DISSERTATION ON

EVALUATION AND ASSESSMENT OF ENVIRONMENTAL IMPACT DUE TO URBANIZATION IN THE KHARGHULI REGION OF GUWAHATI, ASSAM

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Submitted By

SABNAM AKHTAR RAHMAN

Roll No: 230620061015

ASTU Registration No: 161703118

Under the guidance of

DR. BIPUL TALUKDAR and DR. TRIPTIMONI BORAH

Professor

Department of Civil Engineering

ASSAM ENGINEERING COLLEGE

JALUKBARI, GUWAHATI-781013,

ASSAM

DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE

JALUKBARI, GUWAHATI-781013

ASSAM, INDIA

CANDIDATE'S DECLARATION

I hereby declare that **"EVALUATION AND ASSESSMENT OF ENVIRONMENTAL IMPACT DUE TO URBANIZATION IN THE KHARGHULI REGION OF GUWAHATI, ASSAM "** is a report prepared by me in partial fulfillment for the requirement of the award of the degree of Masters of Technology in Civil Engineering with specialization in Water Resources Engineering submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-781013 under Assam Science and Technology University under the supervision and guidance of Dr. Bipul Talukdar and Dr. Triptimoni Borah, Professors, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-781013.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Place: Guwahati

Date:

Sabnam Akhtar Rahman

M. Tech. 3rd Semester

Roll No- 230620061015

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-781013

DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE

JALUKBARI, GUWAHATI-781013

ASSAM, INDIA

CERTIFICATE OF SUPERVISION
SESSION (2023-2025)

This is to certify that the project work entitled **“EVALUATION AND ASSESSMENT OF ENVIRONMENTAL IMPACT DUE TO URBANIZATION IN THE KHARGHULI REGION OF GUWAHATI, ASSAM”** is a project report prepared by Sabnam Akhtar Rahman, Roll No- 230620061015, a student of MTech, 3rd semester, Department of Civil Engineering (Water Resources Engineering), Assam Engineering College under my guidance and supervision and submitted in partial fulfilment of the requirement for the award of the Degree of Master of Technology in Civil Engineering with specialization in Water Resources Engineering under Assam Science and Technology University.

Place: Guwahati

Date:

DR. Bipul Talukdar and Dr. Triptimoni Borah

Professor

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-781013

DEPARTMENT OF CIVILENGINEERING

SSAM ENGINEERING COLLEGE

JALUKBARI, GUWAHATI-781013

ASSAM, INDIA

CERTIFICATE OF APPROVAL
SESSION (2023-2025)

This is to certify that Sabnam Akhtar Rahman, Roll no- 230620061015**,** a student of MTech, 3rd Semester of Civil Engineering Department (Water Resources Engineering), Assam Engineering College, has submitted the dissertation **entitled "EVALUATION AND ASSESSMENT OF ENVIRONMENTAL IMPACT DUE TO URBANIZATION IN THE KHARGHULI REGION OF GUWAHATI, ASSAM"** in partial fulfilment for the requirement of the award of the Degree of Master of Technology in Civil Engineering with specialization in Water Resources Engineering under Assam Science and Technology University.

Place: Guwahati

Date:

Dr. Jayanta Pathak

Professor and Head of the Department

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-781013

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Name: Sabnam Akhtar Rahman

College Roll No: PG-C-23-34

ASTU Roll No: 230620061015

ASTU Registration No: 161703118

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ABSTRACT

In the twenty-first century, one of the most significant demographic development is urbanization. The majority of population growth is focused in urban areas. The study aims in assessing the impact of urbanization in the environment. Land use land cover are drastically changed by urbanization, which has an effect on environmental and hydrological processes.

This study evaluates changes in LULC and their effect on the surface runoff generation. The analyzing of the LULC change for a span of 10 years provides an overview of the impact caused due to urbanization. Using GIS based approach study of the LULC change has been made.

The study determined the runoff generated in the study area using Rational Method for 2-year and 5-year Storm event. In order to evaluate future urban pressures, projected population growth until 2046 has been estimated using Exponential Growth Method.

Population trends and per capita waste production are used to estimate gross waste generation in the study area. The existing drain section is evaluated using Manning's equation. These findings are crucial for water management and sustainable urban development.

Overall, the study highlights the impact of urbanization in the Kharghuli area and the need for mitigating the environmental impacts.

Keywords: Urbanization, Kharghuli, LULC, GIS, Runoff, Rational Method, Population, Exponential Growth Method, Waste generation, Drainage System, Environment

CHAPTER – 1

INTRODUCTION

1.1PROLOGUE

Urbanization is a complex socio-economic process that transforms the built environment, converting formerly rural into urban settlements, while also shifting the spatial distribution of a population from rural to urban areas. It includes changes in dominant occupations, lifestyle, culture and behaviour, and thus alters the demographic and social structure of both urban and rural areas. A major consequence of urbanization is a rise in the number, land area and population size of urban settlements and in the number and share of urban residents compared to rural dwellers (World Urbanization Prospects 2018: Highlights). Urbanisation is a form of social transformation from traditional rural societies to modern, industrial and urban communities. It is long term continuous process. It is progressive concentration of population in urban unit (Ershad Ali,2020). Urbanization is one of the most important demographic trends of the twenty-first century. Majority of the population growth is concentrated in towns and cities. In context to developing countries, most the urban growth is unplanned, leading to rapid densification, and associated construction of buildings resulting in dramatic increase in impermeable areas due to paving and built-up areas. (Bajracharya et al.,2015). Urbanization is one of the dynamic and serious issues at present because rapid urbanization results the haphazard and unplanned growth of cities. The pressure of an ever-growing population becomes a burden on the limited public facilities which are virtually collapsing; there is the need to balance present requirements of land with available facilities while considering future needs. Urbanization is a process through which the productive agricultural land, forests and surface water bodies are being irretrievably decreasing. (Mundhe & Jaybhaye, 2014).
India is the most populous country in the world having 17.78 % of the total world population. 36.6% of the population is urban. (https:/www.worldometers.info/world-population/india-population/).

As population grows, demand for housing and commercial amenities naturally follows. The urbanization adds roads, rooftops, parking lots, sidewalks, and other imperviousness to the landscape (Bajracharya et al.,2015).

1.2 SOURCES OF URBAN GROWTH

According to World Urbanization Prospects 2018, Urban growth has three components: natural increase, migration and reclassification. Their respective contributions to urban growth differ depending, inter alia, on the demographic changes taking place in a country and the size of a given settlement, on spatial planning policies and national definitions of urban space, and on the physical environment and other country-specific or local circumstances.

Natural increase of urban populations results from an excess of births over deaths in urban areas.

Migration to cities from rural areas or from abroad contributes to urban growth whenever the number of in-migrants exceeds the number of out-migrants.

Reclassification contributes to urban growth by enlarging the size of urban areas. When cities grow in area, they incorporate neighbouring settlements and their populations, which were formerly classified as rural. Population growth in rural areas may result in reclassification of settlements from rural to urban, thus accelerating the pace of urbanization.

1.3 EFFECTS OF URBANIZATION

Urbanization has both positive and negative impacts.

Positive Impacts:

a) Economic Growth: Cities offer more job opportunities as compared to rural areas. Thus, boosting the economic growth of the cities. The industrial structure in urban areas contribute to economies of scale, profits and expansion of present industries which in return promote employment opportunities and increase the urbanization (Wu et al., 2018). The additional economy brought in also create economic benefits, provide possibility for a better city infrastructure and optimized public services (Sun et al., 2014).

b) Quality Standard of Living: Urbanization allows for better provision of services, like health and education, as more people are located near each other (Dociu and Dunarintu, 2012). Enhanced transportation and communication networks in cities further elevate living conditions (Insan Ali and Anisur Rahman.,2024)

Negative Impacts:

a) Loss of biodiversity: Exploitation of natural resources harm natural ecosystems reducing biodiversity (Verschuren and Ahmed.,2022).

b) Overpopulation: In big cities, a huge number of people live in a very small space causing consistent congestion in urban areas. Problem of over-population is increasing day by day as a large number of people and immigrants move into cities and towns in search of better life. People from rural or undeveloped areas always have the urge of migrating into city that normally leads to congestion of people within a small area (Insan Ali and Anisur Rahman.,2024)

c) Environmental impacts: Human activities release a wide range of emissions into the environment including carbon dioxide, carbon monoxide, ozone, sulfur oxides, nitrogen oxides, lead, and many other pollutants (Uttara et al., 2012). The lack of sanitation and sewerage systems has lead to the blockage of the drainage system, causing flooding of the city. Toxic wastes from the industries are often deposited into rivers. This results in contamination of rivers which makes the water unsafe for drinking and irrigation, as well as harming the fishes. The environment is often contaminated from the emissions from the industries and cars in the cities which affect the health of city residents (Bodo and David, 2018)

d) Waste generation: Thickly populated urban area consumes large quantities of material and simultaneously releases a lot of solid wastes. The solid wastes include municipal wastes, industrial wastes, hazardous wastes etc. (Rai, 2017).

1.4 OBJECTIVES

- To study the land use/land cover of the region
- To evaluate and assess the effect of urban development on the natural and built-up environment.
- To anticipate the impact of urbanization on the green belt zone of the area and study the impact on other parameters such as soil, water (surface and ground), air, aquatic environment, forest area.
- To prepare mitigation measures to minimize the adverse effects on the environment.

1.5 METHODOLOGY

- Preparation of the Base Map of the study area.
- The Landsat 8-9 data for the year 2014 and 2024 have been downloaded from USGS earth explorer.

- Generation of Land use map from Landsat imagery using Maximum Likelihood Classification method.
- The Digital Elevation Model (DEM) is generated in the Arc GIS.
- The Slope map and Relief map are generated from the DEM in the GIS environment.
- Estimation of runoff generated from the study area using Rational Method formula.
- Population forecasting has been done for the study area using Exponential Growth Model.
- Estimation of Waste water generated in the study area has been carried out for the projected population.
- Some mitigation measured has been suggested to minimize the effects caused due to increase in runoff and wastewater generated in the area.

CHAPTER 2

LITERATURE REVIEW

2.1 BRIEF REVIEW OF FEW REFERENCES

- Bhuvandas Nishi et al., (2012) studies the effect of urbanization on environmental components mainly climate, biosphere, land and water resources. A case study of urbanization in India and metropolitan cities have been carried out leading to conclude on the existing causes of damage to the environment due to urbanization and preventive measures to keep a check on them. Although it is impossible to restrict urbanization it has to be ensured that urbanization proceeds in the right path causing minimum impact on environment.
- Mundhe, N. N. and Jaybhaye, R. G. (2014) studied the changes that occurred in land use /land cover (LU/LC) over a time span of last four decades using modern technology like remote sensing and Geographical Information System. The geographical extend of Pune city is 243.84 km². It consists of 14 administrative wards with the total population of 3.11 million (Census, 2011). The spatio-temporal study of land use /land cover is carried out for 4 decades 1973 to 2011 using remotely sensed data like Landsat MSS (1973), TM (1992), ETM+ (2001) and TM (2011). Utilizing hybrid classification method for interpretation and on-field validation, it has been found that the built-up area of Pune city increased 1973 to 2011 by 43.43 percent from 28.50 km² to 155.99 km². Also, the areas under vegetation, water bodies, agriculture land and fallow land have been decreased.
- Talukdar K.K, (2018) studied the impact of urban growth on land use of Guwahati City, Assam. The study revealed that rural to urban migration is happening on a massive scale due to population pressure and opportunities for jobs in urban areas for general livelihood as well as industrialization. India's urban populations was 17.92% of total populations of India during 1961 (i.e., 79 million). Over the year due to population pressure/migration to urban areas it has increased to 31.30 % of total population as per 2011 census. The total population during 2011 census was 388 million. Urban sprawl has resulted in loss of productive agricultural lands, open green spaces and loss of surface water bodies. In this study, an attempt has been made to monitor land use/land cover of part of Guwahati city over periods of time (i.e., from

1972 to 2016). Satellite remote sensing and GIS is found to be a very effective tool for spatial change detection analysis and inventory of urban areas. The study found that during the last 40 years build up area has increased 38.3 % of the total study area. The open area has decreased -22.12 %. The water body of the study area has decreased -2.79% whereas forest area has decreased 13.28 % of total study area.

- Muttaqin Alfan et al., (2021) carried out its work to determine the land use changes and impact on the runoff in the Keduang sub-watershed, Wonogiri District, Indonesia. Land use change and peak runoff were estimated using remote sensing and Geographic Information System (GIS). Remotely sensed images from the Landsat satellites were used to develop land use maps of the study area in 2009 and 2020. The peak runoff was computed by the Rational Method. The land use map between 2009 and 2020 shows an increase in built areas and dryland agriculture and a decrease in the vegetated area such as a forest and mix garden. The impact of land use change increases the coefficient runoff value in the study area from 0.22 to 0.24. The results showed that peak runoff for 2009 was 358.73 m3/s and in 2020 was 363.38 m3/s there is an increase of 4.66 m3/s.
- Bajracharya A.R. et al., (2015) studied run-off conditions in context of urban areas. The study area is Kathmandu Metropolitan City (KMC). The city is in the stage of rapid urbanization and with it, a rapid increase in built-up spaces. As a result, the city is losing a balance between impervious and pervious cover. Loss of greeneries and unpaved open spaces are causing rapid drain of rain-water. This is creating a disturbance in the hydrological cycle of the area. For assessing the extent of runoff, total runoff was estimated of KMC, as per the surface characteristics and using rational method for calculation. Parameters for determining run-off coefficients were mainly land cover and land use data, soil type and slope of surface. Results show that current runoff is alarmingly high, indicated by the difference between the run-off values of pre and post-development scenarios. Urban development pattern has caused a major impact, in the prevailing run-off and it is very crucial that these issues are addressed in urban planning to promote effective solutions for maintaining water cycle and water resources in urban areas.
- Kishan Bala et al., (2019) studied environmental impacts of urban growth for Hyderabad, Telangana State, India. The study indentified three phases of urban growth and develop scenarios to evaluate the impact of urban growth on several environmental indicators: land use, air quality, and demand for water and energy. The results show

that all developable land will be urban by 2020 and the increase in the number of vehicles will be a major source of air pollution. Demand for water and electricity will rise, and the city will become increasingly vulnerable to shortages of either. The scenarios also show that there will be improvements in local environmental quality as a result of increasing affluence and economic growth.

- Srikrishna. G, (2017) studies the issues and challenges of Urbanization in India. Economy residing in urban areas in India, according to 1901 census, was 11.4%. This count increased to 28.53% according to 2001 census, and crossing 30% as per 2011 census, standing at 31.16%. According to a survey by UN State of the World Population report in 2007, by 2030, 40.76% of country's population is expected to reside in urban areas. As per World Bank, India, along with China, Indonesia, Nigeria, and the United States, will lead the world's urban population surge by 2050. Rapid rise in urban population, in India, is leading to many problems like increasing slums, decrease in standard of living in urban areas, also causing environmental damage.

CHAPTER 3

DESCRIPTION OF THE STUDY AREA

3.1 INTRODUCTION

The study area is Kharghuli, a locality located in the northern part of Guwahati, Assam, India. It is situated on the southern bank of River Brahmaputra. The area lies between longitudes 91°45'31.54"E to 91°46'7.59"E and latitudes 26°11'40.94"N to 26°11'51.22"N (approximately).

Most parts of the Kharghuli area have hilly terrain. Kharghuli area surrounded by lush greenery is considered as one of the green zones in the city.

Rapid urbanization is observed in every part of Guwahati including the Kharghuli area. Due to this ongoing development in the Kharghuli region, a part of the Kharghuli area is proposed to change from green zone to residential area by Guwahati Metropolitan Development Authority (GMDA).

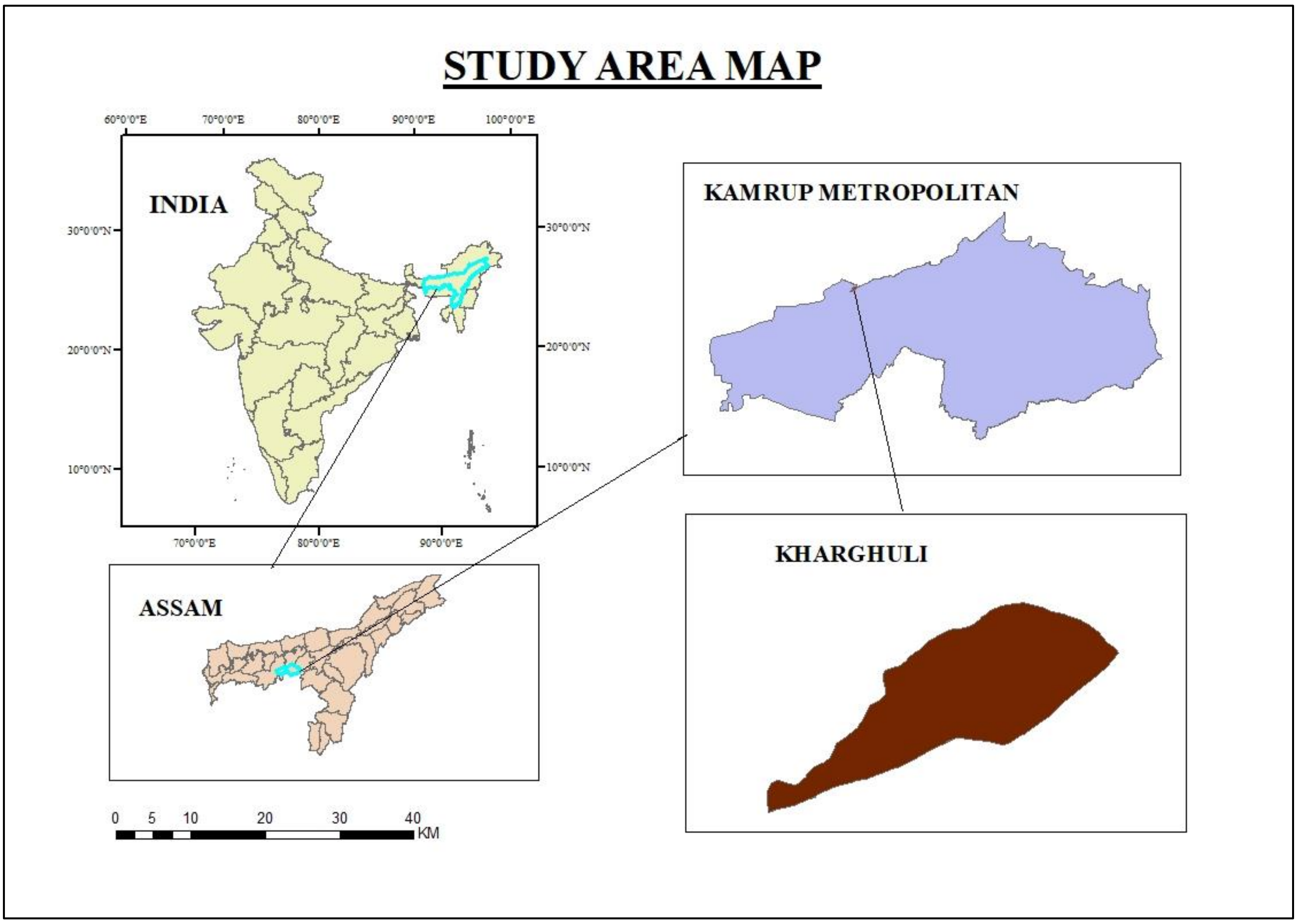

Fig. 3.1- Study Area Map prepared in ArcGIS

Fig. 3.2 – Google Earth Pro image showing the study area- Kharghuli

3.2 CLIMATE AND RAINFALL

Kharghuli located in the hilly terrain of Guwahati has a tropical monsoon climate. The average temperature ranges from 19°C to 30°C. The region receives an annual rainfall of 1600 mm (gscl.assam.gov.in). The relative humidity is about 51 % in the month of February/March and about 70-82% in the rest of the months.

3.3 DELINEATION OF KHARGHULI AREA

The delineation of the study area has been done under GIS environment. For this purpose, a Digital Elevation Model (DEM) is obtained from https://earthexplorer.usgs.gov by creating polygon along the boundary of the study area and setting data in SRTM 1 Arc-Second Global. The DEM tile is downloaded in GeoTiFF format.

The DEM is then processed using a GIS software ArcGIS 10.4. The study area shapefile is created in the ArcGIS software by creating a polygon along the boundary of the Kharghuli area.

The DEM is then clipped to obtain the required study area DEM.

The Elevation Map generated in the ArcGIS shows the height of a point on the earth surface above mean sea level.

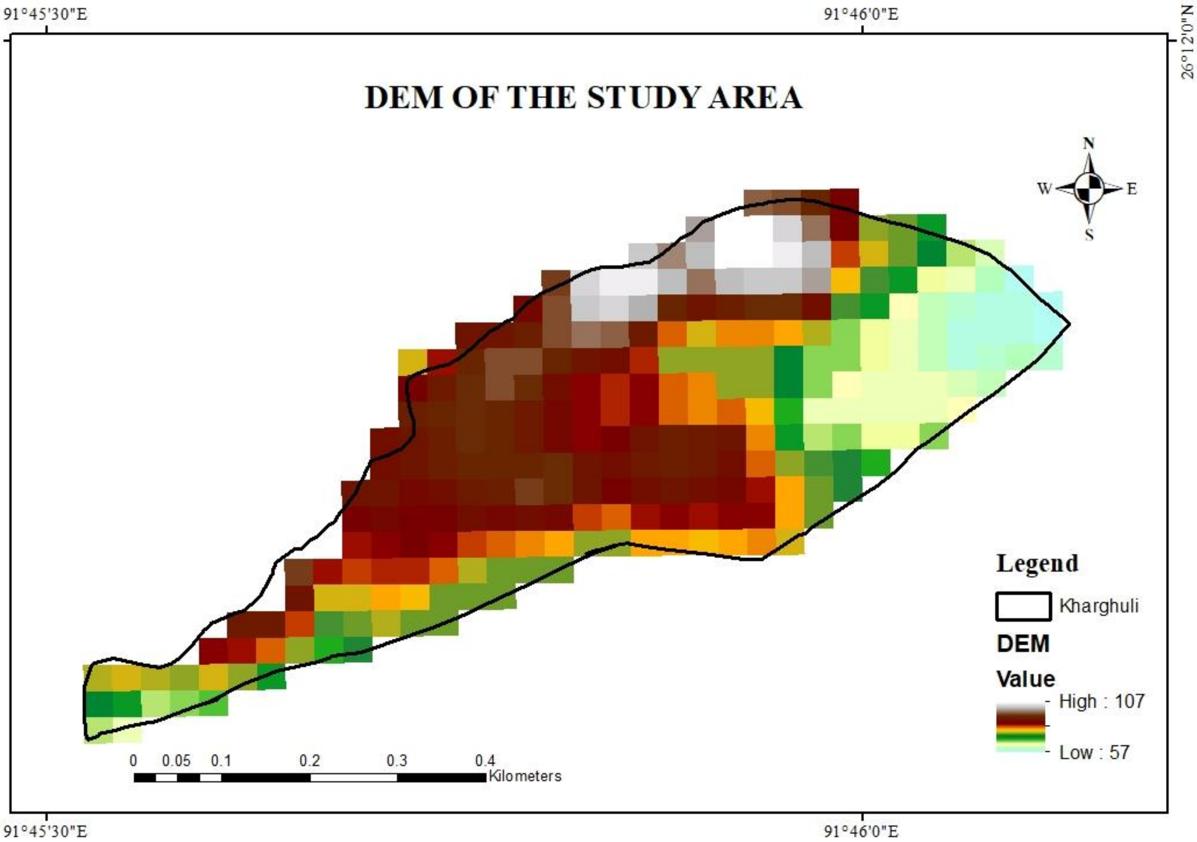

Fig. 3.3 – DEM of the study area

3.4 GENERATION OF SLOPE MAP

The DEM represents spatial variation in altitude and the DEM was used to generate slope map and relative relief map. Slope is an important parameter for stability consideration. It is the first derivative of elevation with each pixel denoting the angle of slope at a particular location. As the slope angle increases, shear stress in soil or other unconsolidated material generally increases as well (Lee et al. 2004). Representation and analysis of slope are of great significance in landform study. The degree of slope controls the amount of run-off, velocity of river as well as the intensity of the processes of erosion, transportation and deposition. Thus, it plays a crucial role in landform development. Its study helps to delineate the character of various landform features as well as to identify the stage of landform development (A. Senthilvelan,2015). The slope value for the study area

Kharghuli ranges from 0° to 25°, thus indicate steep slopes. Higher degree of slope results in rapid runoff and increased erosion with less ground water recharge potential.

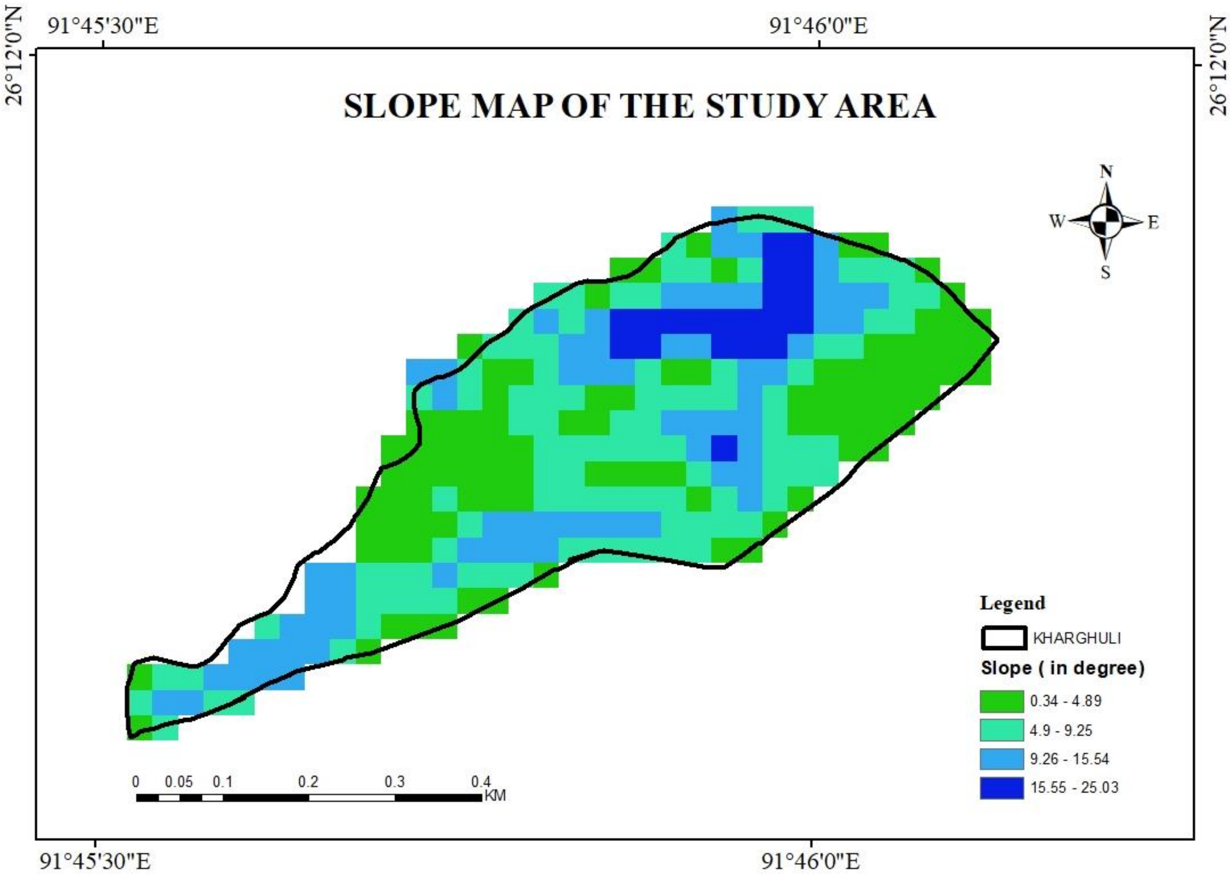

Fig 3.4- Slope Map of the study area

3.5 GENERATION OF RELIEF MAP

Relative relief is defined as the difference in maximum and minimum altitude within an area or facet and is calculated spatially (Pandey et al., 2007). Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as the relief. There is a strong correlation between hydrological characteristics and the Relief of a drainage basin (Schumm 1956). Watershed relief is key factor in understanding the erosional characteristics of the watershed and plays a significant role in development of landforms, drainage development, surface runoff and recharge, permeability and erosional properties of the terrain (Magesh et al.2011).

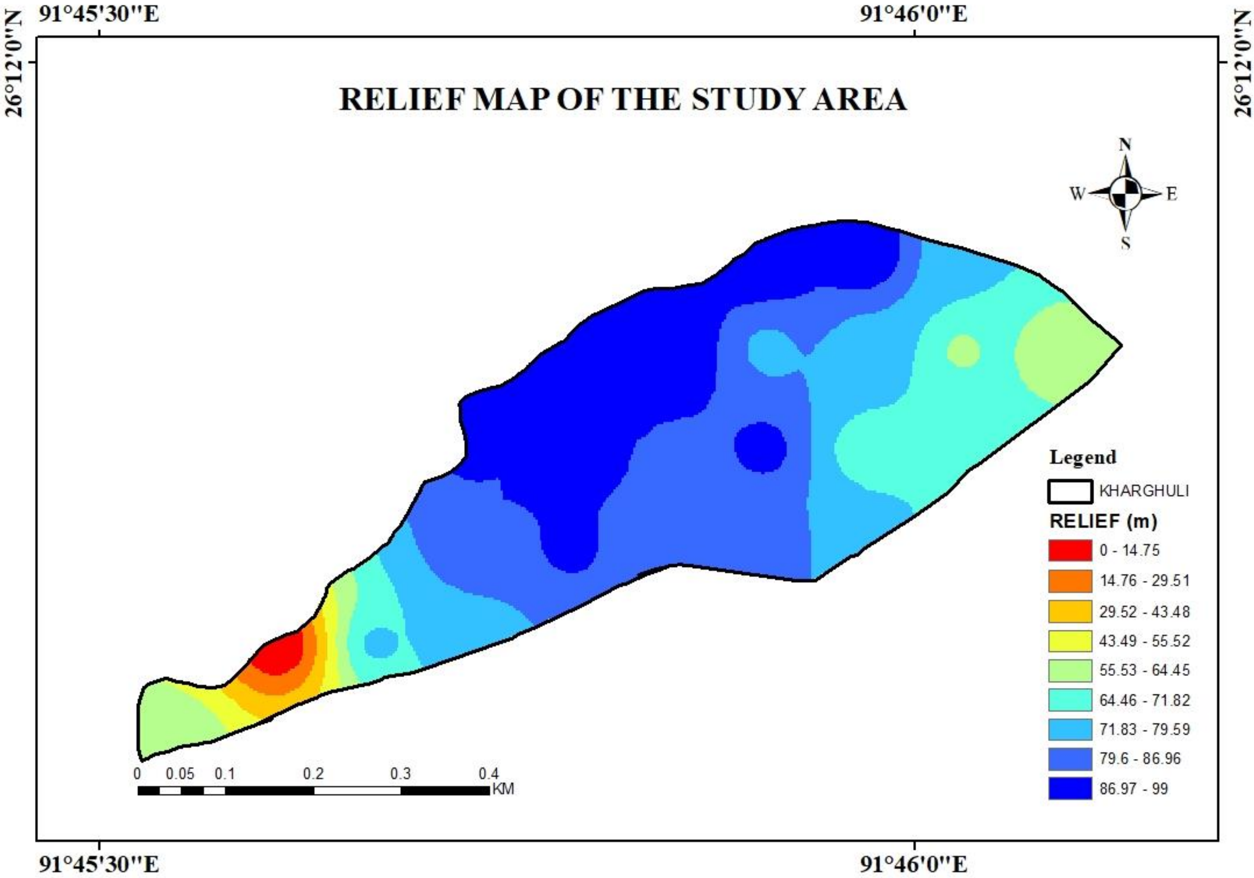

Fig 3.5- Relief Map of the study area

CHAPTER 4

LAND USE LAND COVER

4.1 INTRODUCTION

Land use and land cover is an important component in understanding the interaction of the human activities with the environment. Land use / Land cover (LULC) changes play a major role in the study of global change. Land use/land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster-flooding. These environmental problems are often related to LULC changes (Bala Kishan et al.,2019).

Land use and land cover change (LU/LC) has been recognized as an important force of environmental change on all spatial and temporal scales (Turner, 1994).

Land use cover changes due to urbanization leads to the development of more impervious surfaces that have significant impacts on urban hydrology such as reduction in rainwater infiltration, resulting high surface runoff and peak flow, ultimately increasing the risks of urban flooding and waterlogging.

Conversion of other land class category to urban built-up cover is a direct impact of urbanization.

The study aims to analyze the land use-land cover change in a span of 10 years.

The LULC analyzing is an important factor in understanding urban growth trends. As LULC affects the runoff during storm events, it's analyzing is helpful for city planners.

4.2 METHODOLOGY

For LULC map generation, Landsat data is acquired. The Landsat images obtained from https://earthexplorer.usgs.gov by creating polygon along the boundary of the study area and setting data in Landsat Collection 2 Level 2 and selecting Landsat 8-9 OLI/TIRS C2.

Remote sensing data Landsat 8 path/row 136/042 an acquisition date on 18th March 2024 and Landsat 9 path/row 137/042 an acquisition date on 1st March 2024 have been downloaded. Landsat 8 path /row 137/042 an acquisition date on 24th October 2014 and Landsat 8 path/row 136/042 an acquisition date o 20th December 2014 have also been downloaded. These satellite imageries are processed in the GIS environment. Land Use Land Cover Maps are generated using Maximum Likelihood Classification (MLC) method.

4.3 LANDUSE/ LANDCOVER (LULC) OF THE STUDY AREA

LULC Map of the Kharghuli area for the year 2014 has been generated. 3 classes/category of landuse has been identified.

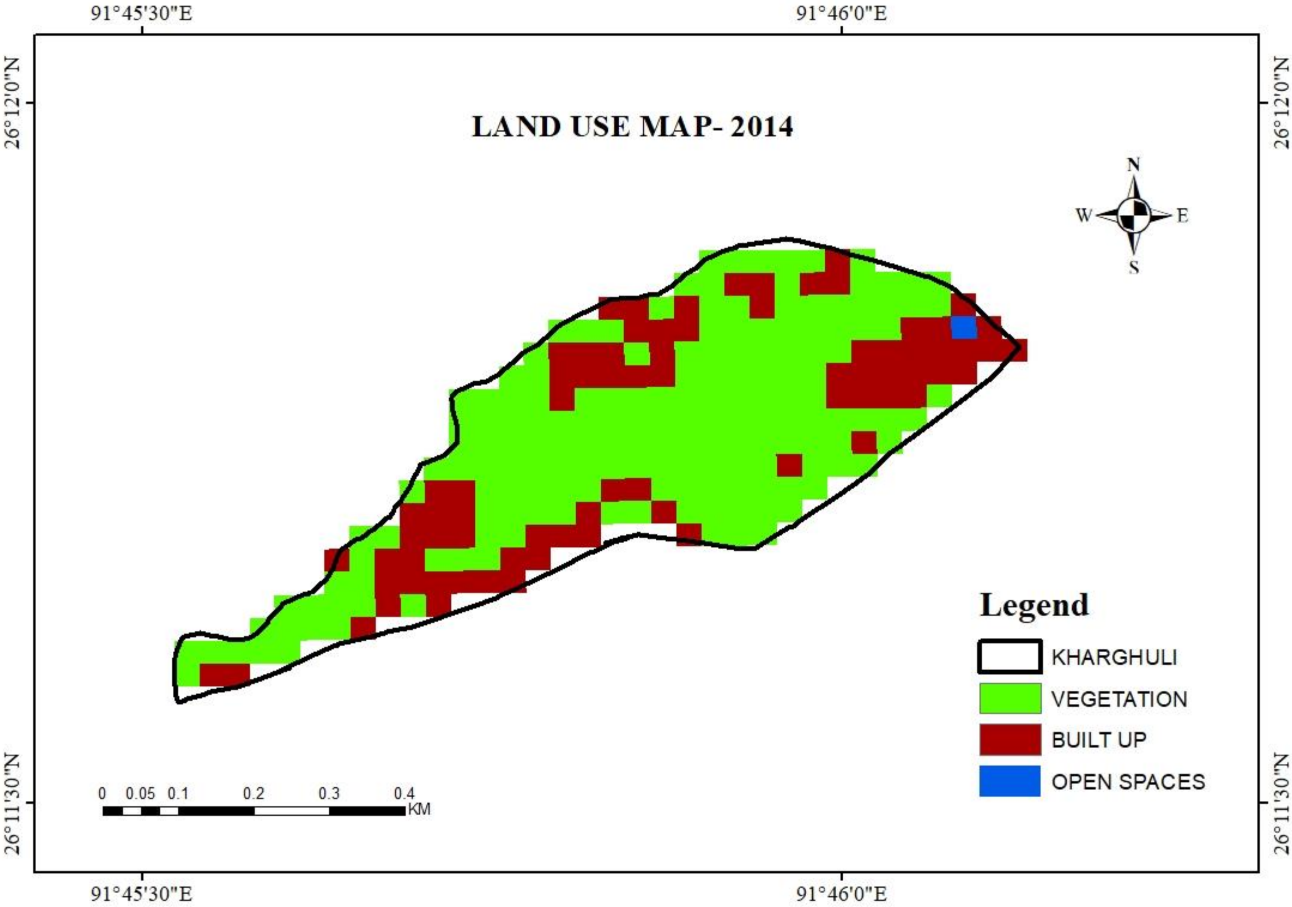

Fig 4.1- LULC Map of 2014

Table 4.1 Area and percentage for LULC 2014

CATEGORY	AREA (Km^2)	PERCENT
BUILT UP	0.0653	29.59%
OPEN SPACES	0.0006	0.26%
VEGETATION	0.1548	70.14%
Grand Total	0.2207	100%

The land use area in percentage can be shown in the pi-chart Fig 4.2

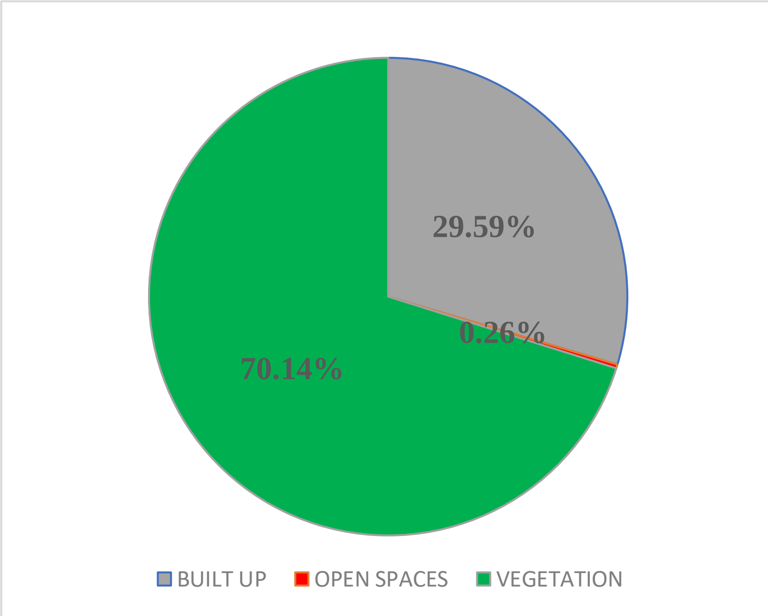

Fig 4.2- Pi-chart showing percentage of land use land cover for the year 2014

LULC Map of the Kharghuli area for the year 2024 has been generated. 2 classes/category of landuse has been identified.

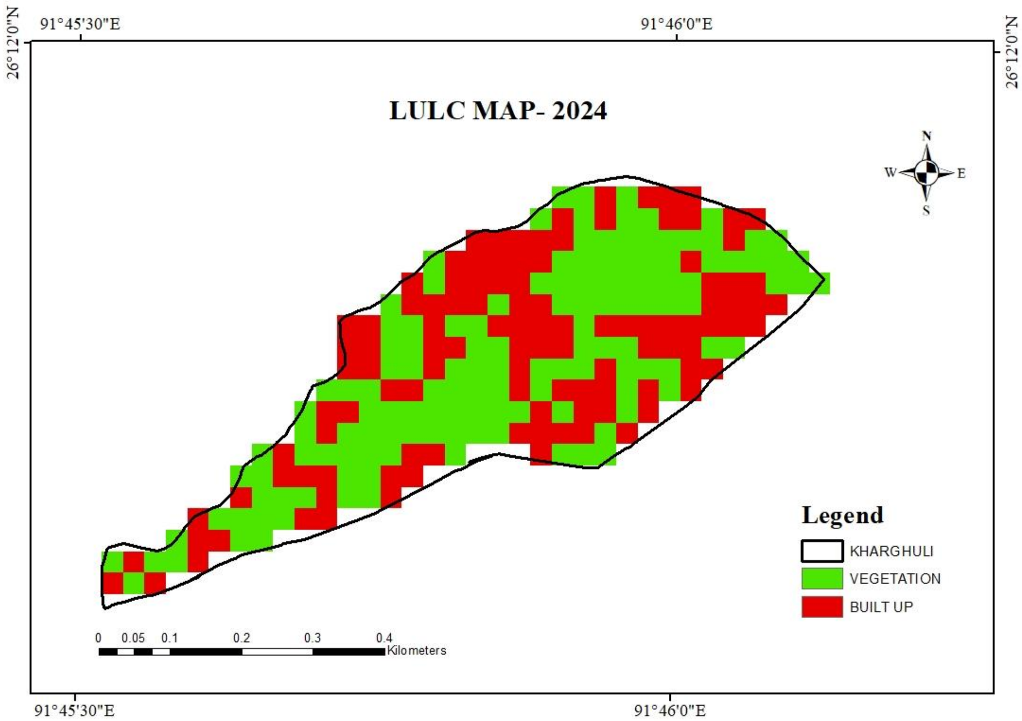

Fig 4.3- LULC Map of 2024

Table 4.2 Area and percentage for LULC 2024

CATEGORY	AREA (Km^2)	PERCENT
BUILT UP	0.0976	44%
VEGETATION	0.1246	56%
Grand Total	0.2222	100%

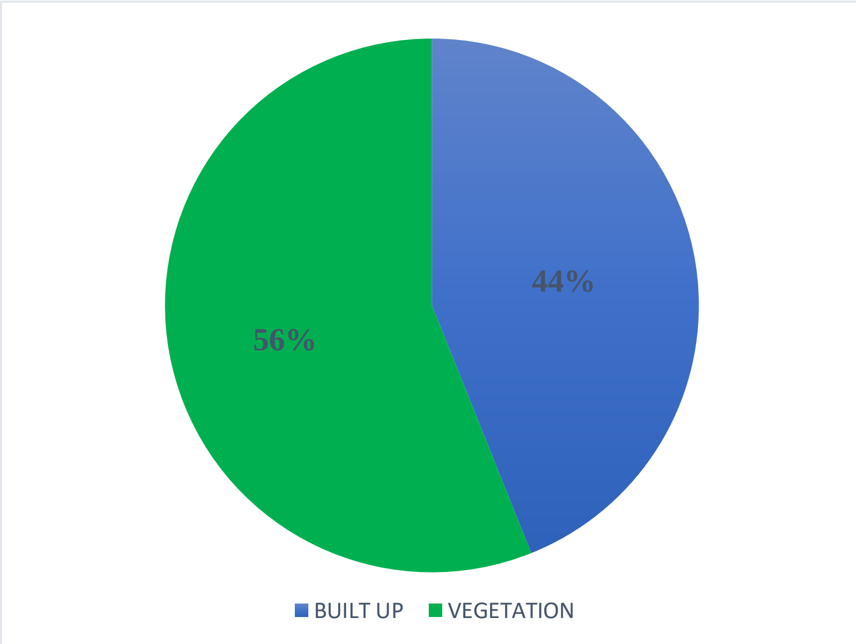

Fig 4.4- Pi-chart showing percentage of land use land cover for the year 2014

4.4 ANALYSIS AND RESULTS

LULC maps and Pi- Diagrams clearly shows the changes in LULC of the Kharghuli area. By comparing the LULC changes of the years 2014 and 2024 it can be observed that the vegetation cover decreased by 14.14% (0.030 Km^2 decrease in area) and built-up cover increased by 14.41% (0.032 Km^2 increase in area). It is also seen that open spaces covered only 0.26% in the year 2014 which further decreased to 0% in 2024.

Table 4.3- Comparison of Area of land use land cover categories for the year 2014 and 2024

LULC CLASS	2014 AREA in Km^2	2024 AREA in Km^2
VEGETATION	0.15484463	0.124605402
BUILT UP	0.065328713	0.097630566
OPEN SPACES	0.000576349	0
TOTAL	0.220749693	0.222235969

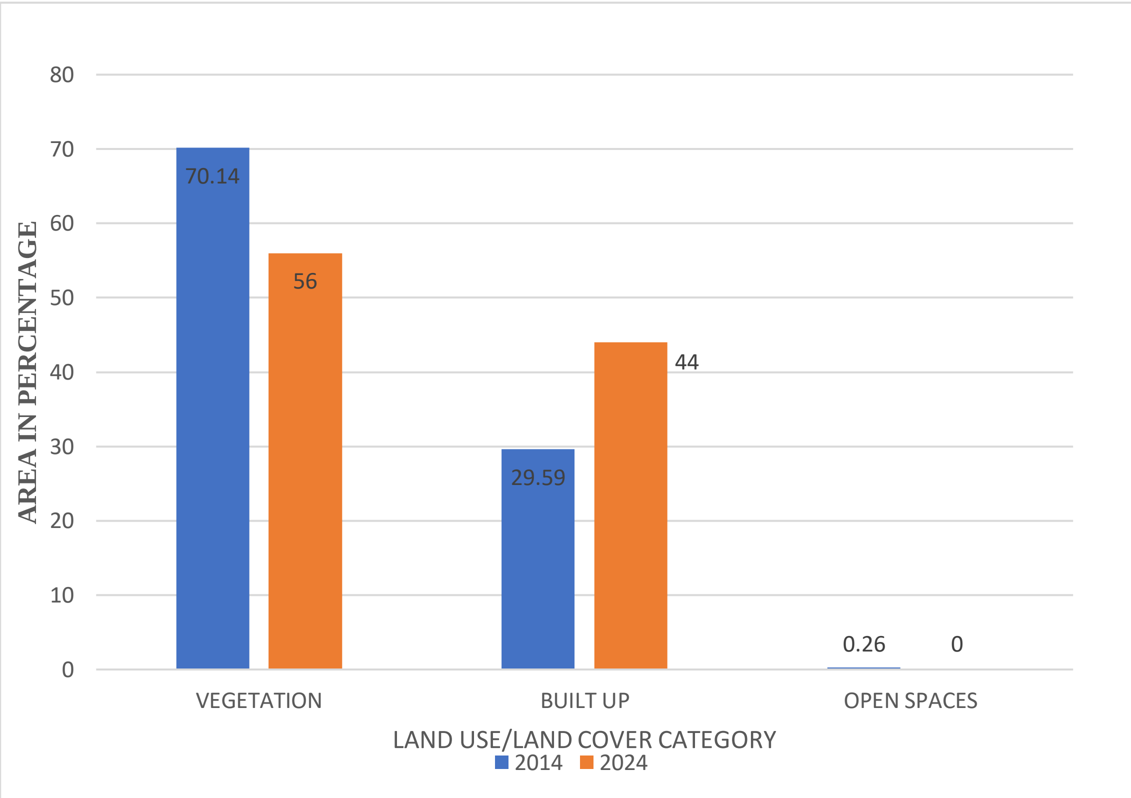

Fig 4.5 Comparison of area in percentage of the LULC for the year 2014 and 2024

It is evident from the comparison that the Kharghuli area has undergone drastic change in LULC type. The increase in the built up is a result of urbanization in the region.

This increase in impervious surfaces can be linked to increase of surface runoff.

CHAPTER 5

SURFACE RUNOFF ESTIMATION

5.1 INTRODUCTION

Runoff is a significant hydrologic component in the water resources assessment (Ibrahim et al., 2021). Most water resource applications rely on runoff as an essential hydrologic variable (Shadeed and Almasri, 2010). Runoff is the flow of precipitated water through a channel in the catchment area after all surface and subsurface losses have been met. River basin features such as length, width, area, shape, drainage design, soil type, vegetation cover, land usage, and hydrological conditions affect the rainfall-runoff procedure considerably (Caletka et al., 2020).

5.2 FACTORS AFFECTING RUNOFF

The amount of runoff from a given drainage area depends on many inter related factors. Watershed characteristics such as slope, shape and size, cover of soil and duration of rainfall have a direct effect on the peak flow and volume of runoff from any area (Chandler and Walker, 1998). Intensity of the storm have direct effect on the runoff yield. Land use cover have a great influence in the runoff.

5.3 RUNOFF ESTIMATION METHODS

For the estimation of surface runoff, many methodologies have been developed in the past such as runoff curve number method, infiltration model method, rational method, modified rational method etc.

The methodology followed here is Rational Method.

5.4 RATIONAL METHOD

Rational method was first used in 1889 developed by Emil Kuichling. The Rational equation is easiest method to obtain peak runoff from watershed. The most common and quickest method of runoff estimation. This is a simple method to estimate the runoff in small areas by using `c’ value or runoff coefficient. It is much easier to represent variation in hydrological responses within that area (Shyamsunder et al.,2021).

The equation of runoff based on Rational Method can be written as,

$$Q = C * i * A$$

Where, Q = Runoff

C = Runoff coefficient

i = Intensity of rainfall

A = Area

The assumptions associated with the rational method as stated in available literature are (Needhidasan.S et al.,2013):

1.The computed peak rate of runoff at the outlet point is a function of the average rainfall rate during the time of concentration, i.e., the peak discharge does not result from a more intense storm of a shorter duration, during which only a portion of the watershed is contributing to runoff at the outlet.

2.The time of concentration employed is the time for runoff to become established and flow from the most remote part of the drainage area to the inflow point of the sewer being designed.

3.Rainfall intensity is constant throughout the storm duration.

5.5 PARAMETERS FOR RATIONAL METHOD

5.5.1 Runoff coefficient

Runoff coefficient (C) is defined as the ratio of the volume of water superficially drained during rainfall to the total volume of precipitation during a certain period (Bedient et al., 2013; Júnior, 2015). Runoff coefficient is a dimensionless factor that is used to convert the rainfall amounts to runoff. It represents the integrated effect of catchment losses and hence depends upon the nature of land surface, slope, degree of saturation, and rainfall intensity. It is also affected by the proximity to water table, degree of soil compaction, porosity of soil, vegetation, and depression storage (Goel, 2011). The value of runoff coefficient is assigned on the basis of land use/land cover classes and is based on the available literature (Sarma, 2011; Ramachandra et al.,2014)

Table 5.1 Runoff Coefficient (C) for different land covers

LAND COVER	RUNOFF COEFFICIENT
Built-up	0.9
Barren land	0.5
Agriculture	0.5
Tree clad area	0.3
Forest	0.3
Scrub land	0.3
Water body/marshy land	0

5.5.2 Time of concentration

Time of concentration (Tc) is most important hydrological parameter for a catchment at which the peak flow occurs. It is the time at which the raindrop from the farthermost point of a catchment reaches to the outlet. The exact time of concentration must be estimated which depends on the size and shape, slope and soil type over the catchment (Gonzalez-Hidalgo et al.,2004). It also highly depends on the type of crops in agricultural area and the rapid urbanization with compacted concrete structures (Raji, P., Uma, E. and Shyla, J.,2011).

For the calculation of time of concentration, the Kirpich formula has been used

$t_i = 0.0195 \times L^{0.77} \times S^{-0.385}$

Where, ti = Time of concentration in minutes

L = Length of flow in m

S = Slope

Travel time, $t_v = v/t$

Where v = minimum velocity in m/sec

t= time in min

The final time of concentration has been considered as

$t_t = t_i + t_v$

5.5.3 Intensity of Rainfall

Estimation of peak runoff for the desired return period is a pre-requisite for planning, design and management of hydraulic structures. The rainfall data is an important parameter for analysis of runoff generated in that area. The annual rainfall in Guwahati was on average 1,681 mm from 2008 to 2012 (Source: IMD Monthly Rainfall data from 2008 to 2012). Of this amount, 63% of the rain fell during the monsoon months (June to September), 31% during the pre-monsoon months (March to May), 5% during the post-monsoon months (October to November), and 1% during winter (December to February). Hence, approximately 94% of total annual rainfall occurred during the wettest seven months (March to September) (Ruby Das et al., 2016).

The Rainfall Intensity Duration Frequency (IDF) relationship is one of the most common tools in water resources engineering, either for planning, designing and operating of water resource projects, or the protection of various engineering projects (e.g., highways, etc.) against floods. The relationship describes relation between mean precipitation intensity and frequency of occurrence (the inverse of the return period) for different time intervals of a given duration. These intervals over which the precipitation intensity is averaged are called durations. The intensity is time rate of precipitation, that is, depth per unit time (mm/hr.).

In the past, many researchers have developed IDF curves for different regions of the world. IDF curves and the empirical equation for Guwahati has been established in the available literature Ruby Das et al., 2016.

Table 5.2 Rainfall intensity for different return period

Duration(min)	**Return Period (Years)**					
	2	5	10	25	50	100
	Rainfall intensity, (i) for different period (mm/hr)					
15	84	105.63	119.74	137.84	151.24	163.7
30	76.63	92.81	103.36	116.9	126.92	136.24
60	62.73	79.96	91.20	105.62	116.3	126.22
120	28.64	40.39	48.05	57.89	65.17	71.94
360	9.75	16.18	20.37	25.75	29.73	33.44
1440	4.17	5.11	5.73	6.51	7.1	7.64

SOURCE: Ruby Das et al.,2016

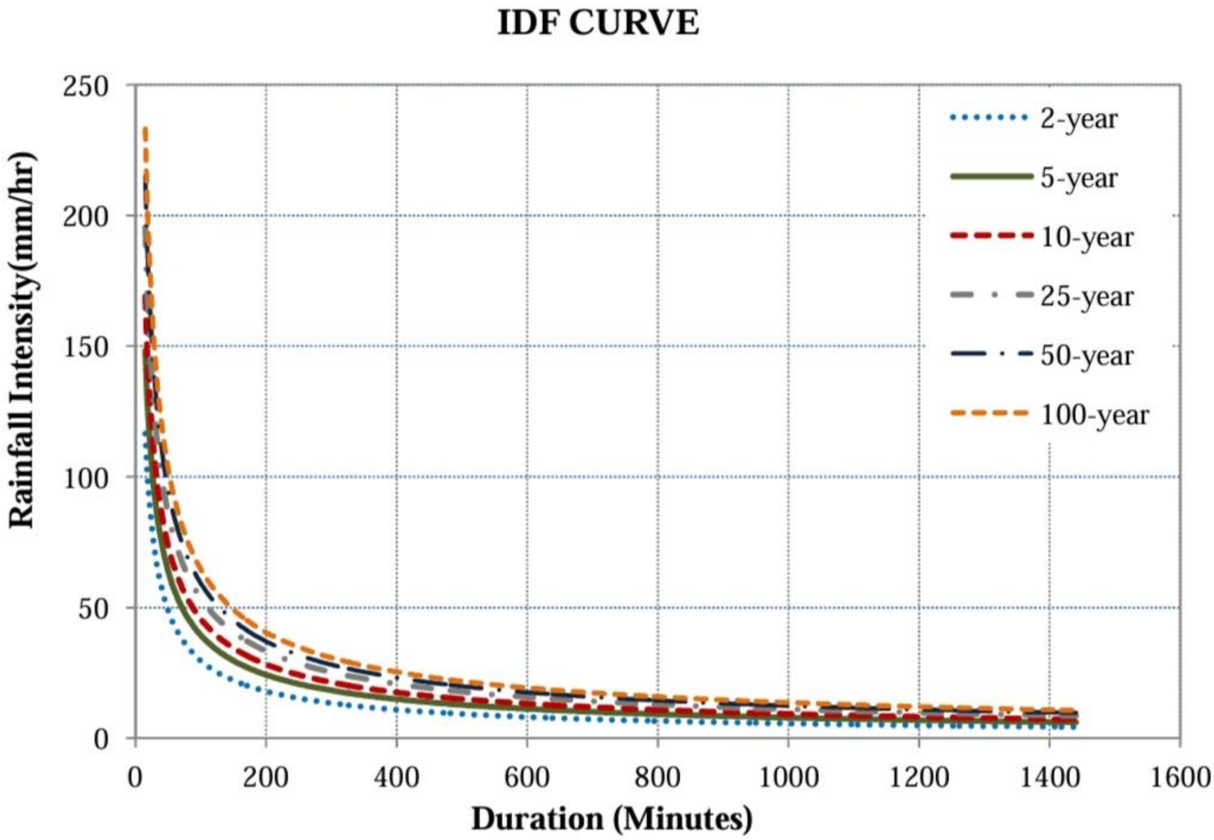

Fig 5.1 Intensity Duration Frequency curve (SOURCE: Ruby Das et al.,2016)

IDF empirical equation are the equation that estimates the maximum rainfall intensity for the different duration and returns period. Different procedures and formulas have been proposed in literature (Chow, 1964; Bell, 1969; Chen, 1983; Aron et al. 1987; Kouthyari and Garde, 1992). IDF is a mathematical relationship between the intensity of rainfall, i, the duration, t_d, and the return period, T.

The empirical equation as used in the literature, $i = a*(t_d)^{-c}$

Where i is the rainfall intensity in mm/hr. t_d is the rainfall duration in minutes, a & c are the fitting parameters.

'a' and 'c' parameter values for return periods of 2, 5, 10, 25, 50 and 100 years have been derived in the literature from which rainfall intensity for a given duration of a rainfall event can be easily calculated (Ruby Das et.al., 2016). These curves and equations have been a help to hydrologists and engineers to plan the drainage network of the city.

Table 5.3 Rainfall IDF Empirical Equation for respective return period

Intensity, I(mm/hr)	$i = a*(t_d)^{-c}$ t_d = duration (mins)		Correlation Coefficient R^2
Return Period, T (years)	**a**	**c**	
2	**821.43**	**0.721**	**0.9600**
5	**983.80**	**0.699**	**0.9589**
10	**1095.40**	**0.690**	**0.9534**
25	**1241.30**	**0.683**	**0.9457**
50	**1350.40**	**0.679**	**0.9403**
100	**1452.30**	**0.676**	**0.9375**

SOURCE: Ruby Das et al.,2016

5.6 ESTIMATION OF SURFACE RUNOFF IN THE KHARGHULI AREA

The methodology used for estimation is depicted in the diagram below

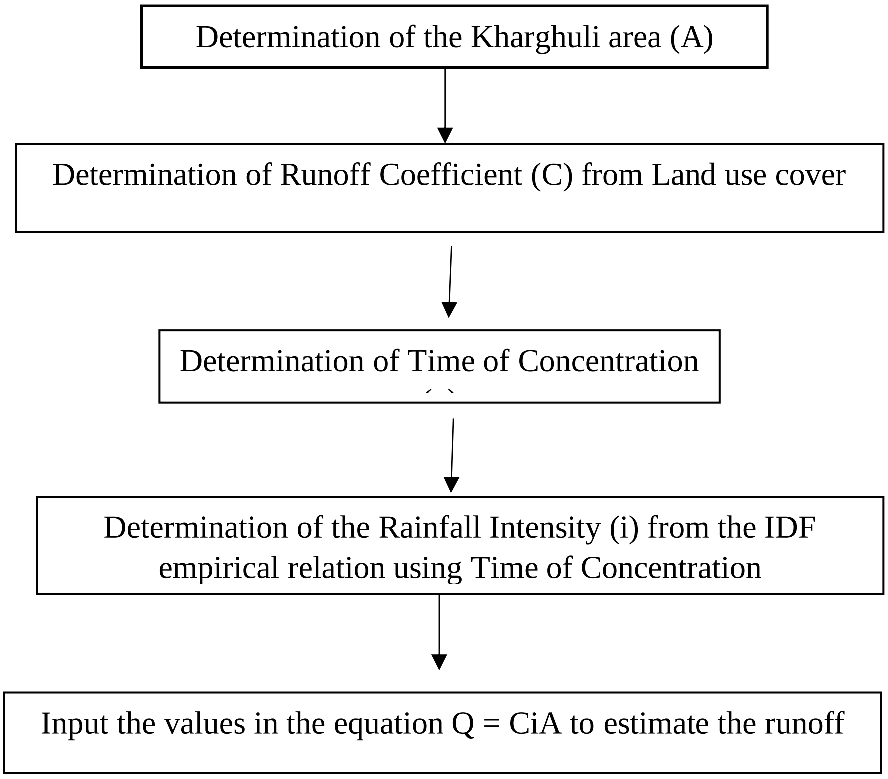

Fig 5.2 -Methodology for Runoff Estimation

Area of the study area Kharghuli, A= 0.22 Km^2.

For the runoff coefficient value determination, the land use land cover of 2024 has been considered by using weighted area method

Table 5.4 Runoff Coefficient for the Study Area

LAND COVER	Area, A (sq m)	COEFFICIENT OF RUNOFF (C)	CA	$C_{WEIGHTED}$
BUILT UP	97630.56641	0.9	87867.51	0.56
VEGETATION	124605.4022	0.3	37381.62	
	222235.9686		125249.1	

From Table, Runoff Coefficient, C = 0.56

Calculation of time of concentration, Kirpich formula,

$t_i = 0.0195 \times L^{0.77} \times S^{-0.385}$

Here, L = 130 m, S = 0.038

t_i = 2.91 min

Length of the channel = 562 m

Therefore $t_v = \frac{L}{V*60}$

Considering velocity, v as 0.8 m/sec

$t_v = \frac{562}{0.8*60} = 11.71$ min

Thus, the time of concentration, $t_c = t_i + t_v = 14.62$ min

Considering a storm event of 2- year return period, from IDF Curve and equation intensity of rainfall for duration t_c = 14.62 min is calculated.

Rainfall intensity, i = 118.7 mm/hr

Putting these values in Rational method discharge formula,

Surface Runoff = 0.28 CiA = 0.28 x 0.56 x 118.7 x 0.22

= 4.09 m^3/sec

Similarly, for a 5-year return period, runoff has been calculated.

For 5-year return period, rainfall intensity, i = 150.8 mm/hr

Surface Runoff =0.28 CiA = 0.28 x 0.56 x 150.8 x 0.22

=5.02 m^3/sec

Table 5.5- Runoff estimation calculation for 2-year and 5-year storm event for the study area

Return Period (years)	Area (Km^2)	Length (m)	Length overland flow (m)	Difference elevation, H(m)	Inlet time, t_i (as per Kirpich formula) (min)	Time of flow, t_v (min)	Time of concentration $t_t = t_i + t_v$ (min)	Intensity of rainfall, i (mm/hr)	Runoff coefficient, C	Discharge Q=CiA (m^3/sec)
2	0.22	562	130	4.94	2.91	11.71	14.62	118.7	0.56	4.09
5	0.22	562	130	4.94	2.91	11.71	14.62	150.8	0.56	5.02

5.7 ANALYSIS

The peak discharge value increases and reaches up to 5.02 m^3/sec for 5-year return period storm as compared to 4.09 m^3/sec for 2-year return period storm. Thus, there is an increase of 18.52 % of runoff for the major storm.

CHAPTER 6

POPULATION AND ITS IMPACT

6.1 INTRODUCTION

The process of relocating people from less developed rural areas to more developed urban areas, such as towns and cities, is known as urbanization. The driving force for such movements is typically a belief that urban areas provide greater opportunities for growth, employment, education, and development than rural areas (Dodman, 2017). WHO estimates that over fifty percent of the global population resides in town and cities and it is predicted that this number may rise to six out of ten by 2030 and seven out of ten by 2050 (World, 2009).

Urban areas are developing twice as quickly as population expansion and are a primary driver of environmental change (Seto & Kaufmann, 2005).

The population of Guwahati city is expanding at a high rate. Assam, the north-eastern state of India, currently has a population of 3.6 crores as of 2021. Guwahati, the "Gateway of Northeast India," is the largest city in Assam, as well as the largest city in north-eastern India. It is the most populous city in the northeast and one of the fastest-growing cities in India. The area population of Guwahati city in 2021 was 1,135,000, a 1.61% increase from 2020 (Kashyap,2022).

6.2 POPULATION GROWTH IN THE STUDY AREA

6.2.1 POPULATION IN THE AREA

Population growth has been observed in almost all the parts of Guwahati city. Guwahati witnessed a very high rate of growth in the period from 1971 to 1991; 8.1 per cent p.a., which is likely on account of the city becoming Assam's capital in 1972, migration from rural Assam and other states of the North-East region of India, and also the cross-border migration from Bangladesh after the latter's formation in 1972. Since then, GMC area has registered slowing down of population growth rate, from 3.3 per cent p.a. in 1991-2001 period and 1.8 per cent p.a. in 2001-11 period (Darshini Mahadevia et al., 2014).

It has been observed that people from different socio-economic groups have gradually settled in the hills present in the Guwahati city region. Due to lack of vacant land and high cost of land in the plains, people tend to settle in the hilly regions. Rapid growth of human settlement has been observed in the Kharghuli region of Guwahati. To accommodate the increasing population, the hilly terrain of the region has been utilized for settlement and development.

According to a survey in 2011, Population (No. of households) in the Kharguli hill was found to be 2822 (AC Nielson 2011).

Population in the city has undergone a 1.97% annual change. These population estimates and projections come from the latest revision of the UN World Urbanization Prospects (Guwahati, India Population 2024. (2025-01-19). World Population Review. https://worldpopulationreview.com/cities/india/guwahati)

This population data and annual growth rate has been used to forecast population till the year 2046.

6.2.2 POPULATION FORECASTING

Population estimation refers to the size of current population in the specific area. Population projection is defined as the numerical outcome of a specific set of assumptions regarding future trends of fertility, mortality and migration (Aryal,2020).

Exponential Growth Method is a mathematical method used for future population projection has been used in this study. The exponential model assumes that the population is growing at a constant rate.

The Exponential Growth Model can be written as,

$P_t = P_o e^{rt}$

Where P_t= current year population

P_o = base year population

r = growth rate

t = time interval (in years)

e = base of the natural logarithms

Considering the base year (2011) population as 2822 (AC Nielson 2011) and growth rate, r as 1.97%, the projection has been done with the time interval of 5 years.

Table 6.1 Projected population with 5-year time interval

YEAR	POPULATION
2011	2822
2016	3114
2021	3436
2026	3792
2031	4185
2036	4618
2041	5096
2046	5623

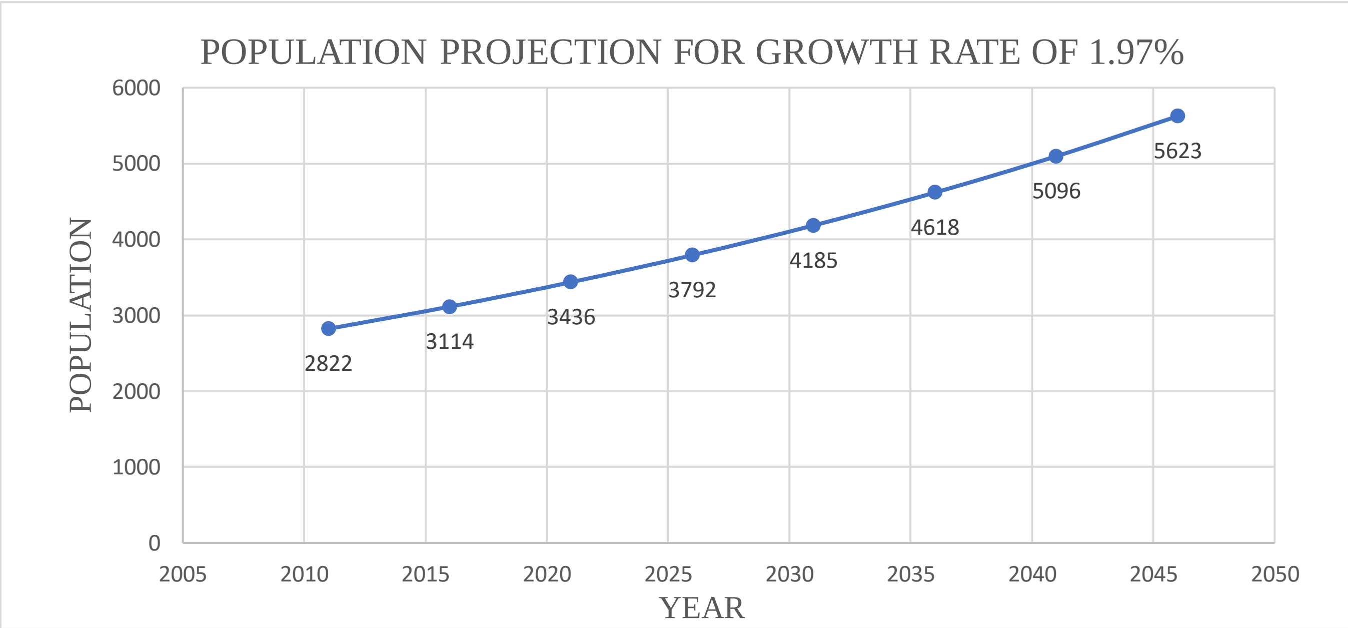

Fig 6.1- Projected Population Chart for population growth rate 1.97%

6.3 POPULATION AND WASTE GENERATION

Currently, 380 billion m^3 (380 trillion liters) of wastewater is generated globally every year (Pratap et al.,2023). Rapid growth of urban population in India has led to equally fast increase in the consumption of water and consequently to generation of wastewater (Kapshe et al.,2013). The quantification of wastewater loads as a per capita value enables comparisons of data across sites with different population size (Daughton, 2020).

Population growth have a direct impact on wastewater generation, which increases with the expansion of population. The projected population for the study area Kharghuli has been used to estimate the wastewater generation, based on constant 108 litres per capita per day waste contribution.

Table 6.2 Population Growth and Waste Water Generation at 1.9% annual growth rate

YEAR	POPULATION	WASTE CONTRIBUTION (lpcd)	GROSS WASTE GENERATION (MLD)	PERCENTAGE INCREASE IN WASTE
2011	2822	108	0.305	
2016	3114	108	0.336	3.15
2021	3436	108	0.371	3.48
2026	3792	108	0.410	3.84
2031	4185	108	0.452	4.24
2036	4618	108	0.499	4.68
2041	5096	108	0.550	5.16
2046	5623	108	0.607	5.70

(Assumed)

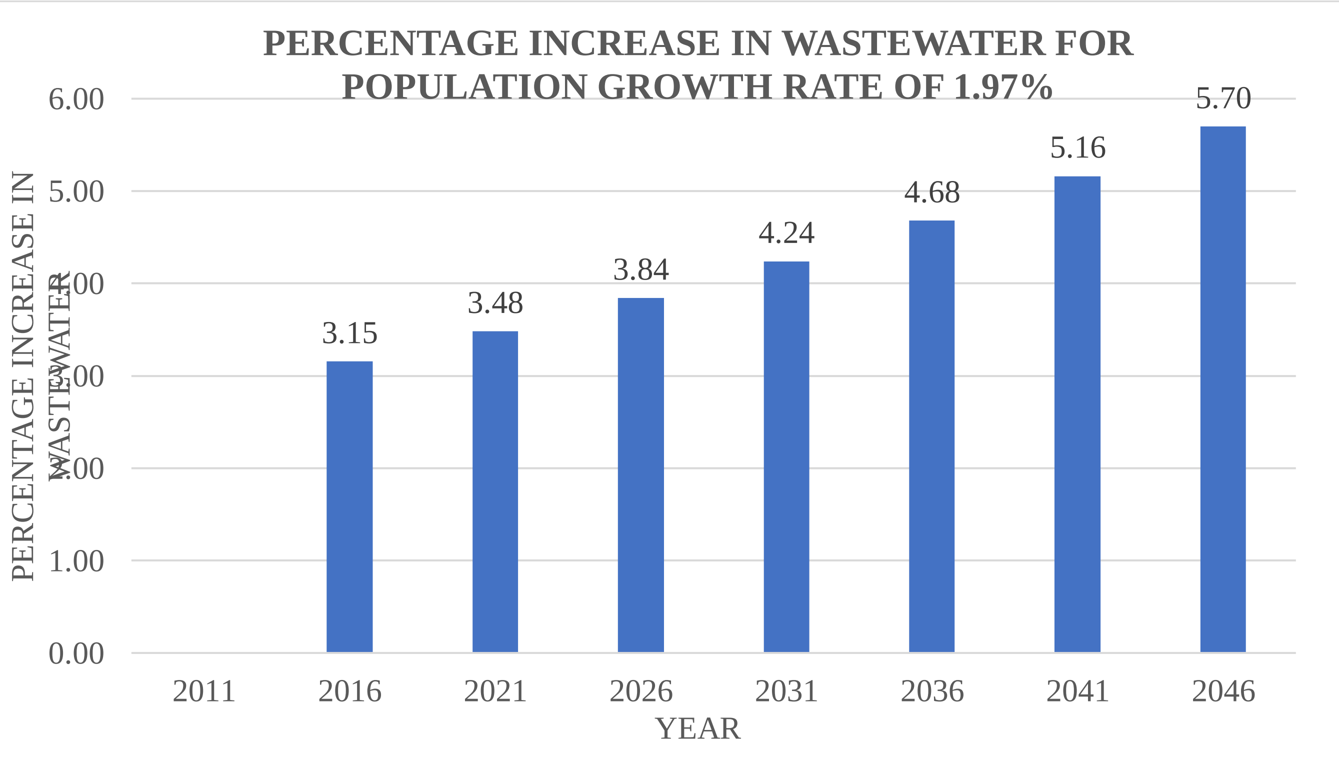

Fig 6.2 Percentage Increase in Waste Water at annual population growth rate of 1.97%

6.4 IMPACT OF URBANIZATION IN THE KHARGHULI AREA

Kharghuli has undergone rapid urbanization over the past few years. The current population growth rate of is 1.97% (Guwahati, India Population 2024. (2025-01-19). World Population Review). The proposal by GMDA of converting a part of Kharghuli area from green zone to residential area will lead to increase annual growth rate. Assuming the annual growth rate to be 2.5%, similar to annual growth rate of Assam (Darshini Mahadevia et al., 2014).

The population projection and wastewater generation from the year 2021 to 2046 has been produced.

Table 6.3 Population Growth and Waste Water Generation at 2.5% annual growth rate

YEAR	POPULATION	WASTE CONTRIBUTION (lpcd)	GROSS WASTE GENERATION (MLD)	PERCENTAGE INCREASE IN WASTE
2021	3624	108	0.391	4.60
2026	4106	108	0.443	5.21
2031	4653	108	0.502	5.90
2036	5272	108	0.569	6.69
2041	5974	108	0.645	7.58
2046	6770	108	0.731	8.59

(Assumed)

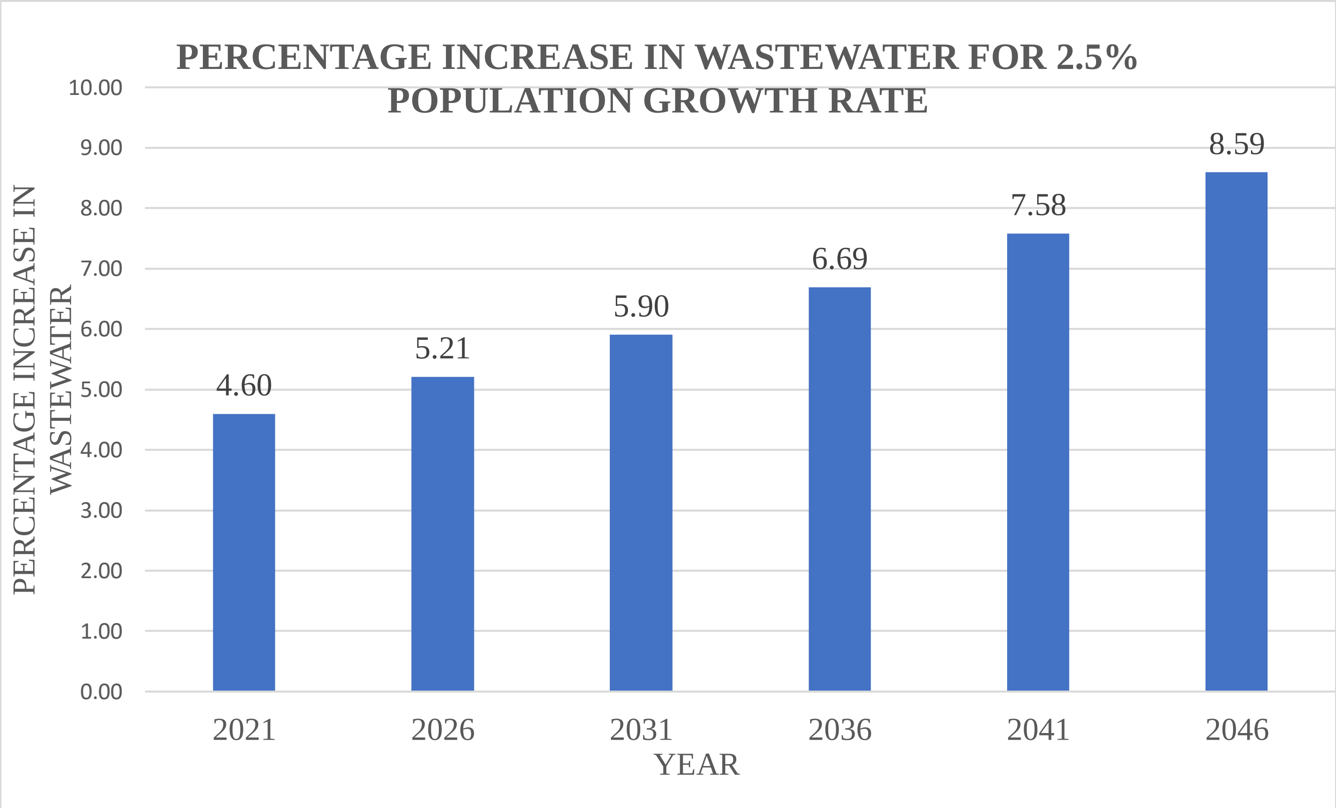

Fig 6.3 Percentage Increase in Waste Water at annual population growth rate of 2.5%

6.5 ANALYSIS

With fast urbanization & industrialization the generation of wastewater has taken a phenomenal growth (R.M. Bhardwaj,2005). The wastewater generated along with surface runoff must be carried for safe disposal. Therefore, for planning and designing of drainage network both surface runoff and wastewater must be considered.

A comparison of population and waste generation from the year 2021 to 2046 for annual growth rate of 1.97% and 2.5% has been made to analyze the impact of urban population growth.

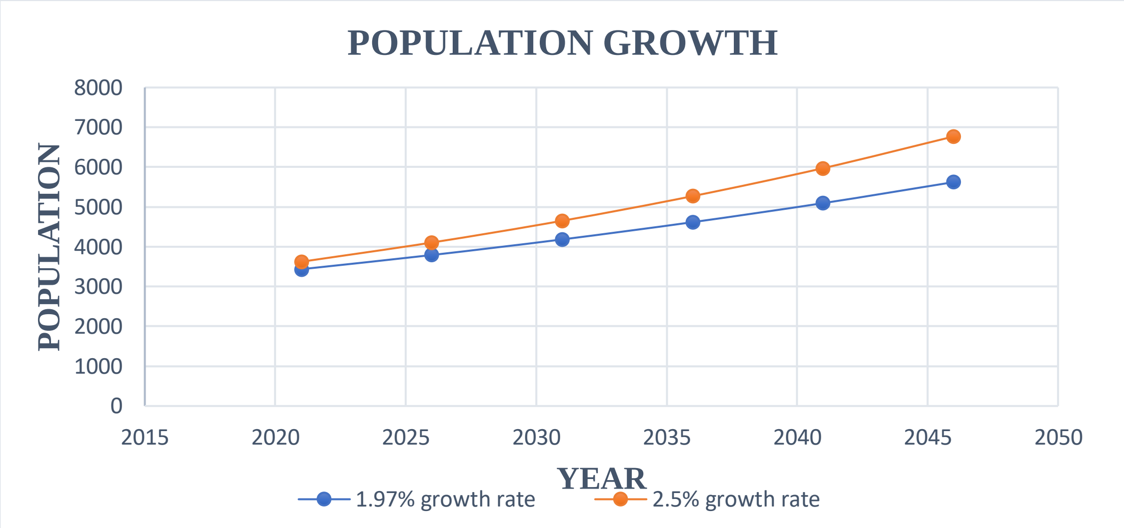

Fig 6.4 Population Projection at 1.97% and 2.5% annual growth rate

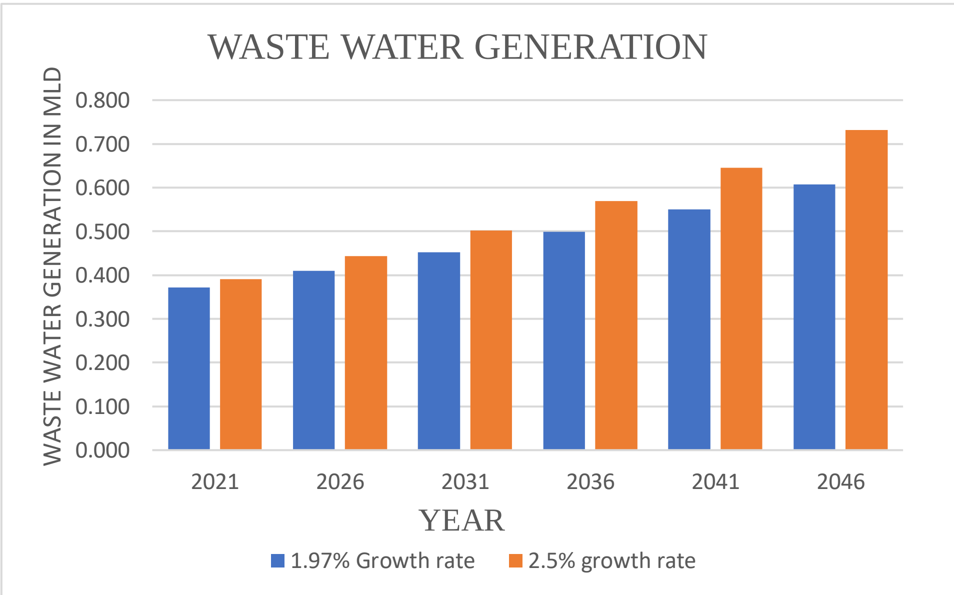

Fig 6.5- Waste Water Generation (MLD) Comparison at 1.97% and 2.5% annual population growth rate

It has been observed that with the higher growth rate the population can reach up to 6770 by the year 2046. It is revealed that with the slow population growth rate the waste generation is low, reaching 0.607 MLD by 2046 as compared to 0.731 MLD of higher growth rate.

CHAPTER 7
EXISTING DRAINAGE SYSTEM

7.1 INTRODUCTION

Urban drainage systems are generally designed to drain out surface runoff from urban areas during storm events. However, storm water exceeding the drainage capacity can cause urban flooding and result in traffic interruption, economic loss and health issues. An increase in impervious land cover leads to more surface runoff, faster runoff concentration and higher peak flow rate. Thus, there is an increasing need to improve drainage capacity to reduce flooding in rapidly urbanizing areas (Mi Pale Kyi et al., 2018).

Drainage is a very important consideration in planning a city to avoid damage due to surface runoff and waterlogging or flooding. A drainage system must be properly designed to efficiently and safely convey the runoff to a disposal site. An efficient drainage system is an essential element of urban planning. For design of an efficient drainage system both stormwater and wastewater consideration are important.

7.2 EXISTING DRAINS IN THE AREA

The discharge carrying capacity has been estimated using Manning's equation of velocity and discharge. The Manning equation is an empirical equation for analysing water flows in channels and culverts where the water is open to the atmosphere which means the flow is not under pressure. Irish engineer Robert Manning in 1891 introduced the equation.

The Manning's equation to estimate velocity of flow in the channel is

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Here, V = Average velocity of flow (m/s)

n= Manning's coefficient

R= Hydraulic radius (m) $= \frac{Area\ (A)}{Wetted\ Perimeter(P)}$

S= Channel bed slope

The velocity equation is used to calculate discharge.

The discharge equation can be written as

$$Q = A \times V$$

Here, Q = Discharge (m^3/s)

A= Area of the channel (m^2)

V= Velocity of flow in the channel (m/s)

From the observation of the study area, the cross- section of the existing drainage system is found to be 1 foot by 1-1.5 feet (0.3 m* 0.3 m and 0.3m*0.45m).

Considering Manning's roughness coefficient, n = 0.015, freeboard of 0.01 m and slope, S = 0.038

Putting these values in the Manning's equation,

V= $\frac{1}{0.015} * (\frac{0.09}{0.85})^{\frac{2}{3}} * 0.038^{\frac{1}{2}}$ = 2.91 m/sec

Discharge, Q = V* A = 2.91 * 0.09 = 0.261 m^3/sec

7.3 ANALYSIS

From the above calculation, it has been found that the existing drainage system in the Kharghuli area have discharge carrying of 0.261 m^3/sec.

CHAPTER 8

RESULTS AND DISCUSION

8.1 INTRODUCTION

The study aims to assess the impact of urbanization in the Kharghuli area of Guwahati, Assam. The land use land cover change is a direct impact of urbanization. The percentage increase in built -up area indicate greater impervious surface thus, changing the surface hydrology of the area. The increase in built up area leads to increase in peak runoff for a major storm event. The urban population is increasing exponentially. The removal of green zone will lead to increase in the construction activities and accelerate population growth. This will result in rapid increase of both stormwater and waste water. This increase in discharges will pose significant challenge to the existing drainage system of the area.

8.2 RESULT

8.2.1 STORM WATER AND WASTE WATER OF KHARGHULI

Total discharge of Kharghuli area has been obtained by combining the stormwater discharges with wastewater discharge contribution.

Peak discharge for stormwater of 2-year Return period combined with wastewater generation for population growth rate of 2.5% has been computed.

Table 8.1 Total Discharge Calculation from stormwater and Waste Water

YEAR	PEAK DISCHARGE FROM STORMWATER (m^3/s)	DISCHARGE FROM WASTE WATER(MLD)	DISCHARGE FROM WASTE WATER (m^3/s)	TOTAL DISCHARGE (m^3/s)
2021	4.09	0.391	0.0045	4.0945
2026	4.09	0.443	0.0051	4.0951
2031	4.09	0.502	0.0058	4.0958
2036	4.09	0.569	0.0066	4.0966
2041	4.09	0.645	0.0075	4.0975
2046	4.09	0.731	0.0085	4.0985

From the above calculation, it has been found that the existing drainage system in the Kharghuli area having discharge carrying capacity of 0.261 m^3/sec is inadequate to carry the peak discharge of 4.09 m^3/s generated from 2-year return period storm. The wastewater further loads the existing drainage system. Thus, the drainage system inefficient to safely convey the combined discharge can create serious damage due to waterlogging or flooding.

8.3 DISCUSSION AND REMEDIAL MEASURES

Urbanization speeds up population expansion, which causes drastic changes in wastewater and stormwater discharges. This leads to number of disruptions including flooding, overburden infrastructure and environmental damage. Therefore, when removing the green zones of the proposed area, ensuring effective storm water management and preservation of the balance of ecosystem is important.

To lessen the environmental harm in Kharghuli, a comprehensive approach involving sustainable urban planning, planned infrastructure development, strict environmental laws and regulation. By tackling issues like water pollution, flooding, soil erosion, environmental degradation Kharghuli can be planned for sustainable development.

Some remedial measures to minimize the effects of urbanization has been suggested:

1. Proper Land use zoning policy must be used for sustainable land use planning and development.
2. Promoting afforestation and green spaces like parts can help mitigate the climate change and improve air quality.
3. Creating dense mini-forest in under-utilized urban lands or creating green roof can support biodiversity.
4. Proper management of waste by ensuring collection and safe conveying to a disposal site.
5. Development of wastewater treatment plant to prevent water pollution and ensuring environmental protection,
6. Drainage system must be developed to efficiently carry the discharge generated in urban areas.
7. Encouraging rooftop rainwater harvesting will help minimizing urban runoff and preventing waterlogging.
8. Enforcing strict laws to avoid illegal settlement thus, preventing overcrowding and environmental degradation.

CHAPTER 9

CONCLUSION

9.1 INTRODUCTION

An integrated remote sensing and GIS based study on the impact of urbanization has been carried out in the Kharghuli area, a locality of Guwahati, Assam. Land use Land Cover maps have been been generated using GIS based approach. The impact of urbanization is assessed by analysing the change within a span of 10 year. Due to urbanization the population in the area is expected to grow exponentially resulting in increased runoff and wastewater. Therefore, proper water management in the study area is essential for sustainable urban development.

9.2 CONCLUSION

- The slope value for the study area Kharghuli ranges from 0° to 25°, thus indicate steep slopes. Higher degree of slope results in rapid runoff and increased erosion with less ground water recharge potential.
- By comparing the LULC changes of the years 2014 and 2024 it has been observed that the vegetation cover decreased by 14.14% and built-up cover increased by 14.41%. It is also noted that open spaces covered only 0.26% in the year 2014 which further decreased to 0% in 2024.
- The peak discharge from storm of 2-year return period is 4.09 m^3/sec and peak discharge value from storm of 5-year return period increases and reaches up to 5.02 m^3/sec. Thus, there is an increase of 18.52 % of runoff.
- Population projection considering current annual growth rate (1.97%) is compared with population projection with higher annual growth rate (2.5%). Population growth reaches up to 6770 by the year 2046 for 2.5% growth rate, as compared to 5623 for slower growth rate.
- With the slow population growth rate, the waste generation is low, reaching 0.607 MLD by 2046 as compared to 0.731 MLD for the higher growth rate.
- The study found that the existing drainage system in the Kharghuli area having discharge carrying capacity of 0.261 m^3/sec is inadequate to carry the combined discharge of 4.0985 m^3/s generated from 2-year return period storm ad projected wastewater by 2046.
- The study provides some suggested remedial measures to mitigate the impact of urban growth in the study area.

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