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Mapping And Analysis of Drainage Systems for Flood Mitigation Along Tetlow Road, Owerri Municipal Council, Imo State, Nigeria Using Gis and Remote Sensing Techniques.

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ABSTRACT
Urban flooding has become a recurring environmental and infrastructural challenge in rapidly urbanizing Nigerian cities due to inadequate drainage systems, uncontrolled urban development, and poor stormwater management. This study focused on the mapping and analysis of drainage systems for flood mitigation along Tetlow Road, extending from Christ Church Junction to Old Stadium Junction in Owerri Municipal Council, Imo State, Nigeria. Geographic Information System (GIS) and Remote Sensing (RS) techniques were employed to evaluate drainage conditions, topography, slope, hydrological characteristics, and flood vulnerability within the study corridor. Primary data were obtained through field observations, drainage condition assessment, and GPS-based geospatial surveys, while secondary datasets included Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), satellite imagery, rainfall records, and drainage maps. Spatial analyses carried out in ArcGIS and QGIS included slope analysis, flow direction modelling, Topographic Wetness Index (TWI), drainage mapping, and flood vulnerability assessment. Results revealed that the drainage infrastructure along Tetlow Road is fragmented, partially collapsed, and largely undersized, resulting in approximately 35–50% reduction in hydraulic efficiency due to blockage, siltation, and structural deterioration. Topographical and hydrological analyses identified low-lying sections around Wetheral Road and Old Stadium Junction as major runoff convergence zones vulnerable to flooding. The study further established that urban expansion and increased impervious surfaces have intensified stormwater runoff within the corridor. The research concludes that ineffective drainage design, inadequate maintenance culture, and rapid urbanization are the dominant drivers of flooding within the area. It recommends drainage redesign and expansion, routine desilting operations, integration of green infrastructure, and adoption of GIS-based urban drainage monitoring systems for sustainable flood mitigation in Owerri and similar urban environments.
Keywords: *Urban Flooding, Drainage System, GIS, Remote Sensing, Flood Vulnerability, Tetlow Road, Owerri.*

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I. INTRODUCTION

Urban flooding is among the most devastating environmental hazards confronting rapidly urbanizing cities in developing countries, particularly in sub-Saharan Africa. Nigeria has witnessed increasing occurrences of urban flooding resulting from climate variability, uncontrolled urbanization, inadequate drainage infrastructure, and poor environmental management practices. In many Nigerian cities, stormwater drainage systems are either insufficient, poorly maintained, or entirely absent, resulting in frequent inundation of roads, residential areas, and commercial corridors during periods of intense rainfall.

Owerri, the capital city of Imo State, is one of the urban centers experiencing persistent flood-related challenges. The rapid urban expansion of the city has significantly altered natural drainage pathways through land reclamation, increased impervious surfaces, and indiscriminate development activities. Tetlow Road, extending from Christ Church Junction to Old Stadium Junction within Owerri Municipal Council, represents one of the critical flood-prone corridors within the city. During the rainy season, the corridor experiences severe waterlogging, obstruction of vehicular movement, deterioration of road infrastructure, and disruption of socio-economic activities.

The major causes of flooding along the corridor include poor drainage design, collapsed drainage structures, blockage of drainage channels by refuse materials, and uncontrolled urban development. These problems are compounded by inadequate implementation of urban planning regulations and ineffective drainage maintenance culture. Consequently, there is a need for an integrated geospatial assessment of the drainage network and flood vulnerability patterns within the corridor.

The advancement of Geographic Information Systems (GIS) and Remote Sensing (RS) technologies has significantly improved urban flood analysis and drainage mapping. GIS and RS provide effective tools for spatial analysis, hydrological modelling, terrain assessment, and flood vulnerability mapping. Through the integration of satellite imagery, Digital Elevation Models (DEM), drainage data, and field observations, flood-prone zones can be identified and suitable mitigation measures proposed.

This study therefore applied GIS and RS techniques to map and analyze the drainage systems along Tetlow Road for flood mitigation purposes. The research aimed at identifying drainage deficiencies, evaluating flood vulnerability patterns, and proposing practical mitigation strategies for sustainable urban stormwater management.

1.1 Aim and Objectives of the Study

The aim of this study is to map and analyze drainage systems for flood mitigation along Tetlow Road in Owerri Municipal Council using GIS and Remote Sensing techniques.

The Objectives are to:

1. Map the existing drainage infrastructure along Tetlow Road using GIS techniques.
2. Identify flood-prone zones within the study corridor.
3. Assess the condition and hydraulic efficiency of existing drainage systems.
4. Analyze topographic and hydrological characteristics influencing flood occurrence.
5. Recommend suitable flood mitigation measures for sustainable urban drainage management.

1.2 Study Area

The study area covers Tetlow Road corridor extending from Christ Church Junction to Old Stadium Junction within Owerri Municipal Council, Imo State, Nigeria. The corridor is approximately 3.2 km in length and comprises residential, institutional, commercial, and transportation land uses.

Owerri lies within the humid tropical climatic zone characterized by heavy rainfall between May and October. The area experiences annual rainfall ranging between 2,000 mm and 2,500 mm, resulting in significant stormwater runoff during peak rainfall periods. Elevation within the study corridor ranges approximately between 55 m and 115 m above mean sea level.

The terrain is moderately undulating with distinct low-lying zones that facilitate water accumulation and flood occurrence.

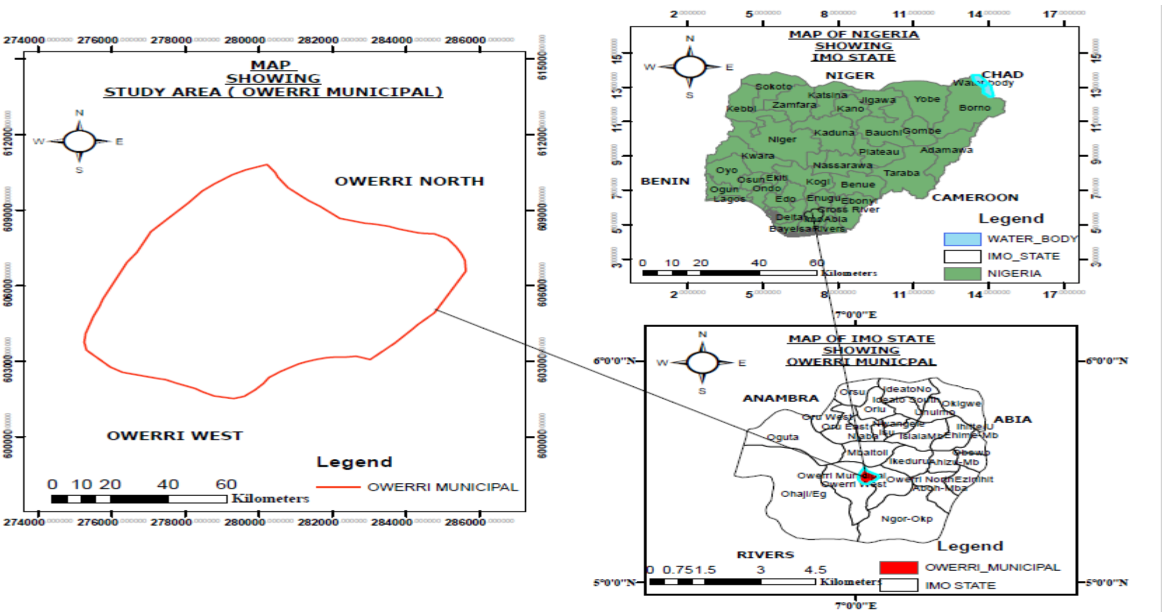

Figure 1: Study Area Map

II. MATERIALS AND METHODS

2.1 Research Design

The study adopted an integrated geospatial research design involving field survey, drainage assessment, GIS spatial analysis, and Remote Sensing techniques. Both primary and secondary datasets were utilized for the investigation.

2.2 Data Sources :Primary Data
- Field drainage condition assessment
- GPS coordinates of drainage structures
- Photographic documentation of drainage failures and flood-prone areas

Secondary Data
- Shuttle Radar Topography Mission (SRTM) DEM
- Satellite imagery
- Existing drainage maps
- Rainfall and climatic records
- Hydrological datasets

2.3 Software and Analytical Tools
The following software packages were utilized:
- ArcGIS 10.x
- QGIS 3.x
- ERDAS Imagine
- Google Earth Pro
- Microsoft Excel

2.4 Data Processing and Analysis
2.4.1 Drainage Mapping
Drainage channels and structures were digitized from field observations and satellite imagery. Existing drainage networks were overlaid with natural flow pathways derived from DEM analysis.

2.4.2 DEM and Slope Analysis
The Digital Elevation Model (DEM) was used to generate elevation and slope maps of the study area. Slope characteristics were classified into flat, gentle, moderate, and steep categories.

2.4.3 Flow Direction and Hydrological Analysis
Hydrological modelling was carried out using flow direction and flow accumulation algorithms within ArcGIS Spatial Analyst environment. These analyses enabled identification of runoff pathways and flood convergence zones.

2.4.4 Topographic Wetness Index (TWI)
Topographic Wetness Index (TWI) was generated to identify areas susceptible to water accumulation and soil saturation.

2.4.5 Flood Vulnerability Mapping
Flood vulnerability analysis was performed using weighted overlay analysis involving:
- Elevation
- Slope
- Drainage density
- Flow accumulation
- Land use characteristics
- Field flood observations

The resulting flood vulnerability zones were classified into:
- Low Vulnerability
- Moderate Vulnerability
- High Vulnerability

III. RESULTS AND DISCUSSION

3.1 Existing Drainage Infrastructure
The drainage infrastructure within Tetlow Road corridor consists primarily of open concrete drainage channels, culverts, and roadside drains. Field observations revealed that many sections of the drainage network are either partially blocked, collapsed, undersized, or completely absent.

The highest drainage deficiencies were observed between School Road Junction and Wetheral Road where drainage channels were either non-existent or structurally damaged. The absence of effective drainage systems within these sections contributes significantly to waterlogging and flash flooding during rainfall events.

Table 1: Condition of Drainage Structures along Tetlow Road

Section of Corridor	Drainage Condition	Estimated Capacity Loss	Major Issues
Christ Church – School Road	Partially Functional	35%	Solid waste blockage
School Road – Wetheral Road	Collapsed/Absent	Severe	No engineered drainage
Wetheral Road – Old Stadium	Functional but undersized	50%	Culvert clogging and erosion

The findings indicate that drainage inefficiency is a major contributing factor to recurring flooding within the study corridor.

3.2 Topographic and Elevation Analysis

The topographic analysis revealed distinct elevation variations within the study area. Elevation ranges approximately between 55 m and 98 m above mean sea level.

Low-lying areas identified around Wetheral Road Junction and Old Stadium Junction function as runoff convergence zones and are highly susceptible to flooding. Conversely, areas around Christ Church Junction are situated on relatively elevated terrain and experience lower flood vulnerability.

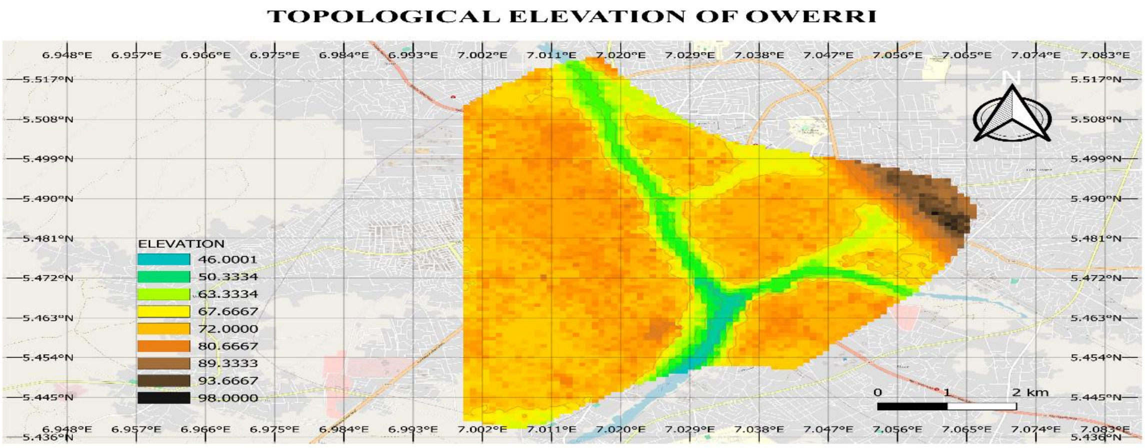

Figure 1: Topographic Elevation Map of Owerri

The Digital Elevation Model (DEM) further revealed a pronounced valley system traversing the corridor, with runoff naturally flowing towards lower depressions.

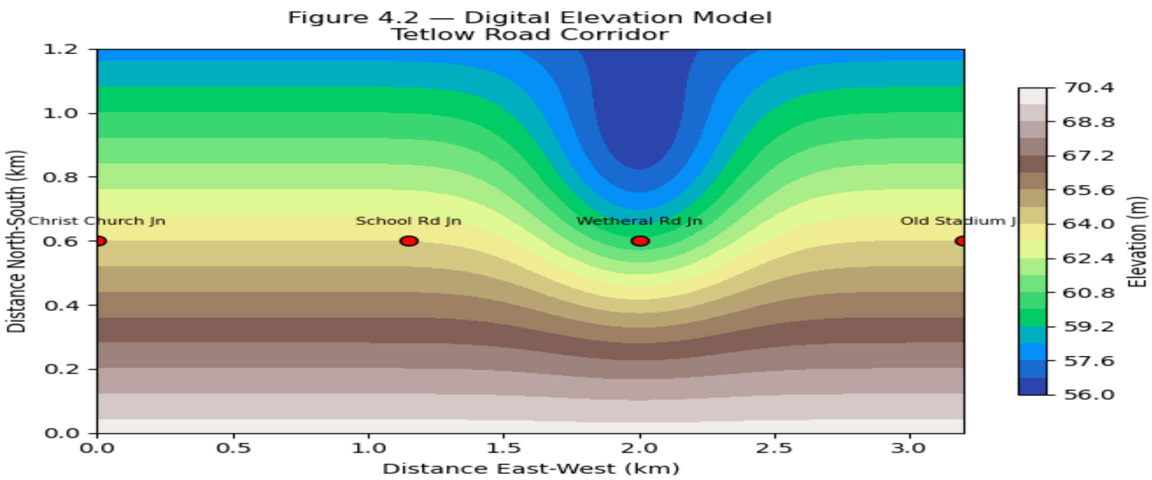

Figure 2: Digital Elevation Model (DEM) of Tetlow Corridor

The DEM analysis established that topography significantly controls runoff movement and flood accumulation patterns within the corridor.

3.3 Slope Analysis

Slope analysis indicated that the Tetlow Road corridor is dominated by moderate slopes ranging between 5° and 15°. Areas with steeper slopes facilitate rapid runoff movement, while flatter low-lying sections encourage water accumulation.

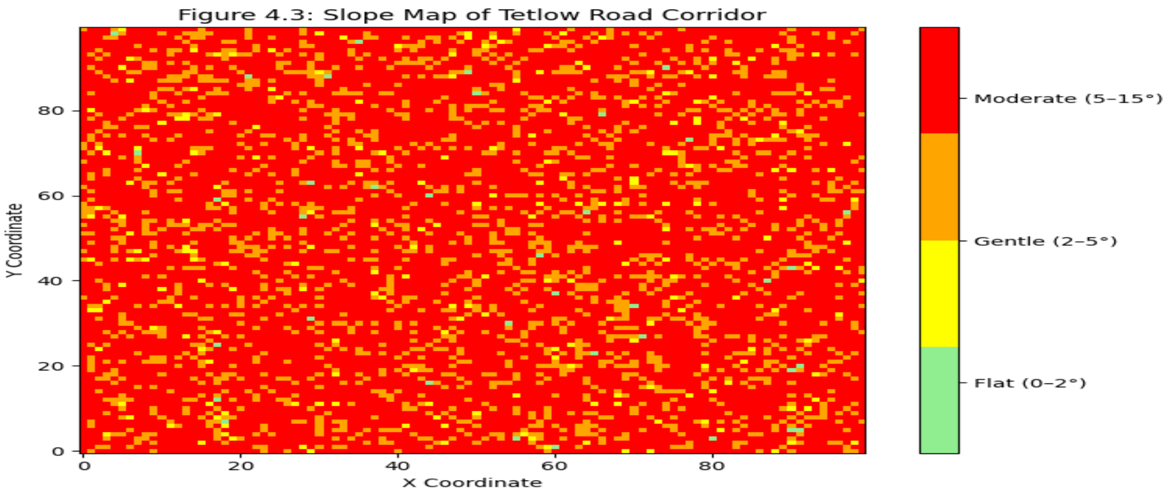

Figure 3: Slope Map of Tetlow Road Corridor

The predominance of moderate slopes suggests that runoff velocities are sufficiently high to transport sediments and debris into drainage channels, thereby contributing to siltation and blockage.

3.4 Flow Direction and Hydrological Characteristics

Flow direction analysis demonstrated that stormwater runoff within the corridor follows natural topographic gradients towards lower valley sections.

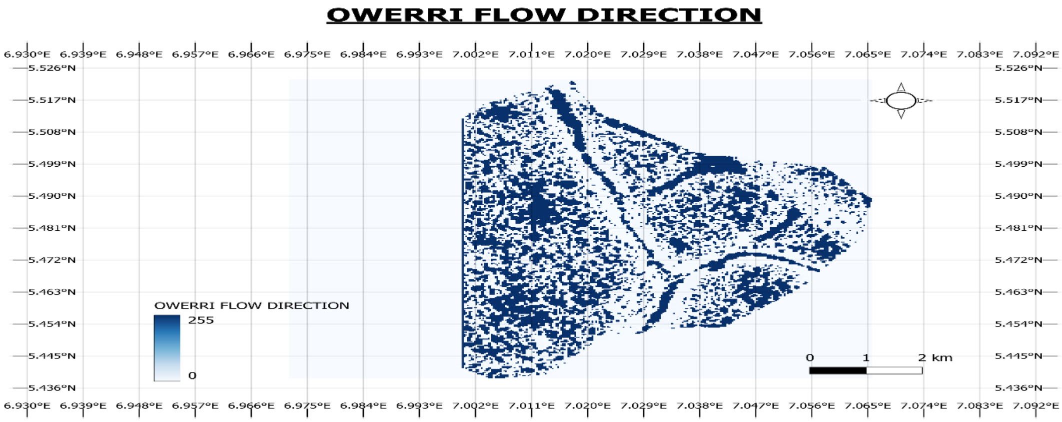

Figure 4: Flow Direction Map of Owerri

The flow accumulation pathways correspond closely with observed flood-prone zones, confirming that flooding within the corridor is strongly influenced by topographic configuration and inadequate drainage conveyance.

3.5 Topographic Wetness Index (TWI)

The Topographic Wetness Index (TWI) analysis identified areas with high moisture accumulation potential.

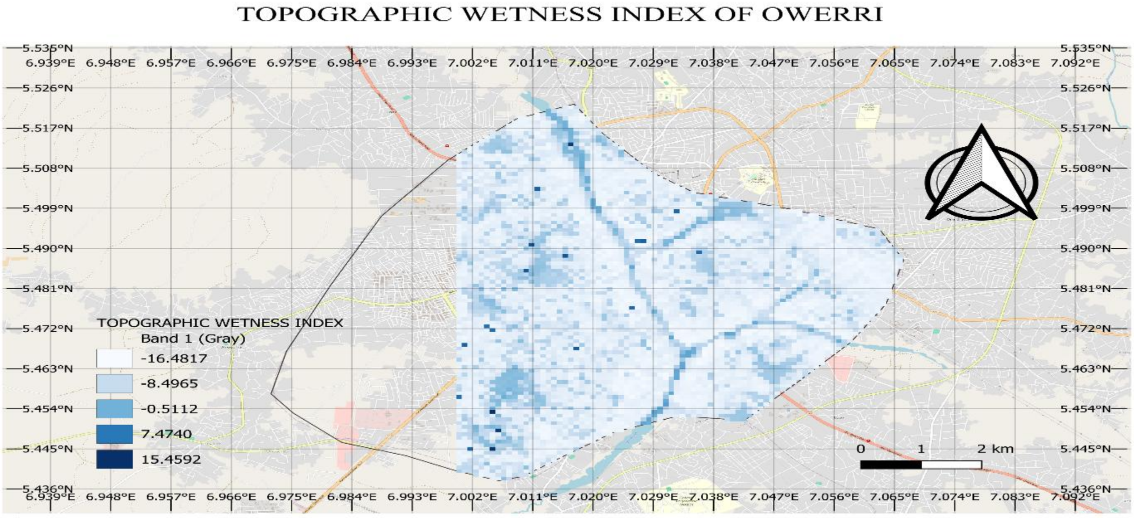

Figure 5: Topographic Wetness Index (TWI) Map of Owerri

High TWI values were concentrated within valley depressions and low-elevation zones, indicating increased flood susceptibility and prolonged surface saturation.

3.6 Flood Vulnerability Assessment

Flood vulnerability mapping classified the study area into safe and flood-prone zones.

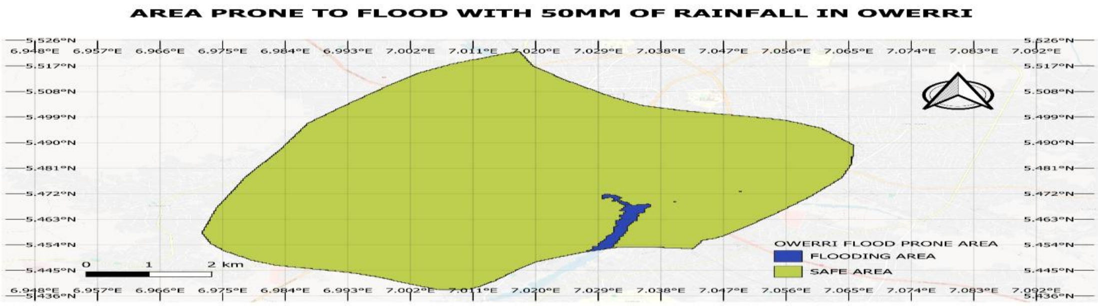

Figure 6: Flood Vulnerability Map of Owerri

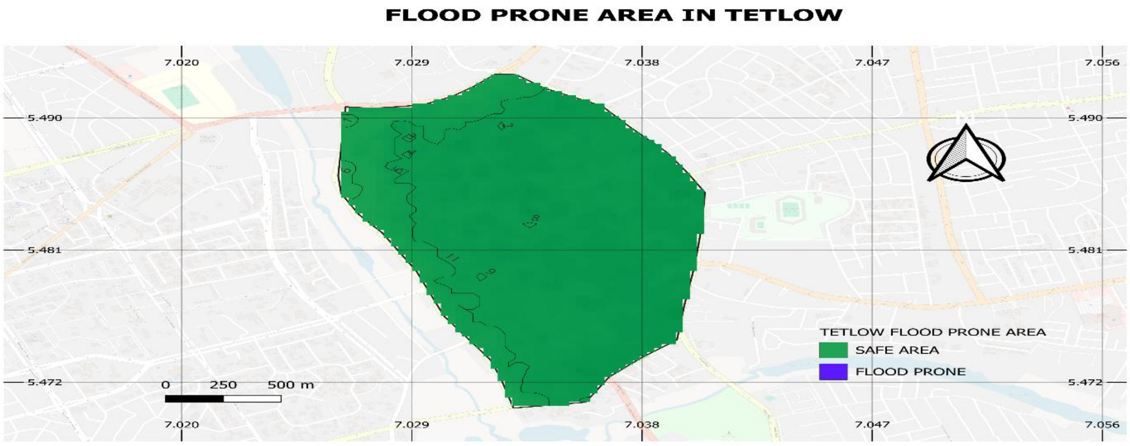

Figure 7: Flood Vulnerability Map of Tetlow Corridor

The analysis revealed that flood-prone areas are concentrated mainly around low-lying drainage convergence zones. The flood vulnerability patterns correspond strongly with drainage deficiencies and poor topographic drainage conditions.

The findings agree with previous studies which established that inadequate drainage systems, urban expansion, and impervious surface development are dominant drivers of urban flooding in Nigerian cities.

IV. CONCLUSION

This study successfully applied Geographic Information System (GIS) and Remote Sensing (RS) techniques to map and analyze drainage systems for flood mitigation along Tetlow Road in Owerri Municipal Council, Imo State, Nigeria.

The research established that drainage infrastructure within the corridor is largely inefficient, fragmented, and poorly maintained. The study further revealed that topography, slope characteristics, and hydrological conditions significantly influence flood occurrence within the study area.

Flood vulnerability analysis identified low-lying sections around Wetheral Road and Old Stadium Junction as highly susceptible to flooding due to inadequate drainage capacity and runoff convergence.

The integration of GIS and Remote Sensing proved highly effective for flood vulnerability assessment, drainage mapping, and urban environmental analysis.

The study concludes that sustainable flood mitigation within Tetlow Road corridor requires integrated drainage redesign, improved urban planning, regular drainage maintenance, and GIS-based stormwater management systems.

V. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

1. Existing drainage channels along Tetlow Road should be expanded and redesigned to accommodate increasing runoff volumes.
2. Routine desilting and maintenance operations should be institutionalized by relevant government agencies.
3. Collapsed and absent drainage sections should be reconstructed using standard hydraulic engineering specifications.
4. Green infrastructure such as vegetative buffers, permeable pavements, and bio-retention systems should be incorporated into urban drainage management.
5. GIS-based drainage monitoring systems should be adopted for continuous flood risk assessment and urban planning.
6. Strict enforcement of environmental sanitation and urban planning regulations should be implemented to prevent blockage and encroachment on drainage channels.
7. Public awareness campaigns should be intensified to discourage indiscriminate dumping of waste into drainage systems.

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