than those for which water is supplied	5 million Tshs≥ Fine or 6 months≤ Imprisonment
7	Any person who; a) washes his person or bathes in any part of the waterworks or waterworks area or in any vessel used by a water authority or community organisation for supplying water from any public tap b) washes ,throw sort causes or permits to enter into water works or water works area or into any vessel used by a water authority or community organisation for supplying water from any public	50,000 Tshs≤ Fine ≤ 1 million Tshs or 1 month≤ Imprisonment≤3 months or to both

	tap, any animal, clothing, material or thing c) wrongfully opens or closes any lock, cock, valve or manhole of the waterworks	
8	1) Any person who deposits or allows or causes to be deposited any earth material or liquid in such manner or place that it may be washed, fall or be carried into the waterworks	1 million Tshs≤ Fine ≤ 5 million Tshs or 12 months ≤ Imprisonment≤3 yrs or to both
	2) Where the earth material or liquid under subsection (1) has been washed into waterworks or sanitation works	10 million Tshs ≤ Fine or 2 yrs ≤ Imprisonment or to both
9	Any person who on any part of the waterworks erects or inhabits or allow or causes to be erected or inhabited any structure whether of permanent or temporary nature or who inhabits any cave, cavity, depression or hole in any part of the water works	1 million Tshs≤ Fine ≤ 10 million Tshs or 6 months ≤ Imprisonment≤ 2 yrs or to both
10	A person who dumps, discharges or cause to be dumped or discharged any unauthorized waste into the sanitation works	1 million Tshs≤ Fine ≤ 3 million Tshs or 6 months ≤ Imprisonment ≤ 2 yrs or to both

7.2.4. Energy and Water Utilities Regulatory Authority (EWURA) Act, 2001

The general function of EWURA is to regulate the provision of water supply and sanitation services by a water authority or other persons. This includes the establishment of standards related to equipment and tariffs chargeable for the provision of water supply and sanitation services.

7.2.5. Urban Planning Act No. 8, 2007

The aims of this act are to provide for the orderly and sustainable development of land in urban areas, to preserve and improve amenities, to provide for the grant of consent to develop land and powers of control over the use of land, and to provide for other related matters. This includes improving the provision of infrastructure and social services for the development of sustainable human settlements.

SECTION 8: SOLID WASTE MANAGEMENT.

Solid waste comprises all the organic and inorganic waste materials that are normally non free flowing and are produced as a result of human and animal activities. They have lost their value to the user and are hence discarded as useless or unwanted by the last user. Solid waste management was not even considered to be an essential basic service in many countries before 1970. Most solid waste management activities existed under the departments of public health, led by a health professional, with a strong focus on waste collection to reduce disease risks. Inadequate collection and improper disposal of solid wastes facilitate multiplication of pathogen causing diseases such as cholera and diarrhea, and provide good breeding sites for disease vectors such as mosquitoes (malaria), flies (diarrhea) and rodents .

8.1. Waste Generation and Classification

There are significant differences between solid wastes generated from different sources. Such sources can be classified as follows:

8.1.1. Households

Solid waste originated from this source is the consequence of household activities. In most cases, up to two thirds of this category consists of organic wastes (composition). In poor neighbourhood traditional cooking can also produce ash, and where sanitation facilities are limited, the waste might also include faecal matter.

8.1.2. Commercial

All solid waste emanating from business establishments such as stores, markets, office buildings, restaurants, shopping centres and entertainment facilities are commercial solid wastes. The wastes typically consist of packaging and container materials, used office supplies and food wastes.

8.1.3. Institutional

Waste originating in police barracks, schools, hospitals, prisons, research organizations and other public buildings. Where the institution involves residents, the waste composition is similar to those from households. For hospital waste it is important for the management system to implement segregation at the hospitals of toxic and infectious waste and conventional household-type waste. After segregation wastes which pose a threat to public health need separate collection and disposal arrangements.

8.1.4. Street Sweepings

These always include dust/sand, dirt and litter although in low-income countries they may also contain appreciable quantities of household refuse, drain cleanings, human and animal faecal matter.

8.1.5. Construction and Demolition

The nature of this material depends upon the resources used in a given region or country for the purposes of construction. In the absence of adequate local ordinances, responsibility for the removal and disposal of these wastes is invariably assumed to lie with the municipality.

8.1.6. Industrial

Although strictly speaking management of such waste lies with the responsibility of the industries, often through lack of control and enforcement the wastes end up in the regular municipal/city waste stream. The wastes are generated from processing and non-processing industries and utilities. Composition is quite site specific and depends upon the natural resources, raw materials and markets which provide the base for a given city's industrial activity. It may include liquid, sludge, solid or hazardous waste.

8.1.7. Sanitation Residues or `night-soil'

Although not part of the solid waste stream, depending on the level of sewerage provided, human excreta collected from public toilets, latrines or septic tanks (often called faecal sludge) may be dumped in streets drains and therefore arise in drain clearing and street sweeping wastes.

From the same sources quantities of waste generated varies according to: household size, income level season, cultural activities and festivities.

8.2. Existing situation

Arusha city has a population of 416,442 as per the 2012 national census, distributed through 25 wards and 155 streets. The solid waste generation rate is 550 tonnes/day, with an average generation rate of 1.08 kg/person/day and a collection capacity of about 302 tons/day, which equals 54.8%, with a 16% recycling capacity, according to data collected from four different known recycling groups. Solid wastes include domestic refuse which consists of degradable food wastes, leaves, dead animals, and non-degradable waste such as plastics, bottles, nylon, , industries and commercial waste. Estimates are given in the chart below.

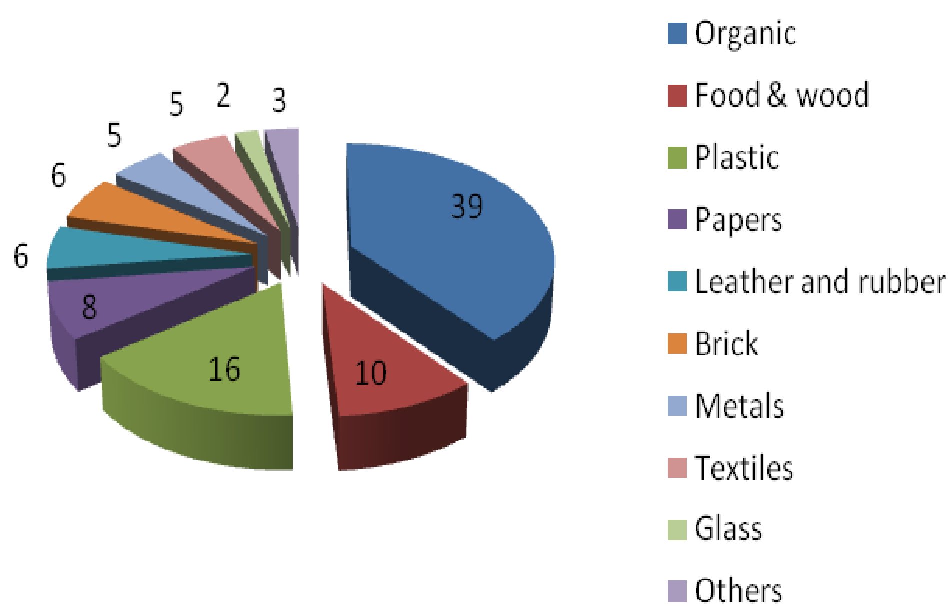


Figure 1: Solid waste composition for Arusha city. (Source: Arusha city council strategic plan and cost recovery for SWM 2012/2013-2017/2018)

The primary storage of solid waste in Arusha city is done by the city dwellers who store their wastes in the plastic sacks and dustbins. There is no communal collection point in the streets due to the improved door to door collection system implemented by the private companies in the 6

CBD wards and the CBOs in the rural residential wards. The collection points in Arusha city are only found in the markets in which a dedicated vehicle usually parks from morning to evening. All entrepreneurs in the market pour their waste into it, and when the vehicle is full it goes directly to the dumpsite for disposal. The collection and transportation of the generated solid waste in Arusha city as well as collection of refuse charges is done by the CBOs and the private operators in their area of jurisdiction. They pay 15% of the amount collected to the city council. The city council only plays a monitoring role and assists when there is a drop in service due to acceptable reasons. Each ward health officer is responsible for coordination of the service, ensuring that that the private operators and the CBOs fulfil their obligations and that the residents pay for the continuity of the service.

8.3. Solid waste management

Solid waste management in Tanzania has been facing several challenges including insufficient coverage of collection systems and methods, lack of institutional arrangement and information resources, inflexible work schedules, and insufficient information on quantity and composition of waste, as reported by (Kyessi and Mwakalinga 2009; Ogwueleka 2009). Furthermore, Momodu (2011) added that the main causes of improper solid waste disposal in Tanzanian Cities and or Municipalities are lack of good infrastructures, non-implementation of existing environmental sanitation laws, irregular and unplanned dumping of solid wastes, population and urban growth due to rural-urban migration, insufficient capital to run solid waste management processes and lack of new technology in waste disposing. Moreover, lack of awareness and active involvement of the households as key stakeholders, delay of households paying collection fees to the organizations concerned and bad relationships between the households and the collectors are other factors hindering the process of proper solid wastes management (Kassim and Ali 2003; Kassim and Ali 2006).

The Arusha City Council as one of the urban centre (City) in Tanzania has started solving the problems of poor solid waste management services by implementing sanitation programmes like the Sustainable Arusha Programme (SAP) 2000-2001 and now the Tanzania Strategic Cities project (TSCP). Arusha city had a plan to improve the collection of SW from 54.9% to 78% in 2018. The Waste Management Strategy has been incorporated into the City's General Planning Scheme (GPS). The strategy has been used by the Council and other key decision makers as a major consideration when defining operational policies, approving investments and allocating budgets. The strategy has 5 targets as mentioned below:

i. To improve level of waste collection and recycling services from 45% to 78% in 2018
ii. To ensure 75% of SW generated is collected, treated and disposed of in 2018
iii. To ensure 80% SWM financial sustainability in 2018
iv. To upraise public awareness and participation to 95% at all levels in SWM in 2018
v. To strengthen institutional framework on SWM to 90% in 2018

A strategy implementation group were set up to monitor implementation activities in accordance with the City General Planning Scheme (GPS). This group report to the City Management Team (CMT) and act as the steering committee for all technical assistance projects relating to waste management and strategy implementation.

Waste can be treated and recycled using a large number of different technologies. But the following categories specify the main groups of treatments:

i. Biological treatment, for example composting and anaerobic digestion;
ii. Incineration with or without energy recovery;
iii. Land filling.

"Disposal sites" may be open dumps, controlled landfills (with periodic soil cover), sanitary landfills (with daily soil cover, leachate management and gas ventilation systems), or composting plants

8.3.1. Dumpsite in Arusha City Council

Currently the Murriet dumpsite is the only crude dumping site for Arusha city. It is located about 5km from the city Centre. With a total area of 26.9 ha, the dumpsite was demarcated with a blocks wall and a razor wire fence to prevent free entrance of animals and human beings. Private organizations and companies are allowed to dump their waste in this dump area after paying the disposal fee to the city authority and showing an official permit to the dump supervisor before offloading the wastes. Some plants were seen just after the dumpsite fence, and residential houses were seen surrounding the dumpsite. Currently, there is no weighbridge to measure the weight of the waste being dumped. Fire eruptions, flies and bad smells are common at this dumpsite.

Figure 2: Murriet dumpsite status

8.3.2. Status of the new sanitary landfill (Muriet sanitary landfill)

The Arusha city council has been funded by the World Bank to construct and operate a new sanitary landfill within Muriet dumpsite area for proper disposal of solid waste and the environment under the Tanzania Strategic Cities Project. Currently, some of the infrastructures have been constructed; these include cell 1, leachate collection channels and pond, storm water collection, fencing off the entire dumpsite area, a guard's hut, water and sanitation facilities, and the main gate.

Figure 3: Some of the infrastructures at the Murriet sanitary landfill – Source: ERC 2016

Although some of the necessary infrastructures have been constructed onsite, the sanitary landfill is not yet operated due to the following:

- Absence of landfill operating machines such as compactors, chain/wheel loaders
- There is no weighbridge to measure the weight of the solid waste brought in
- There is no house/office for the landfill manager to monitor all the landfill operations
- There are no monitoring wells drilled, nor is there a laboratory to monitor leachate qualit y and test the contamination levels, since the final direction of the polluted water from the landfill is outside the landfill.

Waste management is an important part of the City infrastructure as it ensures the protection of the environment and of human health. It is not only a technical environmental issue, but also a highly political one. Waste management is closely related to a number of issues such as urban lifestyles, resource consumption patterns, jobs and income levels, and other socio-economic and cultural factors.

> *'Environmentally sound waste management must go beyond the mere safe disposal or recovery of wastes that are generated and seek to address the root cause of the problem by attempting to change unsustainable patterns of production and consumption.' – Article 21.4 of Agenda 21*

However, the Government of Tanzania has been taking a number of initiatives in terms of formulation of a number of plans, policies and legislation at the central and local levels that are intended to manage the environment in general and solid waste in particular (National Environmental Action Plan (NEAP) 2013-2018 (2013). Also various legislations has been passed to ensure there is proper management practices to serve as a guideline in collecting, storing, transfer and disposal of solid wastes in an environmentally friendly manner; to mention;

- **Environmental Management Act (EMA), 2004.**

This Act provide for, the duties of Local Government Authority (Arusha City Council) in managing and ensure minimization of solid waste generated from different types of households, commercial areas, institutional, street sweeping, industrial, construction and demolition. Additionally the local government authority is requested to designate the area that will be used as waste transfer stations to serve as collection or disposal centres of the solid wastes generated from different sources. But before the respective or responsible authority designate the area to serve as waste transfer centre the following should be observed;

i. Social, health and environmental impact assessment should be carried out

ii. The selected area should be adequate in term of size and located/situated away from t he residential areas

iii. To ensure the designated area is fenced off and secured to prevent unauthorized perso ns from entering

- **Public Health Act, 2009**

The Public Health Act has not going so far from environmental management act, 2004 in the course of solid waste management and minimization from the generating sources. However the public health act has additionally provided for choosing methods of solid wastes disposal guided by the following factors;

i. the climatic condition;

ii. its economic ability and that of its community;

iii. Environmental Health Impact Assessment of that land;

iv. environmental hygienic social benefits available; and

v. The availability of sites for tipping.

8.3.3. Solid waste management challenges

- Improper payment of the refuse collection fees by some of the city dwellers especially in the per- urban wards
- Changes in the population between night and day, especially in the CBD wards; this creat es difficulties in deciding the collection routes of the area since most of the censuses are c onducted in the evening, while most of the waste is produced during the day.
- Improper institutional structures, e.g solid waste management and environmental complia nce placed in a single unit; in this structure there is no environmental auditing, and the im plementation of environmental compliance will be prohibited by other departmental issue s that exist in the city council. The operational activities i.e, solid waste management has to be differentiated and thus the environmental compliance should be in a vertical line so as to crosscut all the departments in the city council structure.
- Low level of enforcement of the laws and the lack of good coordination from other depart ments or sectors e.g. urban planning department, land and housing department etc.

- Political interferences in some wards prohibit the collection of the refuse charges by the ward and street officials, hence leading to lower performance of the city council in provid ing the service.
- Insufficient budget for operations and maintenance as well as the purchase of solid waste equipment's.

8.4. Solid wastes and Drainage Management Systems

8.4.1. Challenges of Solid waste on Drainage Infrastructures

Lack of coordination and integration between urban storm water management activities and other urban services can affect the sustainable and cost-efficient operation of urban drainage systems. For example, solid waste frequently ends up in the storm water drains, but refuse collection servi ces are generally not coordinated with drain cleaning activities. Integrated management and coor dination between the relevant agencies also provides greater opportunities for the control of pollu tion from illegal sewer connections. One of the most important opportunities relates to scope to r educe solid waste in the drainage system, which is particularly important as storm water drainage systems are frequently blocked by refuse.

Many storm water drains become fairly silted up although they probably would still function at l ow-intensity rainfall. Drainage maintenance departments often lack the equipment to transport so lid waste material once it has been removed from the drain. Not only will the solid waste depart ment have the most appropriate equipment for collection and transportation, they will also be abl e to co-ordinate and plan the collection of drain cleanings so that it does not remain on the roadsi de after it has been removed from the drain. This is not only a more efficient use of resources, bu t it also means that the waste is less likely to be washed back into the drain at the onset of the nex t storm event. This is also particularly important from an environmental health perspective as dra in cleanings frequently contain pathogens and are a location for flies to breed.

8.4.2. Proposed Measures for Storm Water System Management on Solid Wastes

- **Community-based initiatives**

Due to the lack of intervention from local government, attempts to improve drainage are often m ade by local residents and elected representatives. Such local initiatives can only work if dischar ge to a local drain or drainage channel is possible. Depending on the leadership and social cohesi on, some community-based organizations are more successful in encouraging collective action b ut assistance from a development partners is often needed to help these initiatives. However, these are often piecemeal approaches and drainage constructions are often disadvantaged by the lack of a secondary network with the capacity to accept increased flows.

Together, the CBD and development partners shall establish a solid waste collection community microenterprise in order to ensure that the drainage system does not get blocked. Not fully self-sustaining, the program is an excellent example of harnessing the energy of communities to help themselves.

Informal settlement upgrading cannot be achieved without the participation of the beneficiary communities, especially where peoples' lives will be disrupted by removal, relocation and partial demolition of their homes. These are complex operations requiring technical skill, ingenuity and patience, but this sort of consensus and collaboration is essential for successful implementation and can only be achieved through participation. Among the many potential roles for community members in the implementation of urban drainage projects is direct employment in construction activities, in order to reduce the total cost. This may also stimulate local enterprise initiatives, training and the development of skills. Alternatively, where private contractors are employed to undertake the physical works, community members may be involved with the monitoring of the quality of the construction.

A review of the literature indicates that there are a considerable number of alternative approaches to storm water management that are appropriate for low-income communities in informal settlements. Although engineered components of drainage infrastructure remain an integral part of strategies to improve drainage, a broader view of storm water management is required which incorporates non-structural, as well as structural, elements. However, these non-structural approaches are not panaceas and there are a number of constraints, briefly outlined below, that will affect successful implementation.

• Public utilities or water companies may have the responsibility for sewerage, whereas road drainage is often the responsibility of the highways authority, and receiving waters may be the responsibility of the local authority or environmental agency. Responsibility for solid waste management is virtually always the responsibility of another department in the municipality. Also, hydrological systems are not constrained by administrative boundaries, and effective drainage area planning requires careful coordination between the relevant institutions responsible for urban drainage in different areas.

Therefore, the overall planning framework needs to be considered in relation to land use in urban and peri-urban areas and, in particular, those communities who inhabit this land.

• The design and implementation of disaster mitigation at the local level, such as that associated with flooding, is a complex task for urban authorities, particularly as they have to cope with a wi de diversity of stakeholders, which may be especially heterogeneous in the urban communities. These stakeholders have different perceptions and relationships to natural hazards, a reflection of different socioeconomic and socio psychological backgrounds. The involvement of diverse stake holders' groups can cause many problems and disputes. Participatory approaches can take consid erable time and, therefore, may not satisfy the demands for immediate investments in infrastructu re, which is envisaged as necessary to bring about improvements. Non-structural approaches to st orm water management can work well, provided the municipal authorities are receptive to the in volvement of community groups in project implementation. Collaboration between government a gencies and non-governmental organizations, in conjunction with communities, is essential but o ften challenging.

Many of these constraints may be overcome if there is a political and institutional commitment to overcoming problems and, specifically, a consideration of and concern with the needs of the urb an poor.

SECTION 9. MONITORING AND EVALUATION

9.1. Storm Water Drainage Sector

Monitoring is the process of observing and checking the progress or quality of storm water infrastructure over a period of time; keep under systematic review. Evaluation is the process of determining the merit, worth or value of the storm water management. It helps in determining whether Storm water system, is meeting its intended objectives, or in answering other management questions.

9.1.1. Existing situation

Currently, the Arusha City Council and TARURA the one responsible for the storm water management without having specific department or specific personnel responsible for handling the system.

9.1.2. Establishment of Monitoring and Evaluation system for Drainage Sector

It is suggested that, there should be a department in Arusha City responsible for the supervision of the storm water drainage system. They should carry out site visits, recording of conditions found on site and proposing measures according to different conditions found at site. Also, there should be meetings held with report writing so as to limit the damage to storm-water infrastructure. There should be a state law that is responsible for the management of Storm water infrastructure on sites that are one acre and larger. This department should set laws that are to be followed by construction companies even during applying for General Storm water Construction Permit so as to monitor them not to damage Storm water systems.

The specific permit requirements of any size of the construction site, should include performing site inspections and sampling Storm water leaving the site. The record and report of monitoring results should be submitted to the department responsible for permit. The monitoring and evaluation of Storm water Drainage System will help to regularly check on the progress of the construction and maintenance of the Storm water drains. This makes it easy to know whether the Storm water system is functioning as intended or not. Monitoring and evaluation help to know if failure in any of the Storm water drains has occurred as well as to plan maintenance as soon as possible so as to ensure it is repaired as soon as possible. Silt accumulation and soil erosion are some of the issues that hinders the Storm water system from functionioning as intended. If this happens the structure should be repaired built.Monitoring and Evaluation of Storm water Systems helps to reduce or limit floods by knowing the areas Storm water drainage system is introduced and where it is necessary to be introduced so as to control floods.

9.1.3. Strengthening M&E system for Drainage Sector in Arusha City

Upon establishing a Monitoring and Evaluation of Storm water systems, the following can be done in order to strengthen the established Monitoring and Evaluation System.

9.1.4. Investing in Monitoring and Evaluation,

The organization to be responsible for Storm water system, should Invest in data sources and collection methods, countryy should focus on the capacity to disaggregate, analyze and use data for program quality improvement and impact.

9.1.5. Storm water system assessments

The assessment of the existing Storm water system. This is carried out by country itself through the organization responsible for Storm water and ideally should be done every two to three years. Storm water system assessments serve to:

- Determine the status of the implementation of the national monitoring and evaluation plan
- Identify any weaknesses in the monitoring and evaluation system
- Build on and strengthen existing monitoring and evaluation efforts

Based on the results of the system assessment, country will then be able to develop a cost monitoring and evaluation plan, implement it, and follow up on the implementation process. The results of the system assessment can then support the inclusion of system strengthening activities in the monitoring and evaluation plan and be supported with funding from a Global Fund grant.

9.1.6. Storm water system Program reviews.

A Storm water system program review is a periodic assessment of an on-going Storm water system program. Storm water system program reviews provide decision-makers an opportunity to evaluate program performance against the priorities identified in the strategic plans, review lessons learned, identify areas for further improvement and inform planning and future implementation.

Table. Targeted Rate of Flood Prone Areas in Arushacity

Item	Current	Short-Term (2025)	Long-Term (2040)
Arusha City (km^2)	268.2		
Flood Area (km^2)	37.9	31.3	7.2
Flood Rate (%)	14.1%	11.7%	2.7%

9.2. Sanitation Sector

9.2.1. On-site sanitation sector

On-site sanitation is managed by Health department within the Arusha City Council (ACC) under the public health act no 1, 2009 and amended by-laws made by the councils. The health department is divided into a curative health department unit and preventive health department unit. Monitoring and evaluation are done by Health department team members to the ongoing and the completed projects. The health department has a duty to check the designs and drawing of houses on-site sanitation facilities submitted in the office for approval before construction. The department unit using the available public health officer advice about good health sanitation practices to the important areas like on the methods, design, type of treatment facility, slope, and location as per by-laws and acts.

9.2.2. Off-site sanitation

Off-site sanitation is managed by Arusha Urban Water Supply and Sanitation (AUWSA). The duties of the authority regarding sanitation are Sewer line services, construction of new sewer network, rehabilitation of existing sewerage network, the connection of new houses to the sewer network system. The authority is practicing Monitoring and Evaluation on the existing sewerage system and its services so as to be sustainable and to meet the intended objectives and goals. The authority also applies Monitoring and Evaluation to any ongoing project regarding the sanitation sector.

There are no current ongoing projects regarding sanitation in Arusha, therefore M & E tool is applied only to the existing sanitation situations under management decisions. Due to presence of onsite and offsite sanitation infrastructure like sewer network, septic tanks, pit latrines and treatment facilities, Health department in ACC and AUWSA practice Monitoring and Evaluation to safeguard the health of people, and to provide adequate sewerage service to the people without any adverse impacts to the environment and to the human health in general.

Table M&E practices in Arusha sanitation sector

	M&E practices in Arusha sanitation sector	Intervals	Responsible
ACC (Health department) & AUWSA	Meetings (Normal meeting, multi-sectoral meeting)	Monthly	Stakeholders, Staff meeting
	Field visit	Daily, Weekly	Technical staff, community
	Communication	Daily, Any emergency	Service center, Receptionists
	Inspection	Daily, Weekly & Monthly	Technical staff member e.g. Engineers, technicians
	Program or project report	Quarterly, Yearly, incidentally	Staff members, managers

- **Field visit**

The technical teams usually visit the site to see the real situation and condition of sewers, Manholes, and treatment facilities. Field visit of the treatment facility at Swaswa and the sewer lines is conducted daily by AUWSA sewerage section team to observe the problems and inconsistencies of the system.

- **Periodic Internal Meeting**

Meetings are done with stakeholders and users of the sanitation system to get any rising issues about the existing services and the infrastructures in general.

- **Multi-sectorial collaboration Meeting**

According to Council health officer and AUWSA, there is a meeting to discuss the risen issues, existing problems or emergencies concerning onsite and offsite sanitation issues. The multi-sectorial meetings mostly involve the key stakeholders which are AUWSA, RUWASA, Community, ward and sub-ward health officers, and the city health department.

- **Communication**

Using Public contact number which is available 24 hours and a complaint book, the people can report any issue regarding sanitation to the office at any time. Technical staff can attend to the incidence at any time do inspections or surveys for solving the reported problem.

- **Inspection**

The inspection to monitor and evaluate the designs and plans of the sanitation system in Arusha is practiced. Inspection to the existing sanitation facilities to ensure the adequate provision of services and health improvement to the people. The inspection of the sites is divided into three types.

- **The routine inspection.**

This is the normal type of inspection done by the Health department preventive unit that follows the programs and plans made by the department.

- **Incidental Inspection.**

This is another type of inspection done by both council and AUWSA to attend the site after an incidence occurred to specific areas, for example, sudden overflow and spills of the sewage out of the sewer line to the community. This incident is very dangerous to community health hence an emergency inspection is done by the authority and health department to observe the situation for remediation.

- **Annual Project Report**

Each year the report is prepared for the ongoing and completed projects. AUWSA and ACC department prepare report each and every year and submit to the service manager and to the management for monitoring, evaluation, analysis and future plans of other coming projects.

9.2.3. Monitoring and Evaluation Challenges and Problems in Arusha sanitation sector

- **Challenges facing Arusha sanitation sector in conducting Monitoring and Evaluation**

The monitoring and evaluation practices sanitation sector are not effectively applied by AUWSA and Health department in ACC to validate the objective of their projects or existing sanitation programs. The findings showed that, Sanitation projects face challenges in implementing M&E practices including;

- Low budgetary allocation in M&E activities,
- Lack of technical M&E staffs,
- Low central government support,
- Poor project reports and information systems,
- Poor community participation.
- The use of unqualified and untrained M&E staffs.

Absence of an independent M&E section in the AUWSA technical department since theTechnical Department is responsible for production, treatment, transportation and distribution of water to customers. It is also responsible for the collection of sewage from customers and the treatment of the same before being disposed to the environment. The department also deals with Designing of water supply and sewerage projects, repair of leaking pipes as well as maintenance of motor vehicles and motorcycle. (http://www.AUWSA.go.tz)

Observed problems during monitoring practices by AUWSA

The following are the problems observed to be facing the sewerage system when conducting monitoring;

- Vandalism of cast iron manhole covers and frames
- Blockage of truck sewers at various areas with deleterious matte such as worn-out clothes and plastic bags

Burying of sewer manholes with construction materials in areas where buildings and civil works are ongoing have recently been completed which resulted in the topsoil, cement, aggregate, and other such sediments finding their way into the sewer system through manholes.

9.2.4. Strengthening M&E System in Arusha sanitation sector

For the sustainability of the sanitation sector, the Arusha Urban Water Supply and Sanitation Authority (AUWSA) and Arusha City Council (ACC) should have a Monitoring and Evaluation plan document. A monitoring and evaluation (M&E) plan in sanitation is a document that will help to track and assess the results of the interventions throughout the life of a sanitation program or project in Arusha city. It is a living document that should be referred to and updated on a regular basis by team or technical staff. While the specifics of each program's M&E plan will look different, they should all follow the same basic structure and include the same key elements. An M&E plan should be developed by the team or staff with research experience, with inputs from program or project staff involved in designing and implementing the program or project.

Table Showing Steps to make and strengthen M&E in the sanitation sector

S/No.	Steps	Action Plans
1	Introduction to program or project	Sanitation program goals and objectives
		Logic model, Logical framework, Theory of change
2	Define Indicators	Table with data sources, collection timing and the staff member responsible for monitoring and evaluation
3	Roles and Responsibilities	Description of each staff members role in M&E data collection, analysis, and or reporting
4	Reporting	Analysis plan
		Reporting template table
5	Dissemination Plan	Description of how and when data will be disseminated internally and externally

Table. Proposed program goals and objectives in sanitation sector

Sanitation problem	Lacking proper sanitation and wastewater treatment facilities
Solution	Establishment of sanitation development plan and measures
Targets	Increased number of people to access proper sanitation and wastewater treatment facilities by 70% in the year 2030, 100% by 2040.

Table Monitoring indicators and Data collection sources

Process indicators	Outcome indicators	Data sources	Timing	Responsible

One training each month to the community about the importance of proper sanitation	100% of people educated and willing to be connected into the public sewer and access to proper onsite sanitation facilities	Training attendance sheets	Month	ACC and AUWSA Sanitation training staff
One Project for detail design of the sewerage system in Arusha city	A complete report in place by the end of 2020	FGD, Literature review	1year	AUWSA sewerage section staff, Research assistants
Two projects for construction of the new sewerage systems and rehabilitation of the existing sewerage systems	70% coverage by the end of the 2040 year	FGD, population-based survey	1year	Field M&E officers

9.2.5. Decision support system to monitor progress of Sewerage System

Table Coverage Rate Served by Sewerage

Item	Current (2020)	Medium-Term (2030)	Long-Term (2040)
Population	620,136	809,453	878,065
Population served by sewerage	173,638	437,105	878,065
Coverage Rate (%)	28%	54%	100%

Table 33. Tread Rate of Wastewater Flow to be Generated

Item	Current	Medium-Term (2035)	Long-Term (2040)
Total Wastewater Flow (m^3/day)	19,937	85,193	109,544
Treatment Capacity (m^3/day)	22,000	47,273	87,544
Treated Rate (%)	6.73%	42.81	100%

CHAPTER 10: CAPITAL EXPENDITURE (CAPEX), OPERATION EXPENDITURE (OPEX) AND SUSTAINABILITY

10.1. CAPEX Needs

The Government of the United Republic of Tanzania through credit from the International Development Association (IDA) is conducting Study and Design on Storm Water Drainage System and Preparation of Drainage & Sanitation Development Plan (DSDP) for Arusha City for a period of 2020-2040. In the conduct of this assignment, identification of Capital Expenditure (CAPEX) needs is essential towards the planning, design stages and implementation of the master plan.

Capital Expenditure (CAPEX) needs is the capital to be invested in constructing or purchasing of fixed assets of the master plan. It includes essential ancillary equipment, vehicles or even office buildings that will support the operation of drainage and sanitation systems. It does not only cover hardware but includes the costs of one-off work with stakeholders prior to construction or implementation, extension, enhancement and augmentation (including costs of one-off capacity building). From the information elaborated on **Table 1** below, the CAPEX for the master plan is estimated at **TZS 477,316,786,361.66.**

Table 34 .CAPEX

Bill No.	Description	Amount in TZS
1	Preliminaries and General (5%)	16,387,238,014.66
	Relocation Services (5%)	16,387,238,014.66
2	Trunk and Reticulation Sewer	68,816,822,782.77
3	Treatment Pond	160,340,730,000.00
4	Storm Water Drain	98,266,737,510.50
5	Prime Cost and Provisional Sum	323,350,000.00
6	Dayworks (2%)	7,210,384,726.45
	Sub-Total - 1	**367,732,501,049.05**
	Add 10% of Sub-Total for Contingency	36,773,250,105

	Sub-Total - 2 (Sub. 1 + Contingency)	404,505,751,154
	Add 18% VAT	72,811,035,208
	APPROXIMATE COST FOR PHASE-01	**477,316,786,361.66**

10.2. OPEX Needs and Sustainability

These are operational expenses (OPEX) a company will incur on routine basis while implementing the master plan. They include employee wages, inventory handling costs and expenditures for office supplies that are operating expenses. OPEX also includes minor maintenance routines needed to keep systems running at design performance, but does not include major repairs or renewals which are recognised as not recurrent. For mature and experienced institutions, OPEX runs between **5%** and **20%** of the CAPEX and can also be calculated from their reports.

Considering the sustainability issues of the master plan, analysis of financial statements of AUWASA for the past eight years **(Table 45)** show that the total revenues of the authority are **67,199,000,000**and total operation expenditures are **56,890,300,000**. This implies that the financial performance of AUWSA can sustainably run the operations of the master plan. The new expanded sanitation facilities in the master plan are also expected to expand revenues as a result of expanded services and customer base.

Table 35. AUWSA Financial Statement

Year	**Personnel Costs**	**Other Costs**	**Production Costs**	**Administration Costs**	***OPEX***	***Revenue***
2010/11	1,391,000,000	298,000,000	1,366,000,000	1,083,000,000	4,138,000,000	4,228,000,000
2011/12	1,696,000,000	324,000,000	1,697,000,000	1,176,000,000	4,893,000,000	4,687,000,000
2012/13	1,715,000,000	406,000,000	1,500,000,000	1,187,000,000	4,808,000,000	5,430,000,000
2013/14	2,347,700,000	646,600,000	2,160,000,000	1,446,000,000	6,600,300,000	8,141,000,000
2014/15	2,963,200,000	687,200,000	2,385,800,000	1,761,000,000	7,797,200,000	8,894,800,000
2015/16	3,395,500,000	411,200,000	2,385,800,000	1,832,000,000	8,024,500,000	9,883,800,000
2016/17	4,028,000,000	408,900,000	3,659,600,000	1,408,100,000	9,504,600,000	12,464,400,000
2017/18	4,865,900,000	576,900,000	4,014,900,000	1,667,000,000	11,124,700,000	13,470,000,000
					56,890,300,000	***67,199,000,000***

10.3. FINANCING SOURCES

Water and sanitation services provision in the country are considered to be a social infrastructure thus are priced below economic levels and making the sector to be chronically under financed. Major investments in the sector depend on government support leaving operations to Water Supply and Sanitation Authorities. Considering this fact, the following methods are proposed for financing the sewerage and storm water management master plan for Arusha:-

10.3.1.Government Budget

Provision of water and sanitation infrastructure in the twenty-first century poses enormous challenges for most nations of the developing world. Financing water and sanitation projects from central government due to inability of the Local Government and Water Supply and Sanitation Authorities to finance these kinds of projects is inescapable due to insufficient resources to fund such projects from their current revenues.

10.3.2.Aid, Donations and Grants

These funds are provided by internal and external aid agencies. Experience from the water and sanitation sector show that most water supply and sanitation infrastructure in the country were funded by non-governmental organizations and development partners through soft loans, aid and grants. Financing for the Water Sector Development Program (WSDP) remains a good example. In the course of implementing this master plan, it is possible to continue accessing financing for sewerage and storm water infrastructure implementation through these arrangements.

10.3.3.Public-Private Partnerships (PPPs)

PPPs arrangements involve public and private sector partnerships and may be a powerful tool for financing and managing water supply and sanitation services in the country. In most developing countries, the public sector is stressed by provision of social needs and the private sector remains with lots of capital, technology and skills that is still untapped. Thus PPPs arrangements can be an efficient delivery of public infrastructure for water supply and sanitation services. In realizing this, the government of Tanzania set up conducive environment and institutional frameworks including PPP policy, Act and regulations so as an effective role can be played by PPPs in the development of social infrastructure and services in Tanzania. This aims to relieve the public sector funds for other overwhelming societies' needs. The PPPs arrangement has worked in many countries and it is in no doubt it will work in Tanzania.

10.3.4. Bonds

A municipal bond is a debt security issued by a city council to finance its capital expenditures, including the construction of highways, schools, bridges, and water and sanitation projects. They can be thought of as loans that investors make to local governments. In this case, implementation of the master plan may also be funded through this arrangement. The advantage of this is that the beneficiary of the undertaking and hence payers of the loan are within the area of jurisdiction instead of those who are indirect beneficiaries.

10.4. COST RECOVERY STRATEGY

10.4.1. Tariffs /User Fees

Revenues received from water supply and provision of sewerage services in the course of the Authorities' activities will be collected and used in cost recovery. These revenues are water user fees from customers from Domestic, Commercial Institutions, Religious and Kiosks; and revenues from sewerage disposal services. Expansion of water supply and sewerage services customer base with the application of modern technologies to reduce costs of operations and collection of user fees will greatly enhance cost recovery.

10.4.2. Taxes/ Levies

The Local Government in Arusha will be responsible for finding sources of funds to finance this important and necessary project. Under normal circumstances, the local government is responsible for ensuring basic needs are provided to its society at the highest possible quantity and quality. Since the authority is mandated to make bylaws, then imposing some kind of levies to those able and willing to pay within the area of jurisdiction can serve as one of the important source of financing.

10.5. Institutional and Financial Arrangements

The three major players associated with the financing and operation of the master plan are the Local Government Authority partly for construction of infrastructure concerning waste management, AUWASA with mandate on sewerage and the Private Sector which offers financing and management opportunities. In the implementation of the master plan, an appropriate MoU to finance and operate the master plan can be set up between AUWASA, Local Government and Private Sector. The MoU should describe in detail responsibilities of parties in question for the financing and implementation of the master plan.