OPTIMIZATION OF MUNICIPAL SOLID WASTE COLLECTION AND DISPOSAL FOR LOKOJA, NIGERIA

By

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CERTIFICATION

Mr. Joseph Siji, a postgraduate Student in the Department of Geography, specializing in Environmental Management, has satisfactorily completed the requirement for course and research work for degree of Master of Science in Geography. The work embodied in this project is original and has not been submitted in part or full for any other diploma or degree of this or any other University.

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TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION

CHAPTER TWO:

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF ACRONYMS

1. MSWM é é é Municipal Solid Waste Management
2. KSSWMB é é Kogi State Sanitation and Waste Management Board
3. GISé é é é é Geographic Information System
4. RS é é é é é .Remote Sensing
5. GPS é é é é ..Global Positioning System
6. GPRS é é é ...General Package Radio System
7. RFID é é é é Radio Frequency identification
8. NA é é é é é Network Analyst
9. MSWé é é é .Municipal Solid Waste
10. MSWMé é é Municipal Solid Waste Management
11. LPé é é é é Littered Points
12. PCSé é é é ..Proposed Collection Point

Acknowledgement

I give glory and honour to the almighty God who has solely ensured the success of this project; I appreciate him not just for the completion of the project but for His mercies that see me through to see this day and beyond. May His holy name always be praised forever. Amen. I would like to employ this opportunity to express my profound gratitude to my amiable supervisor, Professor P. O. Phil-Eze who challenged me to take up this interesting research from the outset; I really appreciate your constructive criticism that has established the empiricism of this research. May the Lordôs favour continue to dwell with your family in Jesusô name. I specially want to appreciate my Uncle, Mr R.T. Obashe who has allowed God to use him to finance this programme, I know that the Lord who has sent you to me at this critical time will continue blessing you. Equally I would like to appreciate my mother, Mrs F.A. Obashe for her parental support, may the Lord continue to be a husband to you. Again, the contribution of every member of staff of Geography Department, University of Nigeria, Nsukka cannot be ignored. While I would not be in a hurry to forget to appreciate a very good friend of mine, Aroloye Benson Friday, who has been of tremendous assistance in providing the ArcGIS software that was used for spatial analysis and Network Analysis in this research, I would like to appreciate Ndichie Cosmas for his initial effort.

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Dedication

This thesis is dedicated to the memory of my late father, Joseph Babalola Obashe

ABSTRACT

Waste accumulation in developing world cities has become common sights in recent times. Management of solid waste has been one of the challenges facing urban areas in the world owing to an aggregation of human settlements and increased consumption thereof that has the potential to produce a large amount of solid waste. The situation is further compounded with failure of some cities in setting up an effective waste collection system. The aim of this study is to develop an effective waste collection and disposal system in Lokoja metropolis, Kogi State, Nigeria through the assessment of the state of MSWM in Lokoja, examination of problems of collection and disposal of MSW, identification of important criteria for locating dumpsters as well as recommending routes for waste evacuation. Two sets of questionnaire were administered, 10 to staff of KSSWMB and 390 to the public in the city. Results of the analysis of questionnaire data, using descriptive statistics, show that across the six zones of the city, the highest percentage of respondents who indicated availability of dumpsters in Lokoja city is 18.0% while the percentage of respondents who indicated absence of dumpsters ranges between 78.7% and 82.0%. Field observation corroborates the analyzed data from the respondents and it was evident that waste management facilities were grossly insufficient in the city. This therefore results in poor urban service delivery which manifests in heaps of uncollected solid waste in most scenic locations of the city. To remedy this situation, we designed and developed an appropriate location of dumpsters and collection plan using Geographical Information System (GIS) software. The ArcGIS 9.3 Network Analyst was used to estimate interrelations between the dynamic factors, like network traffic changes (closed roads due to natural or technical causes, for example, fallen trees, car accidents, etc) in Lokoja and to produce optimized solutions where we determined the best routes and alternative routes for waste evacuation. While it was established that KSSWMB is starved of basic facilities for waste management, it becomes pertinent to procure more basic waste management tools like large capacity roll off dumpsters at the proposed points across the city in order to accommodate the growing volume of waste generated daily. This research recommends uncompromising penalties for defaulters of environmental laws, procurement of waste compactors, and adoption of the optimized network plan for waste evacuation amongst others for optimum performance.

INTRODUCTION

1.1 BACKGROUND TO THE STUDY.

The observed trend of waste accumulation is a continually growing issue of concern not only at local or regional levels but also at the larger global level (Murali, Lakshmana and Nooka, 2014). Management of solid waste is one of the challenges facing urban areas in the world. This is because an aggregation of human settlements has the potential to produce a large amount of solid waste (Oyinloye, 2013). Solid waste therefore refers to the organic and inorganic used-up materials that encompass both a heterogeneous mass of wastes (domestic) as well as a more homogeneous accumulation of agricultural, industrial and mineral wastes (Karsauliya, 2013). Solid waste management on the other hand, refers to ñthe control of generation, storage, collection, transfer and transport, as well as processing and final disposalò of waste in a fashion that is in accordance to societal and economic needs while at the same time compliant to environmental standards and principles (Rhea, 2003). The main problem of urban waste management however, is worth noting not only due to the large quantities of waste produced and the spatial spread, but also the problems encountered in setting up of the systems for collection, transportation and disposal of the wastes (Murali, Lakshmana and Nooka, 2014). In this regard, solid waste management is a serious problem for cities throughout the world. Municipal solid waste management is one among the fundamental and essential services provided by municipal authorities in any country to keep urban centers clean. The collection, transportation, treatment and disposal of solid wastes, particularly wastes generated in medium and large urban centres, have become a relatively difficult problem to solve (Maity, 2014). In the developing world, indiscriminate waste disposal has been one of the causes of environmental deterioration and they affect environmental parameters such as air, land and water quality. Indiscriminate waste disposal leads to the destruction of the aesthetic beauty of the environment, causes flooding and environmental air pollution (Iro, Okorondu, Mbano and Duru, 2012).

Nigerian cities and other cities in the world are experiencing common problems in managing their Municipal Solid Waste (MSW) as Solid Waste (SW) generation is increasing proportionately with the ever growing urban population. Consequently, thousands of lives are lost every year to environment related diseases such as cholera, diarrhea, malaria fever, typhoid fever, river blindness etc as majority of people in the developing countries live in filthy, cockroaches, rats and mosquitoes infected environment (Idowu, Adagunodo, Esimai and Olapade, 2012). In Sub-Sahara Africa (SSA), the state of Solid Waste Management is fast assuming the scale of a major social and environmental challenge as waste generation, both domestic and industrial, continues to increase world-wide in tandem with growth in population (Ezeah, 2010).

Waste management has been adjudged ineffective in many urban and rural areas of Africa as stated in Federal Environmental Protection Agency for the United Nations Conference on Environment and Development (World Health Organization, 1997). This is consistent with the statement made in the National Assessment Report of World Summit on Sustainable Development in which Nigerian cities were declared to be among the dirtiest in the whole world (Okoye, Odumegwu and Omuku, 2012). Over the years, the spatial organization and existing infrastructure of cities in developing countries pose challenges for sustainable solid waste management programs. Much of the problems arise because the urban spatial structure is characterized by high density, unplanned settlements, limited road access, and ever increasing rural-urban migration (Cohen, 2006).

Urban centers are major attractions for the location of private and public facilities which require strategic spatial decision support to enhance practicable maximum service. The science of locating a facility otherwise referred to as a facility location problem, has attracted much attention over the last five decades (Farahani and Hekmatfar, 2009). According to Miller and Shaw (2001) there are three general types of facility location problems:

a) Median problems (minisum): the location of facilities to minimize the total or average travel cost between demand locations and facilities.

b) Center problems (minimax problems): the location of facilities so as to minimize the maximum travel that any customer will travel to a facility and,

c) Requirement problems: the location of facilities according to some pre specified performance Standard.

The median problem is specifically relevant in solving waste bin location problems which is usually to minimize distance between waste generation points and service points. The aforementioned supports location modeling in GIS environment as an efficient way to improve service coverage and efficiency in municipal solid waste management. GIS is one of the most sophisticated modern technologies for capturing, storing, manipulating, analyzing and displaying spatial data through the organization of these data into thematic layers in the form of digital maps (Sutton, Dassau, and Sutton, 2009). Therefore, the combined use of GIS with advanced related technologies (e.g., Global Positioning System) will assist in the recording of spatial data and the direct use of these data for analysis and cartographic representation. Hence, with the paramount factors (minimum walking distance, maximum service coverage, as well as consideration of physical and socio-cultural context of the service area) that determine the location of a waste bin being integrated in GIS, it is believed that more efficient results would be produced by applying GIS to waste management in Lokoja.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Lokoja was once the colonial administrative capital of Nigeria (Adah.2014), it became the headquarters of Kogi Local Government Area as far back as 1976 and was later made Kogi State capital in 1991. Since then, there have been massive changes in all activities of Lokoja including its size, structure, population and other socio-economic development (Olawepo, 2009). These changes have not only reflected rapid growth in MSW generation but constitute a problem to effective management of waste within the city.

Prior to Lokoja becoming the state capital in 1991, it had population that was below 40,000 and by 1991 it increased to 61,784 (Kogi State Ministry of Budget and Planning). However at present, according to the 2006 census declaration, over 196,643 persons now inhabit the city (National Population Commission, 2006) in (Alabi, 2011). The underscoring factors of this population explosion include amongst other factors; the cityʼs geographical location that portrays it as a nodal town thereby making it witness massive influx of both resident and transit migrants; the cityʼs proximity to the Federal Capital Territory (FTC) as well as the city being a connection point between the southern and northern parts of the country. The implication of this therefore manifests in daily accumulation of solid wastes which are already common sights within the city; its associated health and environmental hazards as well as its aesthetic depletion.

In Lokoja, and all of Kogi State, solid waste management is solely undertaken by Kogi State Sanitation and Waste Management Board (KSSWMB) which apparently seems helpless to organize adequate and prompt collection and safe disposal of waste within the city in the face of steady overwhelming population growth (Uzondu, 2012).

The complexity of growth in Lokoja in relation to its inhibiting factors has equally complicated the problem of prompt evacuation of solid waste within the city. Meanwhile, waste collection and transportation, a vital aspect of waste management is the contact point between the waste generators (residential, commercial and industrial establishments) and the waste management system. This relationship needs to be carefully managed to ensure an effective system as the environmental impact caused by municipal solid waste demands special social and environmental attention (Siddam, Khadikar and Chitade, 2012). However, how this contact point can be efficiently managed in Lokoja has not been studied. Equally, in reality, there, are no provisions for standard waste collection (dumpsters) facilities in the city except the only recently improvised drums. The drums get filled up in no time owing to their limited sizes and spread to litter the immediate environment thereby further worsening environmental condition.

With the absence of these standard dumpsters, the residents of the city resort to dumping of waste on open plots, abandoned buildings, river banks, drainage channels, road divides, etc. These wastes often eventually dissipate into water body especially river Niger and pose series of health risks to the people who use the river for domestic purposes around Sintaku, Kpatakpoli, Icheu

This practice of indiscriminate dumping of MSW has the potential of giving rise to water and air pollution, green house gas emission and may give rise to other gases that cause serious problems to the human health and environment (Remigios and Wiseman, 2012). The upsurge in MSW recently has tasked the environmentalists to conceive various management practices that one could engage in while managing waste. Several management in the past and present include open dumping, burning, scavenging, separation, recovery, storage, evacuation and recycling. Pivotal to the aforementioned management practices is collection and transportation of MSW to places where these respective management practices could be enhanced. This prompt transport or movement of MSW however, could only be ascertained if MSW bins are strategically located where they could swiftly and promptly be evacuated. Several related works like Aremu (2012), employed GIS for finding the optimum location of municipal solid waste bins in parts of Ilorin. He was able to establish some optimum points of waste bin location but his work was silent on how to access the location of bins for waste evacuation to the approved sites. Equally, the work of Anifowose, Omole and Akingbade (2011) was on waste disposal site selection using Remote Sensing and GIS for Akure and environs. They identified potentially suitable sites for landfill after buffering the environment. However, little or nothing was said by them on the efficient routes for transporting waste from Akure environs to the identified landfills. Ogwuche (2013), in almost a related way to Anifowose, Omole and Akingbade (2011), employed GIS in determining spatial location of dumpsite and scheduling in Bauchi, Nigeria. He identified disposal method in place, data on solid waste generation, and schedules for households and the dumpsites in the area. However, his work fails to identify how to evacuate waste from the identified indiscriminate dumpsites to areas designated for waste disposal using optimized routes. In addition, Thompson, Afolayan and Ibidunoye (2013) developed a system that enhances waste management in planning and combating the menace of improper solid waste disposal by allocating and relocating of bins. In a like manner, their work does not incorporate effective collection means of waste from located and relocated bins. Babalola and Busu (2011) apply GIS for selecting landfill site in Damaturu by combining Analytic Network Process used in determining relative importance of weights of factors like land suitability. Transporting waste to the identified appropriate landfill was not discussed.

From these related works, GIS was used to identify suitable sites of dumpsters, landfills but fails to integrate transport system, a vital aspect of waste management into the works. It is therefore apparent that appropriate locations of dumpsters as well as best route ways for transporting evacuated waste have not been fully studied in Lokoja, Nigeria. It is this gap in knowledge that motivates this research work.

1.3 AIM AND OBJECTIVES

The aim of this study is to develop an effective waste collection and disposal system in Lokoja metropolis, Kogi State, Nigeria.

In a bid to achieving this aim, the following objectives would be painstakingly pursued. They are as follows, to;

1. Assess the state of Municipal Solid Waste Management in Lokoja Metropolis.
2. Examine problems of collection and disposal of Municipal Solid Waste in Lokoja Metropolis.
3. Identify important criteria for locating waste collection sites in a cost effective manner.
4. Identify optimal routes for MSW collection and disposal points in Lokoja.

1.4. THE STUDY AREA

1.4.1. GEOGRAPHICAL LOCATION

Lokoja is located within latitudes 7° 45' N and 7° 51' N and longitudes 6°41'E and 6°45'E. It is the administrative headquarters (Capital) of Kogi State situated at the confluence of the Niger and Benue rivers within the lower Niger trough with an estimated area of 63.82 sq km(Figures 1 and 2). It serves as the gateway to the north and the south of Nigeria. The status of Lokoja as an administrative headquarters of Kogi State brought some institutions like the Federal University Lokoja, Kogi State Polytechnic, the Federal Medical Centre, Kogi State specialist hospital and a host of other institutions in the city.

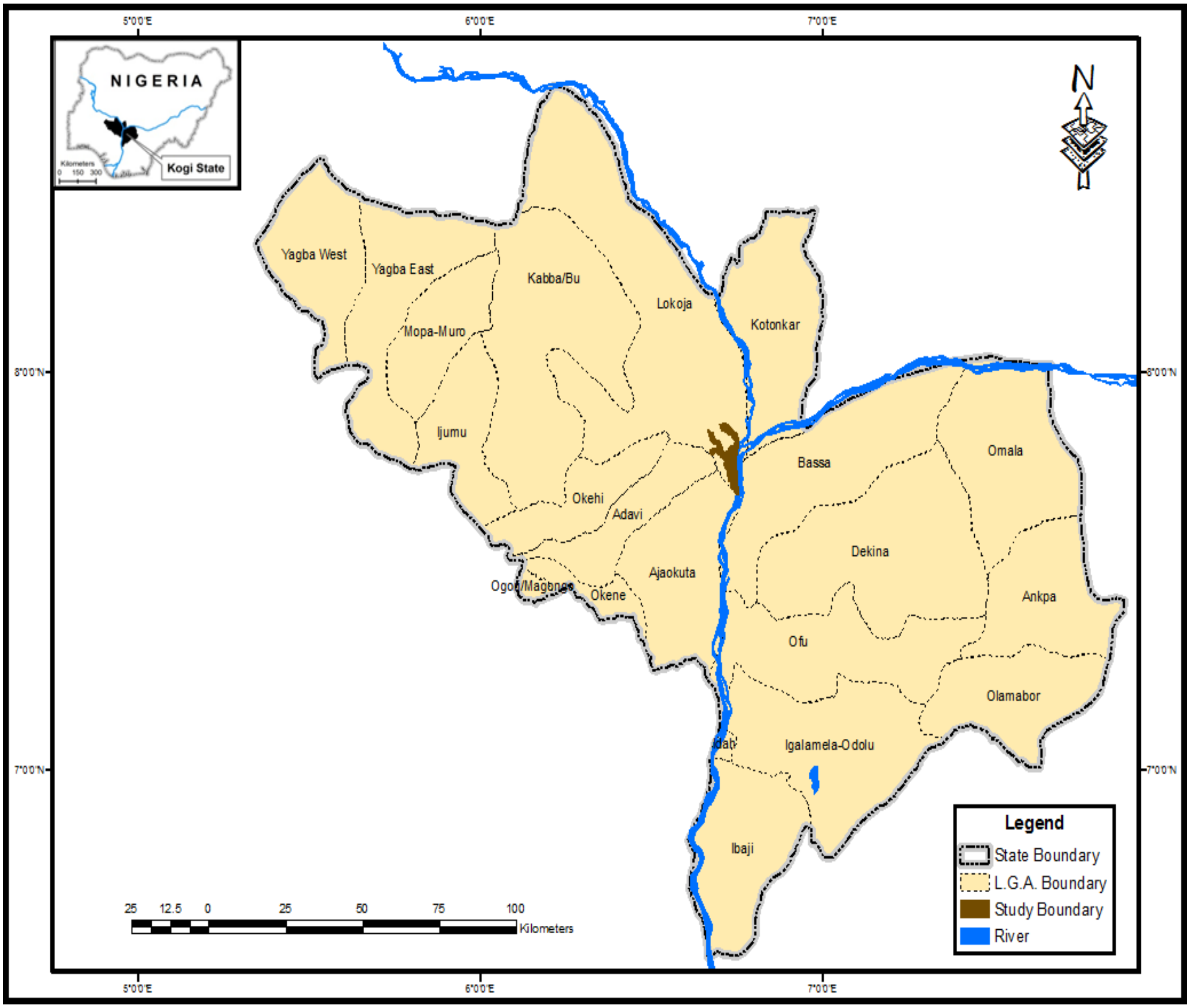

Fig 1: Kogi State showing the study area

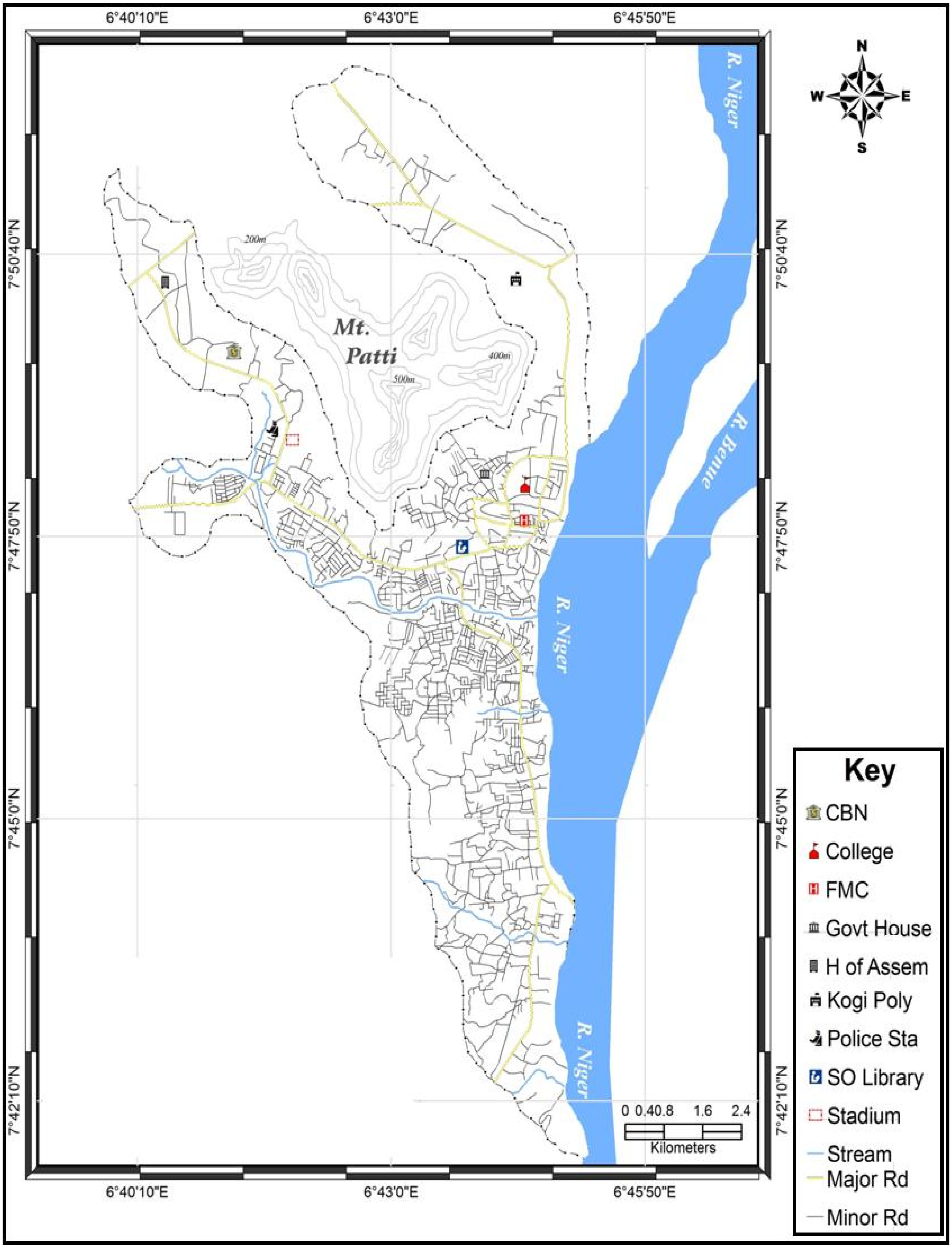

Fig 2: Lokoja Metropolis

1.4.2 GEOLOGY

Lokoja is dominantly underlain by the Precambrian Basement Complex. However, part of the area is underlain by Cretaceous sediments which unconformably overlie the Basement Complex. Migmatite covers about half of the area outcropping at the southwest, west, northwest and central parts of the area. The South and the southeast parts of the area are underlain by undifferentiated older granite, mainly porphyroblastic granite, granite gneiss with porphyroblastic gneiss and fine grained biotite granite. The northern part of the area is made of ridges (Mount Patti) of Cretaceous sediments of the Southern Bida Basin (Lokoja Sub- Basin).

The ridges are dominantly composed of feldspathic sandstone and siltstone which are separated by the biotite hornblende gneiss. Thick alluvial deposit occurs around the Rivers Niger and Benue drainage system (Omali, 2014). Lokoja, falls within both the crystalline and sedimentary hydrogeological provinces of Nigeria and occupies part of the middle Niger Basin whose genesis seems closely connected with the crustal movements of the santonian orogeny of southern Nigeria and which later became filled with past orogenic sediments only to be altered by tertiary uplifts (Kogbe, 1976). Among the major formations identifiable in the area are:

(i) the Precambrian basement complex

(ii) the sedimentary formation of cretaceous period and

(iii) quaternary deposits of alluvium and sandbars

Within the basement complex are such igneous and metamorphic rocks as granites, gneisses, schists, and magmatites. Directly overlying the basement complex are sedimentary formations composed of rounded to sub-rounded coarse conglomerates, clay-sand-pebble admixtures and cross stratified sandstone (Hazel, 1956).

The granite is coarsely porphyritic, with biotite and hornblende being the main ferromagnesian mineral. The gneisses are characterized by fairly regular banding in which predominantly light bands alternate with predominantly dark bands. Individual bands vary in thickness from a few millimeters to several centimeters. The schists include mica-schists, quartz-schists, and quartz-muscovite schist, in which quartz is usually dominant over muscovite. The quartz-muscovite schists are comparatively well exposed and form rounded hills or ridges due to resistant intercalated quartzite bands. The rocks are broadly oriented in the north-south direction and marked by a sub-parallel alignment of elongated and closely packed feldspar phenocrysts, mainly microcline and a corresponding preferred orientation of biotite mica and iron minerals (Ayuba, Omonona and Onwuka, 2013).

1.4.3 RELIEF AND DRAINAGE

The relief of Lokoja consists of unique physiographic regions mainly made up of a number of intermittent valleys sandwiched to the west and east by the Patti ridge and river Niger respectively. The city lies on the western bank of the River Niger at an altitude of 45 - 450m above sea level. The northern part of the town is dominated by a high plateau, the Patti Ridge, which reaches an altitude of 450m above mean sea level (Alabi and Enete 2012). The presence of the Patti ridge and river Niger had streamlined the settlement to a linear pattern and equally have modifying effect on the local climate as river Niger and Patti ridge absorb and release heat alternately during the day and night (Alabi, 2009). Lokoja is drained by river Niger and other two small rivers; River Meme and Ero and thus exhibit dendritic pattern of drainage. At their upper courses, the tributary valleys are incised and the streams in Lokoja dry up during the dry season. Even the perennial streams, have no continuous flow during the dry season but divide up into ponds of varying length.

1.4.4 CLIMATE

The climate of Lokoja is characterized by wet and dry Aw type of climate as classified by Koppen. It has annual rainfall of 1016 mm and 1524 mm ninety percent of which falls between April and October with mean annual temperature of 27.7°C (Ifatimehin, Musa and Adeyemi, 2009). The dry harmattan winds are felt mostly between December and February owing to the influence of North East Trade Wind (Ct) while the Tropical Maritime Air (Mt) brings rainfall over the city during the rainy season. The dry season is between November and March but may be punctuated by sporadic showers during this season. Nevertheless, the area is subjected to cool dry North Easterly (NE) wind originating from the Sahara desert. From April the season changes bringing moist south-westerly wind which originates from the Atlantic Ocean and is characterized by high relative humidity. Windspeed ranges between 3.0 and 4.6 Knots in the months of June/July and 1.5 to 3.7 Knots for December/January. The prevailing direction of wind for the months of June/July and December/January are South to South Westerly and North Easterly respectively.

1.4.5. VEGETATION

The vegetation type around Lokoja can be broadly classified as savanna woodland with a subdominant grass component. It is a form of Guinea Savanna vegetation, which is a mixture of two types based on the proportion of woody species.

(1) Savanna woodland where trees and shrubs form a fairly close canopy

(2) Tree savanna where the trees and shrubs are scattered. Typical tree species include: *Lophira lanceolata, Terminalia glaucescens, Daniela oliveri* (most abundant), *Hymenocardia acida, Vitex doniana, Detarium microcarpum, Afzelia africana, Acacia senegalensis*, and *Parkia*

biglobosa. Common weeds include *Andropogon, Hyparrhenia and Pennisetum*. Whenever the canopy is open, grass is dominant. *Isoberlina doka* tend to grow in almost pure communities while *Monotes kerstingii* forms pure open stands of rather small scrubby trees on sandy eroded slopes of sparse grass cover. *Uapaca togoensis* is locally dominant on low hills or slopes while rocky hills have their own characteristic vegetation usually with abundant sprawling shrubs such as *Acacia ataxacantha* and *Canthium venosum*. In general, the average tree height in the area ranges between 6-8m while the grasses are tall with an average height of 0.8-1.5m.

Riparian Forest occurs immediately adjacent to water courses; tree and shrub species are generally the same as those in the adjacent location, Common riparian species identified include the following*: Pterocarpus santalinoides, Brachystegia eurycoma, Berlinia grandiflora, Terminalia glaucescens* and *Cola laurifolia*.

1.4.6 BRIEF HISTORY OF LOKOJA'S EVOLUTION AS A CITY

Lokoja, the capital city of Kogi State, was founded according to European historical records by William Balfour Baikie. Lokoja occupies a unique place in the history of Nigeria. With the discovery of the Niger in 1830 by the Lander Brothers, the river became the principal route into the interior of the area that later became known as Nigeria. Owing to its strategic location, the city became a favourite spot for Europian explorers, merchants, missionaries and administrators. The interest shown on the town by various classes of person culminated in the establishment of a model farm (by Dr. Baikie) in 1845, a consulate in 1865 and its becoming the headquarters of the Northern Protectorate in 1900. The highly strategic location of Lokoja at the confluence of the Niger and the Benue, its position almost in the centre of the country and the early interest shown on it by the agents of colonial power projected Lokoja for rapid growth and development. Lokoja has for long been an administrative centre as it was the capital of the

British colonial government after amalgamation of Northern and Southern Nigeria Protectorates (Official Gazette Kogi State Ministry of Information, 2011).

1.4.7 POPULATION AND ECONOMIC ACTIVITIES

The creation of Kogi state on 27th August, 1991 with Lokoja as the capital no doubt brought an influx of population to the capital city and according to 1991 census, Lokoja had the population of about 77,516 people, which increased to 196,643 in 2006 (Nigeria Official Gazette, 2009). The increase in human population brought rapid development, which modified land use pattern in the area. Today Lokoja is a trade centre for fishing and agricultural products following its location at the confluence of the Niger and Benue rivers. In addition, transport services, banking, tourism, light manufacturing and leisure services thrive well within the city.

1.5 THEORETICAL FRAMEWORK AND LITERATURE REVIEW

1.5.1 GRAPH THEORY

Network analysis in GIS rests firmly on the theoretical foundation of the mathematical subdisciplines of graph theory and topology. Any graph or network consists of a set of vertices and the edges that connect them. Within graph theory, there are methods for describing, measuring, and comparing graphs, and techniques for proving the properties of individual graphs or classes of graphs. Some elements of graph theory are not concerned with the cartographic characteristics (e.g., shape or length) of the features that comprise a network but, rather, with the topological attributes of those features. Therefore, graph theory is a framework upon which our research on optimization of solid waste collection and disposal for Lokoja metropolis using ArcGIS Network Analyst hinges. An important interest of this research lies in its quest to investigate spatial network with the employment of graph theory. Concepts from the mathematical areas of topology and graph theory are valuable for revealing and analyzing the spatial network of geographical entities and their spatial arrangement. In fact, these mathematical frameworks have been used so far in different applications of a wide range of fields for this purpose (Almeida, Morley and Dowman, 2007).

Graph theory is a branch of mathematics concerned about how networks can be encoded and their properties measured (Rodrigue and Ducruet, 2013). From the point of view of geography, graph-theory measures are a powerful tool not only to illustrate transport networks structural problems, but also to describe and analyze network structure and accessibility, and to evaluate and compare the evolution of networks through time. The origins of graph theory can be traced to Leonhard Euler who devised in 1735 a problem that came to be known as the "Seven Bridges of Konigsberg". In this problem, someone had to cross once all the bridges only once and in a continuous sequence, a problem the Euler proved to have no solution by representing it as a set of nodes and links. This led to the foundation of graph theory and its subsequent improvements that gave rise to Dijkstra Algorithm of traversal algorithm by Dutch Scientists in 1959. Dijkstra algorithm is a graph traversal algorithm for the shortest path problem for weighted graphs and solves that problem that does not have the edge with a negative weight and by creating the shortest path tree and shortest path from the start point to all vertices gives a graph calculation (Ayazi, Mashhorroudi and Ghorbani (2014). The use of graph theory allows understanding of how objects covering the surface interact and the implications they have on spatial organization. It has been enriched in the last decades by growing influences from studies of social and complex networks. A graph as a symbolic representation of a network and its connectivity implies an abstraction of the reality so it can be simplified as a set of linked nodes. In transport geography most networks have an obvious spatial foundation, namely road, transit and rail networks, which tend to be defined more by their links than by their nodes. Consequently, all transport networks can be represented by graph theory in one way or the other. The following elements are fundamental at understanding graph theory:

Graph. A graph *G* is a set of vertex (nodes) *v* connected by edges (links) *e*. Thus $G=(v\ ,\ e)$.

Vertex (Node). A node *v* is a terminal point or an intersection point of a graph. It is the abstraction of a location such as a city, an administrative division, a road intersection or a transport terminal (stations, terminuses, harbors and airports).

Edge (Link). An edge *e* is a link between two nodes. The link (*i*, *j*) is of initial extremity *i* and of terminal extremity *j*. A link is the abstraction of a transport infrastructure supporting movements between nodes. It has a direction that is commonly represented as an arrow. When an arrow is not used, it is assumed the link is bi-directional.

Sub-Graph. A sub-graph is a subset of a graph *G* where *p* is the number of sub-graphs. For instance ***G' = (v', e')*** can be a distinct sub-graph of ***G***. Unless the global transport system is considered in its whole, every transport network is in theory a sub-graph of another. For instance, the road transportation network of a city is a sub-graph of a regional transportation network, which is itself a sub-graph of a national transportation network.

Buckle (Loop or self edge). A link that makes a node correspond to itself is a buckle.

Planar Graph. A graph where all the intersections of two edges are a vertex. Since this graph is located within a plane, its topology is two-dimensional. This is typically the case for power grids, road and railway networks, although great care must be inferred to the definition of nodes (terminals, warehouses, cities).

Non-planar Graph. A graph where there are no vertices at the intersection of at least two edges. This implies a third dimension in the topology of the graph since there is the possibility of having a movement "passing over" another movement such as for air and maritime transport. A non-planar graph has potentially much more links than a planar graph.

Simple graph. A graph that includes only one type of link between its nodes. A road or rail network are simple graphs.

Multigraph. A graph that includes several types of links between its nodes. Some nodes can be connected to one link type while others can be connected to more than one that are running in parallel. A graph depicting a road and a rail network with different links between nodes serviced by either or both modes is a multigraph.

A transportation network enables flows of people, freight or information, which are occurring along its links. Graph theory must thus offer the possibility of representing movements as linkages, which can be considered over several aspects:

Connection. A set of two nodes as every node is linked to the other. Considers if a movement between two nodes is possible, whatever its direction. Knowing connections makes it possible to find if it is possible to reach a node from another node within a graph.

Path. A sequence of links that are traveled in the same direction. For a path to exist between two nodes, it must be possible to travel an uninterrupted sequence of links. Finding all the possible paths in a graph is a fundamental attribute in measuring accessibility and traffic flows.

Chain. A sequence of links having a connection in common with the other. Direction does not matter.

Length of a Link, Connection or Path. Refers to the label associated with a link, a connection or a path. This label can be distance, the amount of traffic, the capacity or any attribute of that link. The length of a path is the number of links (or connections) in this path.

Cycle. Refers to a chain where the initial and terminal node is the same and that does not use the same link more than once is a cycle.

Circuit. A path where the initial and terminal node corresponds. It is a cycle where all the links are traveled in the same direction. Circuits are very important in transportation because several distribution systems are using circuits to cover as much territory as possible in one direction (delivery route).

Clique. A clique is a maximal complete subgraph where all vertices are connected.

Cluster. Also called community, it refers to a group of nodes having denser relations with each other than with the rest of the network. A wide range of methods are used to reveal clusters in a network, notably they are based on modularity measures (intra- versus inter-cluster variance).

Ego network. For a given node, the ego network corresponds to a sub-graph where only its adjacent neighbors and their mutual links are included.

Nodal region. A nodal region refers to a subgroup (tree) of nodes polarized by an independent node (which largest flow link connects a smaller node) and a number of subordinate nodes (which largest flow link connects a larger node). Single or multiple linkage analysis methods are used to reveal such regions by removing secondary links between nodes while keeping only the heaviest links.

Dual graph. A method in space syntax that considers edges as nodes and nodes as edges. In urban street networks, large avenues made of several segments become single nodes while intersections with other avenues or streets become links (edges). This method is particularly useful to reveal hierarchical structures in a planar network.

The organization of nodes and links in a graph conveys a structure that can be described and labeled. The basic structural properties of a graph are:

Symmetry and Asymmetry. A graph is symmetrical if each pair of nodes linked in one direction is also linked in the other. By convention, a line without an arrow represents a link where it is possible to move in both directions. However, both directions have to be defined in the graph. Most transport systems are symmetrical but asymmetry can often occur as it is the case for maritime (pendulum) and air services. Asymmetry is rare on road transportation networks, unless one-way streets are considered.

Assortativity and disassortativity. Assortative networks are those characterized by relations among similar nodes, while disassortative networks are found when structurally different nodes are often connected. Transport (or technological) networks are often disassortative when they are non-planar, due to the higher probability for the network to be centralized into a few large hubs.

Completeness. A graph is complete if two nodes are linked in at least one direction. A complete graph has no sub-graph and all its nodes are interconnected.

Connectivity. A complete graph is described as connected if for all its distinct pairs of nodes there is a linking chain. Direction does not have importance for a graph to be connected, but may be a factor for the *level* of connectivity. If $p > 1$ the graph is not connected because it has more than one sub-graph (or component). There are various levels of connectivity, depending on the degree at which each pair of nodes is connected.

Complementarity. Two sub graphs are complementary if their union results in a complete graph. Multimodal transportation networks are complementary as each sub-graph (modal network) benefits from the connectivity of other sub-graphs.

Root. A node *r* where every other node is the extremity of a path coming from *r* is a root. Direction has an importance. A root is generally the starting point of a distribution system, such as a factory or a warehouse.

Trees. A connected graph without a cycle is a tree. A tree has the same number of links than nodes plus one. ($e = v\text{-}1$). If a link is removed, the graph ceases to be connected. If a new link between two nodes is provided, a cycle is created. A branch of root *r* is a tree where no links are connecting any node more than once. River basins are typical examples of tree-like networks based on multiple sources connecting towards a single estuary. This structure strongly influences river transport systems.

Articulation Node. In a connected graph, a node is an articulation node if the sub-graph obtained by removing this node is no longer connected. It therefore contains more than one sub-graph ($p > 1$). An articulation node is generally a port or an airport, or an important hub of a transportation network, which serves as a bottleneck. It is also called a bridge node.

Isthmus. In a connected graph, an isthmus is a link that is creating, when removed, two sub-graphs having at least one connection. Most central links in a complex network are often isthmuses, which removal by reiteration helps revealing dense communities (clusters).

Shortest Path Algorithms:

A) Djikstras' Algorithm:

1) Finds single-source shortest path in weighted graph

2) It replaces the Breadth First Search (BFS) queue with a Priority Queue. Vertices are added to the Priority Queue by their distance away from the source.

3) If negative weight is used, Dijkstraôs algorithm might fail.

4) The runtime of Djikstras' depends on how the Priority Queue is implemented.

5) Dijkstra's algorithm does not work with negative weight arcs.

B) Floyd-Warshall's Algorithm:

1) Finds all-pair shortest path in weighted graph

2) Uses Adjacency matrix.

3) The Floyd-Warshall algorithm compares all possible paths through the graph between each pair of vertices.

4) Negative weights are allowed but Negative cycle is not allowed.

5) The time complexity of this algorithm is O(V^3) and it is slower.

C) Bellman-Ford Algorithm:

1) Finds single-source shortest path in weighted graph and detects negative cycles.

2) Its basic structure is very similar to Dijkstra's algorithm, but instead of greedily selecting the minimum-weight node not yet processed to relax, it simply relaxes all the edges, and does this $|V|$ ī 1 times, where $|V|$ is the number of vertices in the graph. The repetitions allow minimum distances to accurately propagate throughout the graph, since, in the absence of negative cycles; the shortest path can only visit each node at most once.

3) Bellman-Ford cannot find the shortest path that does not repeat any vertex in such a graph.

4) The runtime: Bellmanï Ford runs in O($V*E$) time.

The use of graph theory is becoming an increasingly important tool upon which network analysis and understanding of complex urban scenes lie. Starting from initially unstructured geospatial data sets of urban areas entities, this research shows how a graph-theoretic approach can be applied in these circumstances towards the analysis of urban scene spatial topology (networks) for the purpose of identifying shortest path within a given network system.

1.5.2. LITERATURE REVIEW

Debate on how best to manage Municipal Solid Waste in the world (MSW) is still ongoing within the research community as contemporary perception of solid waste evacuation is converging. As such, the issue of solid waste management in Nigeria is not new as it has formed a subject for consideration and thought since the past few decades. The awareness of existence and perhaps, the danger of irregular waste evacuation have been brought into discourse by the general review of effects and impacts of MSW on our environment. More importantly, effective ways of managing this unavoidable phenomenon called ñwasteò perhaps through prompt evacuation with the aid of various techniques have been brought to the fore by various scholars. This review therefore, reflects the special study on various aspects of waste management carried out in different parts of the globe by Arebey, Hannan, Basri, Begum and Abdullah, (2010), Solano, (1999), Apaydin and Gonullu, (2007), Illeparuma (2010), Mwakalinga and Kyessi (2009), Salami, Susu, Patinvoh and Olafadefan (2011), Idowu, Adagunodo, Esimai and Olapade (2012), Chalkais and Lasaridi, (2010), Ezeah (2010), Markovic, Janosevic, Jovanovic and Nikolic (2010), Aboyade (2011), Wahab, (2012) among other scholars.

Despite these recurrent studies, it could easily be said that management of Municipal Solid Waste remains a global challenge especially the persistent problem of irregular waste evacuation that has attracted the interest of societies, ministries, government functionaries and stakeholders generally. Eze and Asadu (2003) in Nwachukwu (2010) observe that one of the most pervasive problems of contemporary cities in all regions of the world, especially the developing countries is solid waste management problem accentuated by the process of urbanization and urban development. In developing a new approach for efficient solid waste management in Nigeria, they observe that there is need for proper sensitization of all stakeholders. This will enable them to agree, adopt and implement realistic action plans. They, call for reorientation of Nigerians towards achieving attitudinal changes through sound education and technological developments in the area of environmental management.

Interestingly, Salami, Susu, Patinvoh and Olafadefan (2011) believe a man or woman ceases to generate waste only when he or she is in a state to be disposed of as a waste. The implication of this is enormous as ever increasing world population would always increase per capita waste generation and thus further mount pressure on our fragile environmental asset. According to them, Solid Waste encompasses the heterogeneous mass of throwaways of residence and commercial activities as well as the more homogeneous accumulation of single industrial activities and equally generated by almost every activity. This underscores Oyelola, Babatunde and Abiodun (2011) assertion that solid waste generation spans all stages of human activities.

While recognizing the rate of waste generation, Idowu, Adagunodo, Esimai and Olopade (2012) view wastes to be a continually growing problem at global and local levels and require the attention of stakeholders. On this platform, Singh, Chauhan and Katiyar (2012) observe that increase in growth rate in all fields or spheres of manȏs endeavour have led to a steady rise in waste accumulation. According to them, high population, rapid economic growth and rise in community standard have been pointed out as keys to high rate of Municipal Solid Waste generation in the world cities. This equally reinforces OöNeill (1998) view that the amount of waste being generated continue to increase worldwide without a concomitant rise in disposal facility. In other words, since the population of Lokoja has been growing, it follows that MSW generation grows as well and poses serious challenge of collection and disposal by the management authority.

Chronologically, Yahaya, Ilori, Whanda and Edicha (2010) believe that waste generation was not an issue in the pre-industrial time as population was smaller, thereby generating little wastes which were mainly organic wastes. These wastes were always buried in the ground for composting and inturn improve soil fertility while aiming to sustain food production for the population then. However, following the industrial revolution in the 18^{th} century, rapid population growth, rise in living standards, environmental problems became noticeable. The twentieth century and particularly the period post World War II saw a dramatic increase in the production of urban solid waste, reflecting unprecedented global levels of economic activities (Leao, Bishop and Evans, 2001). In this light, Rahman and Rahman (2011) believe urban solid waste problem has grown in leaps and bounds and became so complex in Bangldesh owing to its increasing population occasioned by industrial growth. This corroborates Singh, Chauhan and Katiyar (2012) observation that increase in growth rate in population, industrialization, economy, and rise in community living standard have propelled solid waste accumulation in India. Additionally, several authorities have attributed these similar and other associated factors to accumulation of waste elsewhere in the globe. In rural or urban areas in Nigeria, the volume of solid waste being generated continues to increase coupled with lack of infrastructure for adequate waste treatment and indiscriminate disposal of waste. Nigeria with a population growth rate of about 2.8% per annum and an urban growth rate of about 5.5% per annum generates about 0.58 kg solid waste per person per day (Amakihe, 2011).

In recent years, due to a number of cost, health, and environmental concerns, many municipalities have been forced to assess their solid waste management and examine its cost-effectiveness and environmental impacts, in terms of collection points, designing collection routes and disposal sites. During the last decade, there have been numerous technological advances, new developments, mergers and acquisitions in the waste industry. The result is that both private and municipal haulers are giving serious consideration to new technologies such as computerized vehicle routing software, GIS and Remote Sensing (Karadimas, Kolokathi, Imoula, Defteraiou,Vassili, Loumos, 2007).

With regards to these review, Municipal Solid Waste Management (MSWM) therefore becomes an important entrypoint for integrated urban management support. This refers to what Idowu, Adagunodo, Esimai and Olopade (2012) view as the discipline associated with the control of generation, storage, collection, transfer and transportation, processing and disposal of solid waste in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics and other sound environmental considerations.

Recently, the impact of waste on public health has prompted engineers and scientists to explore waste management solutions with more favourable environmental footprints. However, because waste management is an activity that requires huge cost, it is necessary to justify the investment in terms of environmental, technological and economic feasibility by achieving expected and high level of efficiency (Tavares, Zsigraiova, Semiao and Carvalho, 2008). Among these environmental footprints are application of GIS to Waste Management System (WMS) optimization through the selection of transfer stations and Waste Management System (WMS) optimization through the selection of waste collection and transportation routes (Markovic, Janosevic, Jovanovic and Nikolic, 2010).

GIS has been successfully used in a wide variety of applications, such as urban utilities planning, transportation, natural resources protection and management, health sciences, forestry, geology, natural disasters prevention and relief, and various aspects of environmental modelling and engineering among others. Among these applications, the study of complex waste management systems, in particular, siting waste management disposal facilities and optimizing Waste Collection and Transportation (WC&T), have been a preferential field of GIS applications, from the early onset of the technology (Chalkias and Lasaridi,2011). Explicitly, Geographical Information System (GIS) has been adjudged a good decision support tool for waste management planning when applied for defining the possible option for optimizing solid waste management through integration of various field parameters like road accessibility, land use cover with population, residential location and other relevant data or other associated data that would help in the selection of sites in order to reduce time wastage and enhance accuracy (Tamilenthi, Chandra, Vijaya and Rose, 2011).

Remote sensing is one of the excellent tools for inventory and analysis of environment and its resources, owing to its unique ability of providing the synoptic view of a large area of the earthὂs surfaces and its capacity of repetitive coverage. Its multispectral capability provides appropriate contrast between various natural features where as its repetitive coverage provides information on the dynamic changes taking place over the earth surface and the natural environment (Navalgund et al; 1983 in Oyinloye, 2013).

Further, the role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations. In this manner, aspects such as customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial areas to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill, are important. GIS is a tool that does not only reduces time and cost of site selection, but also provides a digital data bank for future monitoring programme of the site (Tomlison,1990 in Oyinloye, 2013).

Nowadays, integrated GIS technology has been recognised as one of the most promising approaches to automate the process of waste planning and management. Geographical Information Systems (GIS) is an information system for capturing, storing, analyzing, managing and presenting data which are spatially referenced consists of a geo-referenced spatial database and it also includes all required parameters for MSWM. These parameters involve city maps, collection points, transfer stations, collection and transportation road network, as well as the location and capacity of disposal sites (Sharholy, Ahmad Vaishya and Gupta, 2007).

ArcMap (GIS Software) software has the capability to input and store the geographic (coordinate) and tabular (attribute) data, to find specific features based on location or attribute value regarding the interaction between multiple datasets, to visualize geographic features using a variety of symbols and to display the results in a variety of formats such as maps and graphs (Khajuria, Matsui and Machimura, 2011). In addition, it can be used to display, edit, create and analyze spatial data; browse, find and present geographic information of management system.

Many researchers have applied GIS to capture, store, analyze, manage, and present data on waste collection, transportation, transfer method, specific site situation, distribution of road network, etc. Siddam, Khadikar and Chictade (2012) optimize the route for collection and transportation of municipal solid waste of Chandrapur city of Maharshtra state of India using geo-informatics technique. They generated data on population density, municipality boundary map, existing road network map, storage bins location etc. Equally, collection vehicle details obtained from Chandrapur aided the digitizing of roads and the position of bins to its northing and easting using a handheld GPS. In a similar way, Rahman and Rahman (2011) propose options for better solid waste management for Mohammadpur Thama by obtaining data using Global Positioning System (GPS) to locate the existing waste bins and illegal disposal sites. They employed GPS data and high resolution images to generate spatial data and used ArcGIS 9.2 to recommend efficient waste management options.

In the same vein, Markovic, Janosevic, Jovanovic and Nikolic (2010) apply GIS, Analytic Hierarchy Process (AHP) and Clark Wright Savings algorithm in optimizing solid waste management in the Republic of Serbia. GIS according to them was employed to locate the collection points of waste, AHP for the selection of optimal solid waste system solution and the Clark Wright savings algorithm was used for vehicle routing.

Bhambulkar (2011) employ ArcGIS version 9 for the identification of best routing in the municipality of Nagpur. He employed the network analyst to estimate interrelations between the dynamic factors, like network traffic changes or closed roads due to natural or technical causes like fallen trees, car accidents etc in the area under study and produced optimized solution.

Chalkias and Lasaridi (2011) observe that optimization of WC&T using GIS techniques is capable of providing significant economic and environmental savings through the reduction of travel time, distance, fuel consumption and pollution. This they believed could be effective after employing GIS 3Dimension modelling in the island of Santo Antao, Republic of Cape Verde, an area with complex topography and achieved up to 52% fuel savings just as implementation of

Waste Routes across the USA from March 2003 to the end of 2003 yielded 984 fewer routes while saving $18 million.

In a similar manner, Nuortio, Kyotojokib, Niska and Braysy (2006) develop a GIS-based method for the optimization of waste collection routes in Eastern Finland by estimating an average route improvement in comparison with the existing practice of about 12%. They proposed a combination of routing and rescheduling optimization which introduced extremely significant savings (40%).

Karadimas and Loumos (2008) propose a method for the estimation of municipal solid waste generation, optimal waste collection and calculation of the optimal number of waste bins and their allocation. This method uses a spatial Geodatabase, integrated in a GIS environment and was tested in a part of the municipality of Athens, Greece. After the reallocation of the waste bins, their total number was reduced by more than 30%. This reduction had a direct positive impact on collection time and distance and in turn encourages prompt evacuation and disposal of wastes.

Chalkias and Lasaridi (2009) develop a model in ArcGIS Network Analyst in order to improve the efficiency of waste collection and transportation in the Municipality of Nikea, Athens, Greece, via the reallocation of waste collection bins and the optimization of vehicle routing in terms of distance and time travelled. First results demonstrated that all the examined scenarios provided savings compared to the existing empirical collection organization, in terms of both collection time (savings of 3.0% -17.0%) and travel distance (savings of 5.5% - 12.5%).

Arebey, Hannan, Basri, Bugum and Abdullah (2010) again found out the usefulness of integration of communication technologies like Radio Frequency Identification (RFID), global positioning system (GPS), general packet radio system (GPRS) and geographic information system (GIS) for monitoring and to enhance efficiency, improved performance on real-time bin status, estimation of solid waste amount and time as well as location of the truck service. The implementation of this system with graphical user interface provide data about the trucks and the bin thereby ensuring reallocation of bins into appropriate sites that would provide optimal service to the host neighbourhood.

In the meantime, the advent of Geographic Information System (GIS) in Nigeria has paved way for the analysis of points for prompt collection and disposal of solid waste after considering certain factors and criteria. GIS role in solid waste management is as large as its many aspects of planning and operation which is dependent on the spatial data. As such, Iro, Okorondu and Mbano, (2012) employ GIS tools for waste management in Owerri through cartographic modeling, buffering operation, overlay of various geographic data to generate new set of data, and thereafter used single criterion query to determine the possible areas for solid waste collection points for all the land uses. They employed Multi criteria queries to determine the most suitable sites for solid waste collection within New Owerri area.

In the same vein, Adeofun, Achi, Ufoegbune, Gbadebo and Oyedepo (2011) apply GIS in optimizing waste collection and determined the appropriate locations for siting refuse dumpsites in Abeokuta by performing various buffering analysis on drainages, land-cover and roads using Analytical Hierarchical Process (AHP) to rank suitability for disposal sites location. They succeeded in cutting the cost of fuelling waste collection trucks as a result of reallocating collection bins in strategic locations that would reduce waste collection vehicle journey. Aremu, Adeleke and Sule, (2011), on this premise, presented a simple, rapid but robust technique for spatial location of Municipal Solid Waste bins in Ilorin using TranCAD software. They identified paramount factors that determine the location of waste bins while highlighting and creating buffer for environmental constraints, minimum walking distance, maximum service coverage, as well as consideration of physical and socio-cultural context of the service area. This gives a platform of identifying the potential service points where a waste bin could be placed. Further they located waste bins at the shoulders of roads after eliminating unsuitable areas while considering the following constraints:

Å30m distance away from environmental sensitive areas such as rivers and streams.

Å30m distance away from infrastructural sensitive areas such as bus stops and intersections

Å10m distance away from property fence and entrance.

Å20m shoulder space for vehicle maneuvering during ingress to and egress from service point.

In a related manner, Anifowose, Omole and Akingbade (2011) analyze Akure environs using ArcView GIS 3.2 and Remote Sensing to develop a user interface for selecting a waste disposal site while creating buffer zones for various factors that determine a suitable location of waste disposal facility. They considered at specific, environmentally safe predetermined distances away from potential landfill sites to be 500m, 250m, 2km and 500m for rivers, fractures, settlement and major road network respectively.

From the existing research works reviewed above, it is noted that most of the works were mostly carried out in other countries. In Nigeria the few studies (Aremu, Adeleke, and Sule (2011), Anifowose, Omole and Akingbade (2011), Iro, Okorondu, Mbano and Duru (2012) and Adeofun, Achi, Ufoeghune, Gbadebo and Oyedepo (2011) were carried out only recently in various parts of the country. However, in Lokoja, the only found literature on waste management (Abdusalam, Ibrahim, and Fatoyinbo, 2011) was done on pollution implication of various illegal dumpsites in the city. As it stands, no research has been done on appropriate or accurate location of waste bins for prompt evacuation of waste, frequency of waste evacuation as well as best route ways in Lokoja. It is this gap in knowledge that this research work intends to fill.

1.6 RESEARCH METHODOLOGY

This research work relied on the use of Global Positioning System to get the coordinates of littered sites or indiscriminate refuse dump points in the city and point of waste evacuation (where recently provided drums were stationed); questionnaire and oral interview with the KSSWMB personnel as well as residents of the city. Questionnaires were administered randomly across the six zones of the city viz; Adankolo, Felele, Ganaja, Kabawa, Lokongoma and Secretatriat to provide information on the state of MSW management in Lokoja city using an existing delineated map obtained from Kogi State University GIS Laboratory, Ayingba (Fig.1.3).

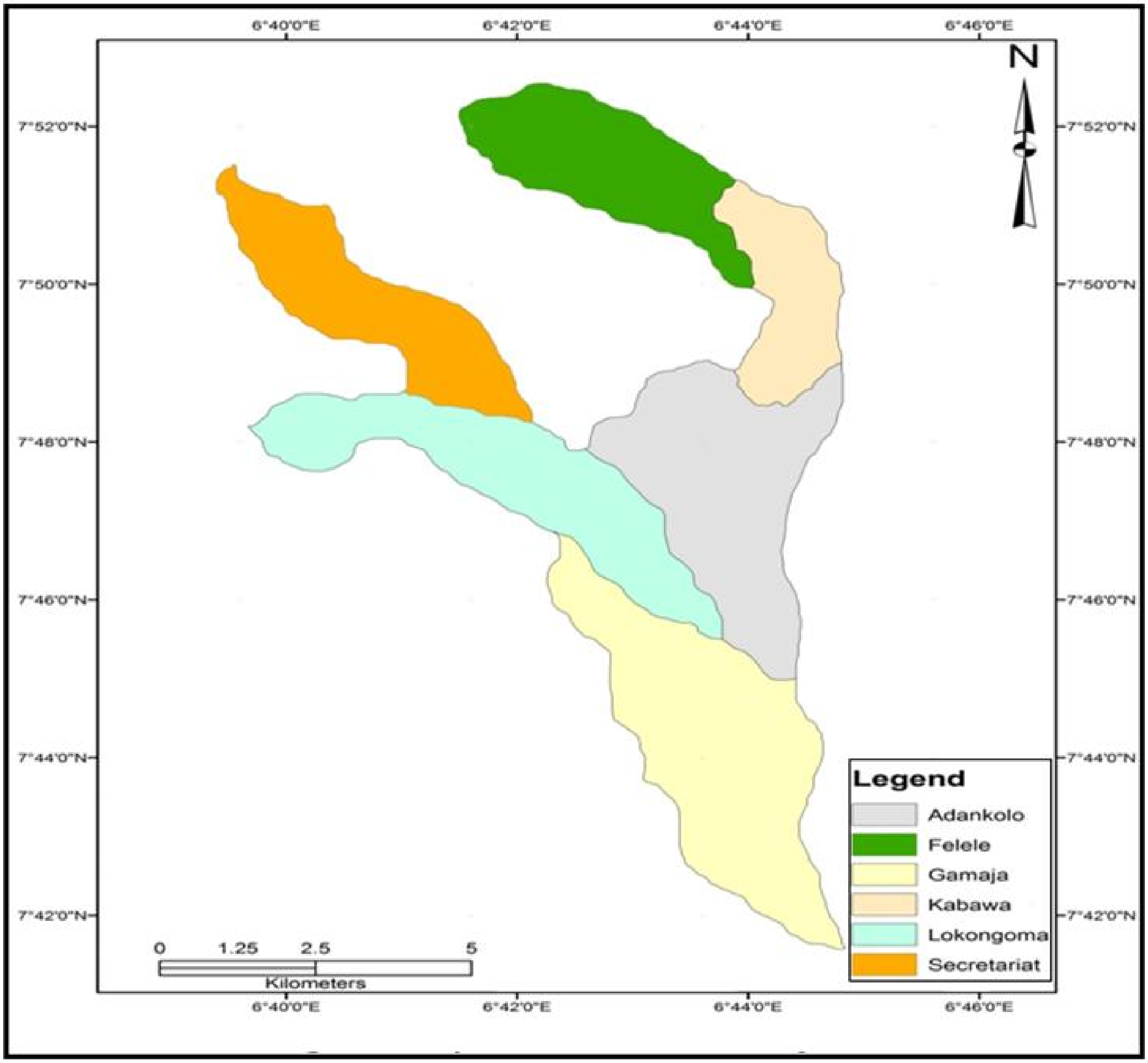

Fig 3: Various wards of Lokoja metropolis

1.6.1 METHODS OF DATA COLLECTION

Primary data employed for this research work were mostly firsthand information which are in original form. That is, age of the respondents, educational attainment, data on number of waste management board personnel, number of available trucks for waste collection, frequency of accumulation of waste, frequency of evacuation of waste from the littered sites and from the drums, e.t.c. were obtained from the field using questionnaire. Handheld GPS was used to take the geographic coordinates of the existing littered sites in the city and the location of the recently provided drums for waste storage.

On the other hand, secondary data for this research were those relevant data obtained from published journals, inaugural lectures and textbooks on waste management obtainable from Nnamdi Azikiwe Library, University of Nigeria, Nsukka, Kwara State Library, Ilorin and Federal University Library, Lokoja. Equally, several published articles like journals, inaugural lectures, textbooks and theses were obtained from internet. Base map of Lokoja metropolis was obtained from Kogi State lands and survey, Lokoja and overlaid on google earth to update the city map and for effective digitizing as well as for Geo-referencing.

1.6.2 SAMPLING

The sample size for this research was statistically determined using ñYaro Yamaneò (1967) formula:

$$n = \frac{N}{1 + N(e)^2} \quad \text{é é é é é é é é é é é é é é} \quad (1)$$

Where n is the sample size; N is the finite population, e is level of significance (or limit of tolerable error), I is unity (a constant).

The 2012 population of Lokoja City was projected from the 2006 National Polulation Commission (NPC) figure of 196,643 using formula:

$$P_o = \frac{P_t(1+r)^n}{100} \text{..} (2)$$

Where:

P_o is Projected population; P_t is Population of the base year, r is rate of growth (2.1) and n is 6 years. Projected population of 232079 was obtained for Lokoja after applying the formula

$$Po = \frac{P_t(1+r)^n}{100}$$

This value substituted in ñYaro Yamaneò (1967) formula:

$$n = \frac{N}{1 + N(e)^2}$$

gave n = 400

This therefore gives a sample size of 400 respondents.

Questionnare were administered randomly to sample of 390 respondents in the city. 65 copies of questionnaire were administered randomly in each ward to give residents opportunity of being sampled. Similarly, another set of questionnaire (10) were randomly administered to the staff of KSSWMB to obtain information on the activities of KSSWMB and various issues that affect them.

1.6.3 INSTRUMENT VALIDATION

Questionnaire for this research was reviewed and validated by three experts from Geography Department, University of Nigeria, Nsukka. After expertsô review, their observations, suggestions and corrections were incorporated in the questionnaire. Thereafter the questionnaire was subjected to a formal pre-test/reliability test. To determine the internal consistency of the research instrument, 30 copies of the questionnaire were administered to 30 respondents from Nsukka who are students and staff of the University of Nigeria. Their responses were subjected to Cronbach Alpha reliability coefficient using *Statistical Package for Social Sciences* ***(SPSS)*** to rate each question in the polychotomous questionnaire type. From the analysis, a Cronbach alpha coefficient of 0.69 was obtained. The score obtained showed that the questions in the questionnaire are relevant to the subject they were constructed to investigate.

1.6.4 METHOD OF DATA ANALYSIS

Available data of the study area on existing map was geo-referenced and digitized to define all the geographic dataset in the study area and to create buffer zone for the purpose of defining environmentally safe distances and environmental sensitive zones. In this light, ArcGIS 9.3 software was used to recommend suitable sites for locating dumpsters in order to enhance regular waste evacuation based on convenient distance to households and maximum service coverage. This was done using;

1. Application of specifications of UN standards as adopted by Iro, Okorondu, Mbano and Duru (20120 into the query builder as follows; 10m or more from roads (Roads Ó10m) for easy collection and to prevent road blockage, 20m or more from residential areas (Res Ó20m) and 20m or more from commercial areas as well (com Ó20m) so it will be within the proximity of users and 40m or more from public use (public use Ó40m) so it would not constitute nuisance to people using public facilities.
2. Overlay of digitized Lokoja road network map on Lokoja google earth image to ascertain the appropriateness of the location of dumpsters.

In addition, ARC GIS 9.3 Network Analyst (NA) software was used to find best waste collection route to the approved waste dumpsite. Equally, available data on parameters of waste collection optimization obtained through questionnaire was subjected to various descriptive statistical analyses like bar charts.

1.7. NETWORK DATASET CREATION

Network Dataset defines how features that participate in a network connect to each other. This involves creation of geodata-based network of road features. The default connectivity for a network dataset places all sources in one connectivity group and assigns all edge sources endpoint connectivity. This was achieved through creation of network dataset from the feature source or sources that participate in the network. The geospatial database was framed in Arc GIS for the allocation and analysis of collection bins. The database was derived through the sources such as digital maps from basemap obtained from Lands and survey Lokoja and online capturing of spatial data with the use of GPS technology. The city roads on the digitized map were merged to ensure topological quality and distance in kilometer was then selected for the purpose of information on road length. Further, advanced connectivity was incorporated into the model that can represent complex scenarios, such as multimodal transportation networks. In a shape file based network, there is only one edge source, hence there is no need for multiple connectivity groups. Also, it models streets with endpoint connectivity and builds the network dataset from simple features (lines and points) and turns.

1.8. NETWORK ANALYSIS

Network analysis is the process of capturing network traffic and inspecting it closely to determine what is happening on the network. A network analyzer decodes, or dissects the data packets of common protocols and displays the network traffic in human-readable format. Network analysis is also known by several other names: traffic analysis, protocol analysis, sniffing, packet analysis, and eavesdropping to name a few. Essentially, Network Analyst produces direction maps and driving directions to guide in traversing from origin to destination. Also, it determines the total distance to travel in getting to a given destination. The issue of choosing the best routing path for vehicles, when it is time dependent, has been a critical matter in the transportation routing problem, as it involves cost, manpower, time and service quality. In general, the shortest path is mistaken for the shortest distance measure without, taking into account other conditions that might delay arrival of the vehicle, such as road congestion, road closure, fallen utilities along the route etc. If the shortest road based on distance measure has a traffic congestion, it might be better off to take a route that might seem longer in distance but could really get the vehicles to their destinations faster due to less traffic congestions (Alazab, Venkatraman, Abawajy, and Alazab, 2011).

1.9. CARTOGRAPHIC MODEL

Cartographic modeling refers to flowchart used in describing sequences of workflow in geospatial analysis. It aids presentation of data and analytic procedure in systematic or graphical form. Various vector data like road network, public spaces, rivers etc were extracted from the existing map and google earth and the data were georeferenced to ascertain their accuracy in a real world scenario. These data further require integration of digitized and georeferenced data to enhance data analysis and manipulation for the purpose of producing expected feature using appropriate software. The end product of this sequence of operation is the display of data as maps, charts and tables as illustrated in various sections of this work.

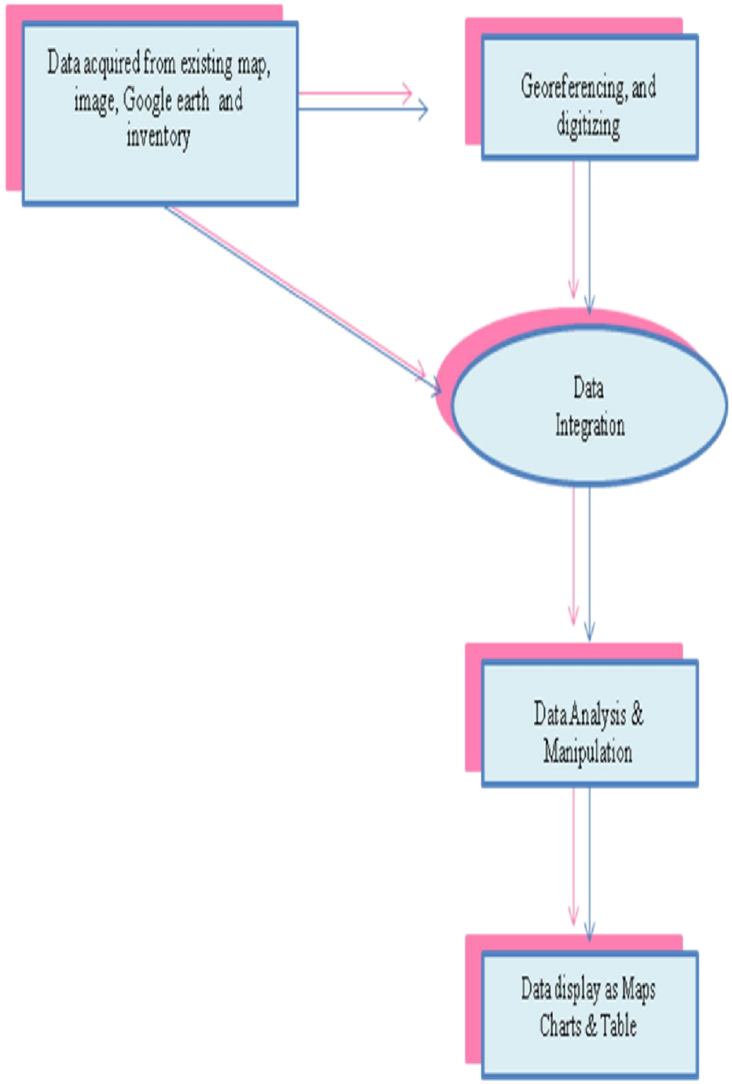

Fig. 4: Flowchat of data analysis

1.10. PLAN OF THE PROJECT

The project was structured into six chapters;

CHAPTER ONE

Chapter one, which is the introduction, contains the background of the study, statement of the research problem, aim and objectives of the study, description of the study area, review of literature, the research methodology and the plan of the project.

CHAPTER TWO

Chapter two assessed the present state of Municipal Solid Waste management and collection points in Lokoja metropolis. This chapter examines the present waste management practices such as frequency of waste evacuation, timing of waste evacuation (schedule of operation), disposal system (whether open dumping, engineered landfill and incineration), availability of dumpsters, staff strength, availability of fund, availability of collection trucks etc.

CHAPTER THREE

Chapter three assessed the factors that constitute problems of collection and disposal of Municipal Solid Waste in Lokoja Metropolis. Much work here was devoted to the assessment of various factors like accessibility, availability of collection trucks, relief and number of personnel as they affect prompt collection and disposal of MSW in Lokoja.

CHAPTER FOUR

Chapter four identified and defined important criteria for locating waste collection sites in a manner in which time and cost would be minimized. For optimum location of dumpsters, ArcGIS9.3 was employed to define suitable location

CHAPTER FIVE

This chapter employed GIS to determine potential suitable sites for MSW collection points and equally engaged GIS network analyst tool to determine the best and alternative routes for waste collection in the city.

CHAPTER SIX

Chapter six contained the summary of findings, recommendations and conclusion.

CHAPTER TWO

2.1. WASTE MANAGEMENT PRACTICES IN LOKOJA

The problem of MSWM is acute in cities and towns as the disposal facilities have not been able to keep pace with the quantum of wastes being generated (Debishree and Samadder 2013). Solid waste management varies a lot in Nigeria and adopted technique depends on availability of functional equipment, skilled personnel, requisite solid waste administration among others (Ajadike, 2007). Solid waste management in Lokoja was discussed under the following headings.

2.1.1. AVAILABILITY OF DUMPSTERS IN LOKOJA

Dumpsters are large, usually metal trash receptacles designed to be hoisted up by a truck in order to be emptied in a designated waste dump. Presently in Lokoja, absence of dumpsters was observed in the course of this study though drums, mainly located along some parts of the city major roads, were recently provided for waste collection. This was gathered, after the researcherφs in-depth interview with some residents of the city revealed that the drums were only provided recently to commemorate centenary anniversary. From the analysis of the respondents on availability of dumpsters, it could be seen that in Kabawa and Felele only 6 respondents indicated that there are dumpsters in their neighbourhood while 57 respondents indicated absence of dumpsters. In Lokongoma and Secretariat, 8 respondents indicated there are dumpsters while 85.5% and 82.0% again indicated that there are no dumpsters respectively. In the same vein, 10 respondents in Adankolo indicated availability of dumpsters in their nieghbourhood and in Ganaja 11 respondents indicated the presence of dumpsters. The overall result shows that 317 out of 390 respondents corresponding to 81.3% indicated absence of dumpsters while 49 respondents (12.6%) indicated presence of dumpsters. Table 1 shows that frequencies and percentages of absence of dumpsters in all the Zones in Lokoja outnumber those of presence of dumpsters in the city. The summary of the analysis of availability of dumpsters is presented in Table 1. Additionally, post questionnaire interview reveal there are no dumpsters in the city and some respondents have mistaken drums for dumpsters.

TABLE 1: Availability of Dumpsters within Neighbourhoods

	Zones	Adankolo	Lokongoma	Kabawa	Felele	Secretariat	Ganaja
Available	**Frequency**	10	8	6	6	8	11
	Percentage	15.4%	13.1%	9.4%	9.4%	13.1%	18.0%
Not Available	**Frequency**	52	53	57	57	50	48
	Percentage	80.0%	85.5%	89.1%	89.1%	82.0%	78.7%

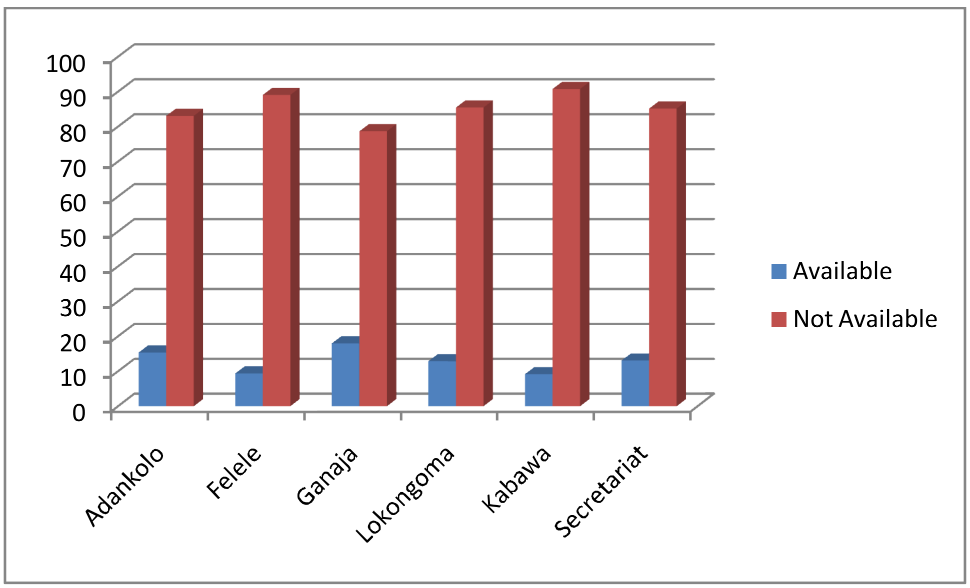

Figure 5: Analysis of Availability of Dumpsters

Plate 1.Top Left: Indiscriminate dumping of refuse in the road divide along Ajaokuta Road (Aniebo Quarters).
Top Right: Litters of Waste adjacent confluence stadium.
Bottom: Illegal waste dumpsite Adankolo.

Plate 2: Top: One of the drums supplied for waste collection in the capital city
Below: Recommended dumpster for Lokoja Metropolis.

2.1.2 DISPOSAL SYSTEM

Solid wasted evacuated in Lokoja by KSSWMB are mainly dumped openly at the metropolitan approved site at crusher, Felele. Analysis of waste disposal system, one of the waste management functional elements shows that response from interviewed KSSWMB staff indicating open dumping accounts for 77.8% while 11.1% indicated landfill. But as it stands the disposal system is not a landfill type though there are stretches of shallow pit within this site that waste would be envisaged to fill up but that does not, in anyway, look like a landfill disposal site. As shown in Table 2, the response of open dumping of waste outweighs other management practices.

TABLE 2: Solid Waste Management Functional Element Carried Out By KSSWMB

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Open dumping	7	77.8	87.5	87.5
	Landfill	1	11.1	12.5	100.0
	Total	8	88.9	100.0	
Missing	System	1	11.1		
Total		9	100.0		

On the part of the residents, some who have drums located close to their residences deposit their wastes in the drums, while many dump their wastes on open plots, some along the road, and some inside the gutters as well as others who use their backyards as waste dumping ground. The statistics of various points where sampled residents deposit their wastes in Lokoja is presented in Table 3.

TABLE: 3 ANALYSIS OF POINT OF WASTE DISPOSAL

	Adankolo	Felele	Ganaja	Lokongoma	Kabawa	Secretariat
Backyard	12.3	9.4	13.1	19.4	16.9	14.8
Gutter	12.3	21.9	18	6.5	27.7	13.1
Along the Road	9.2	17.2	18	8.1	20	23
Drum	10.8	17.2	18	33.9	12.3	9.8
Open Dump	55.4	34.4	31.1	30.6	23.1	37.7

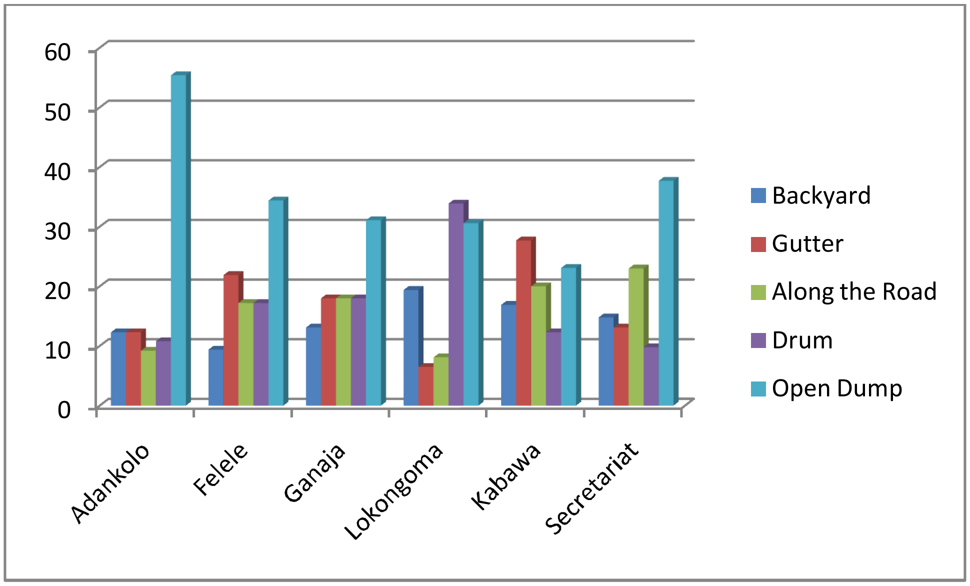

Figure 6: Analysis of point of waste disposal

Plate 3: KSSWMB Designated refuse dump site

2.1.3 FREQUENCY OF EVACUATION

Solid waste is evacuated daily from various points according to the response from KSSWMB staff that were interviewed. Analysis of data from the KSSWMB staff showed 100% response of daily evacuation of waste mainly from the drums provided along the major road. Further interview revealed that the compactor and crew members embark on only one trip per day between 6.00 am and 11:30 am.

TABLE 4: ANALYSIS OF FREQUENCY OF WASTE EVACUATION

	Zones	Adankolo	Lokongoma	Kabawa	Felele	Secretariat	Ganaja
Everyday	Frequency	4	16	7	14	16	11
	Percentage	6.6%	27.6%	10.8%	21.9%	26.7%	19.0%
Twice a week	Frequency	12	20	17	5	17	8
	Percentage	19.7%	34.5%	26.6%	7.8%	28.3%	13.8%
Every saturday	Frequency	12	17	9	9	8	10
	Percentage	19.7%	12.1%	14.1%	14.1%	13.3%	17.2%
Once a month	Frequency	11	4	18	11	3	13
	Percentage	18%	6.9%	27.7%	17.2%	5%	22.4%
None	Frequency	22	8	14	25	16	16
	Percentage	33.8%	13.8%	21.5%	39.1%	26.7%	27.6%

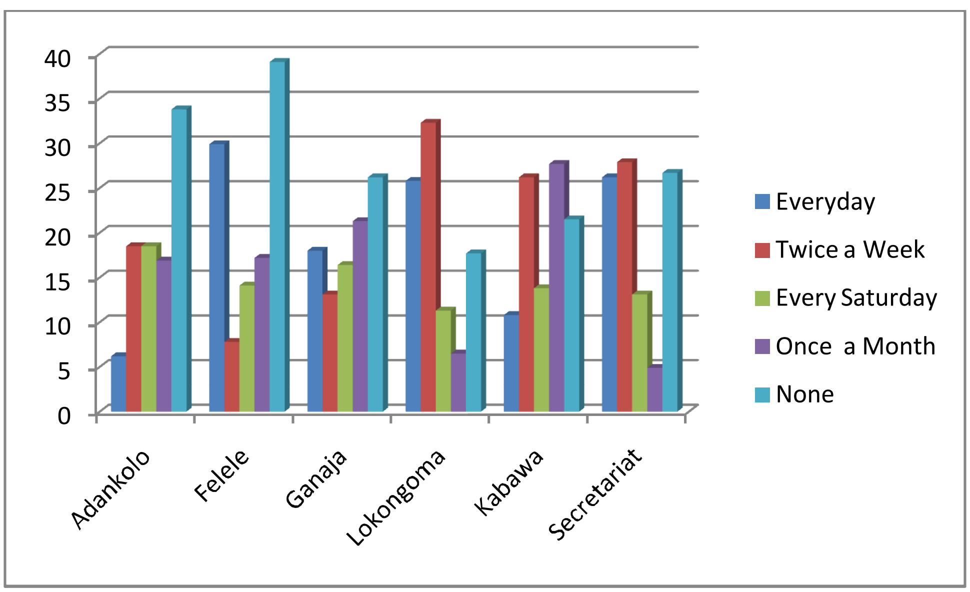

Figure 7: ANALYSIS OF FREQUENCY OF WASTE EVACUATION

Table 4 explains the scores of respondents that indicated None outweighs other responses for Everyday in Adankolo, Felele, and Ganaja with 33.8%, 39.1%, and 27.6% respectively. In secretariat, 16 respondents responded to everyday, 17 for twice a week accounting for 26.7%, 38.3% respectively. Overall result showed that 68 out of 373 respondents corresponding to 18.2% indicated that KSSWMB evacuates waste everyday, 79 respondents (21.2%) indicated KSSWMB evacuates waste once a month, 65 respondents (17.4%) indicated waste is evacuated every Saturday, 60 respondents (16.1%) indicated waste is evacuated once a month while 101(27.1%) showed that KSSWMB does not evacuate waste at all. Equally, it was discovered that KSSWMB evacuates waste daily but does not cover the whole city regularly. Additionally, findings from some residents of the city indicated that the activities are restricted to where the drums for waste collection were recently provided. This is corroborated by the findings of the Labaran (2014) that the work of KSSWMB is concentrated around GRA, government house road.

2.1.4 WASTE COLLECTION TOOLS IN LOKOJA

Standard waste collection receptacles are rarely available at household level in most parts of sub-Saharan Africa and in Nigeria particularly, many low and middle income households use whatever container that is readily available, such as baskets, cans, buckets, open drums and sometimes black bin bags for waste collection (Ezeah, 2010). In the event of our fieldwork in Lokoja, several waste storage tools were discovered and analyzed from our questionnaire in Table 5

TABLE 5: ANALYSIS OF WASTE COLLECTION TOOLS IN LOKOJA

	Adankolo	Felele	Ganaja	Lokongoma	Kabawa	Secretariat
Carton	10.8	12.5	11.5	11.3	16.9	3.3
Basket	21.5	25	18	27.4	26.2	19.7
Bucket	13.8	34.4	16.4	8.1	24.6	14.8
Waste Bin	53.8	21.1	54.1	51.6	32.3	62.3

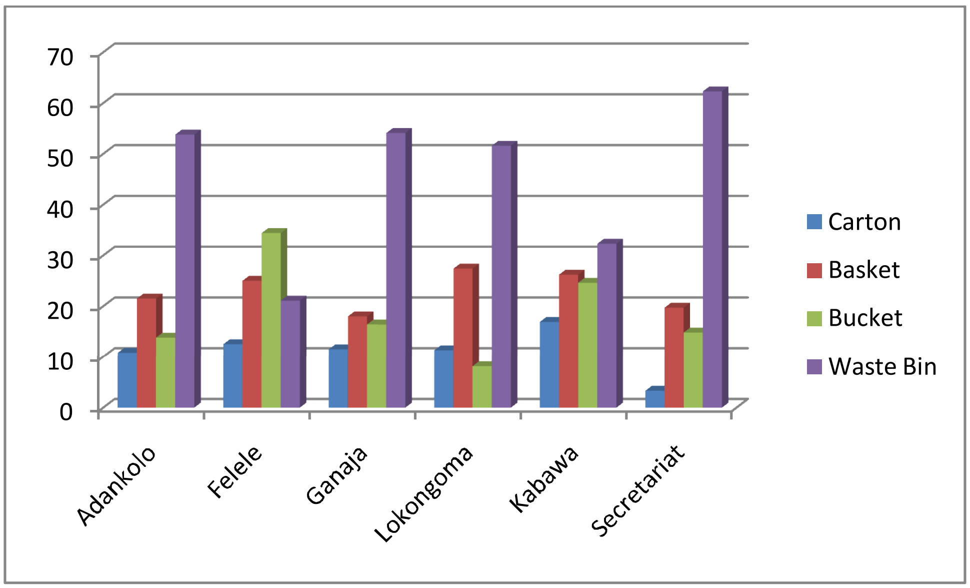

Figure 8: Analysis of Waste collection tools in Lokoja

From our analysis, it is comprehensive that waste bin is majorly used as waste storage tool in Lokoja except for Felele where bucket and basket appear to be tools for waste storage. However, post questionnaire interview reveal that most of the wastes stored in the tools are either thrown in the drains or on open fields following absence of dumpsters in the city.

2.1.5 TIME OF SOLID WASTE EVACUATION IN LOKOJA

Researcherôs personal observation and interview with one of the senior staff of the board gave some insight into period of operation of KSSWMB in the city. In the course of a three-day observation of the boardôs activities it was discovered that the board discharges her field workers around 6 00 am ï 11:30am daily. This, they said, is practiced to avoid traffic congestion which the city experiences during the day.

TABLE 6: ANALYSIS OF TIME OF SOLID WASTE EVACUATION

	Adankolo	Felele	Ganaja	Lokongoma	Kabawa	Secretariat
Morning	27.7	25	27.9	32.3	36.9	55.7
Afternoon	9.2	21.9	23	14.5	15.4	8.2
Night	16.9	20.3	21.3	11.3	21.5	8.2
Anytime	46.2	29.7	26.2	37.1	26.2	26.2

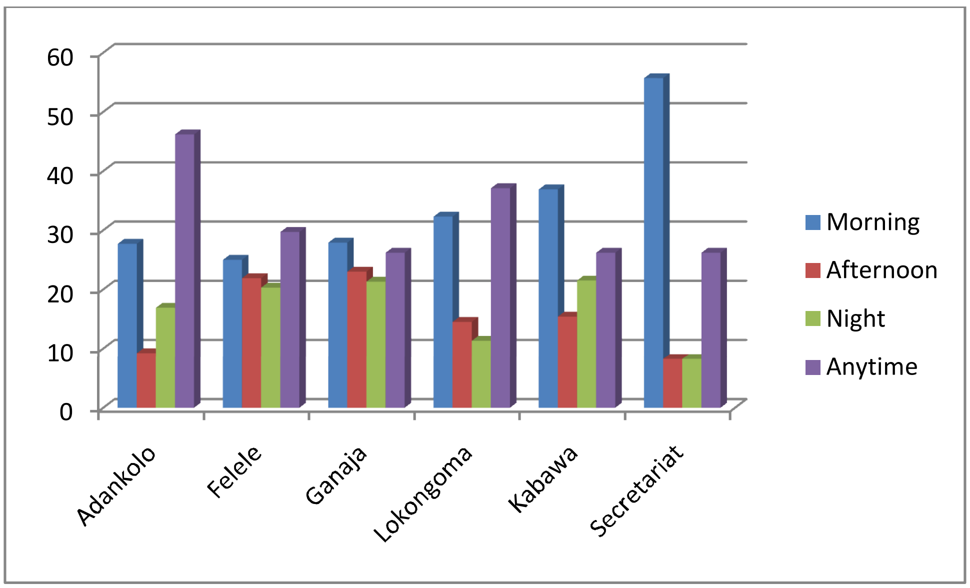

Figure 9: Time of Waste Evacuation

2.1.6 STAFF STRENGHT AND WELFARE

KSSWMB has about 270 staff including the administrative staff across the state. The staff were redeployed from their various area offices across the state recently meaning that all the staff now function within the city. On welfare package of KSSWMB staff, two senior staff and four junior staff were interviewed separately to know whether they are well remunerated. Their responses showed that they are not well remunerated and that government has been defaulting in the payment of their allowances. This particularly could spell doom on expected waste management results.

2.2 SPATIAL DISTRIBUTION OF MUNICIPAL SOLID WASTE IN LOKOJA

The size of municipal waste generation in Lokoja varies with the peculiarities of the zones that make up the city. These peculiarities range from social status of the neighbourhoods within the city, adminitrative status, commercial and residential nature of the zones in the city. The size of waste generated in different zones as shown in Fig. 7 have been categorized into areas of high, medium and low size waste generation.

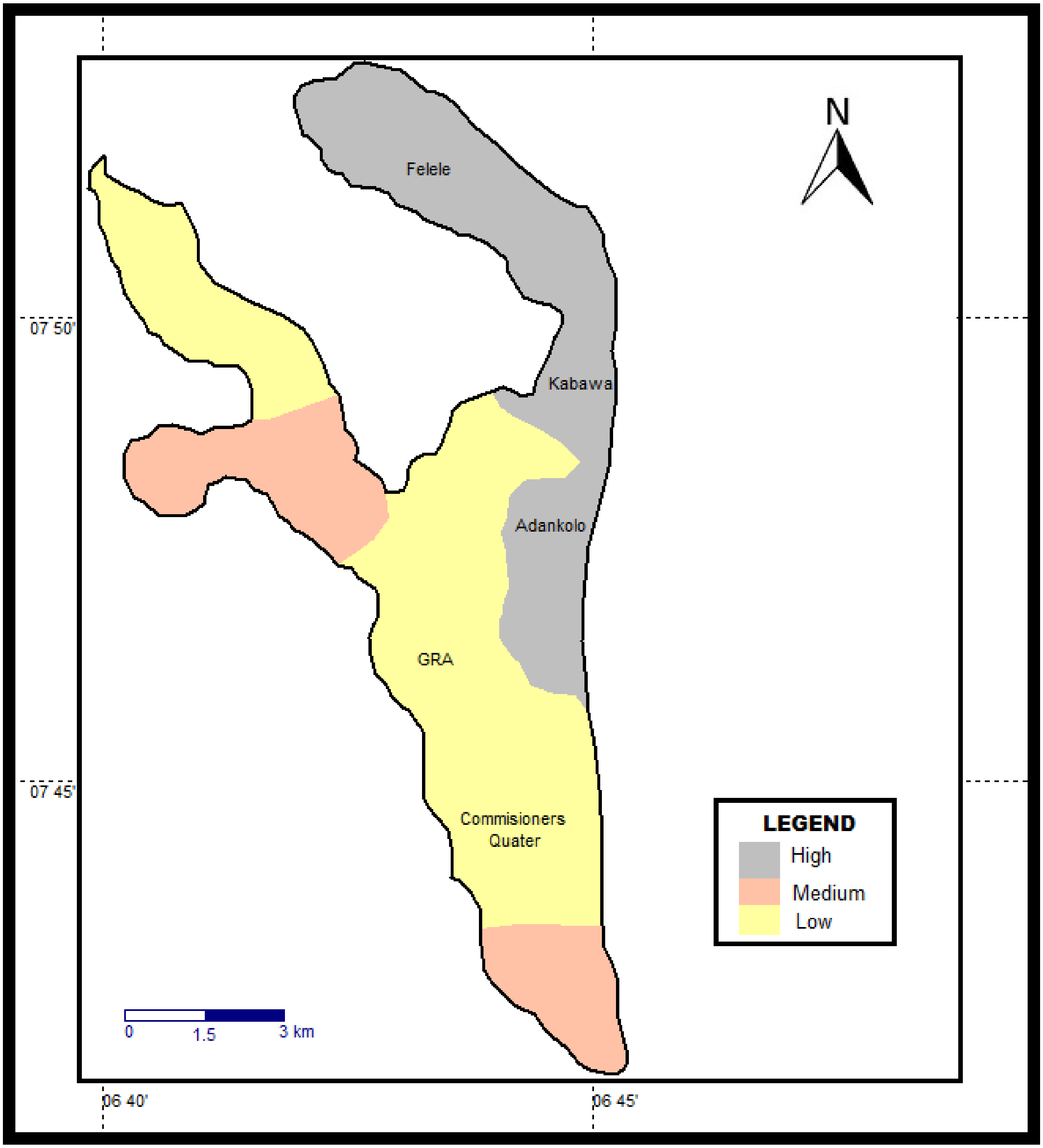

Fig. 10: Lokoja showing waste generation hierarchy across the city

2.2.1. AREA OF HIGH WASTE GENERATION

Kabawa ranks highest in the category of neighbourhood with highest volume of waste generation. Though Kabawa zone is not the only area where refuse is generated and dumped indiscriminately in Lokoja, part of Adankolo especially adjacent marine quarters and Felele are equally prominent. Apart from the fact that waste is generated on daily basis in these aforementioned areas, the occupants of the areas are insensitive to the aftermath thereof as they chose to dump their refuse on open plots, drainages and several abandoned buildings. The situation in Kabawa is so pathetic that commuters plying Muritala Muhammed road need not to be told how deplorable Kabawa area is as whoever plies the road is always besieged with obnoxious odour that emanates from the zone. In reality, every area in Kabawa is a mess with about 150 houses per hectare sq aggregation, congested with population and clustered in a manner which would not encourage accessibility for sanitation. The situation along the river bank in Adankolo, NIWA dock and Felele is not too different from what is obtainable in Kabawa as indiscriminate dumping of refuse has besieged these areas equally.

2.2.2 AREA OF MEDIUM WASTE GENERATION

There are areas in Lokoja where waste accumulation appears to a medium extent. Confluence beach hotel and its environs, Lokongoma phase I and II, Otokiti village, opposite Army Barracks both of which are in the Secretariat zones make up areas in this generation hierarchy. There appears to be organized system of waste storage in these areas probably due to the social status of the residents, moderate population density of the area as well provision of waste collection drums within some part of these area. Though litter of waste is still evident in some places within this area, this is due to the limited size of the drums and irregularity of evacuation that results in spillage of waste from the drums into the drains within the area.

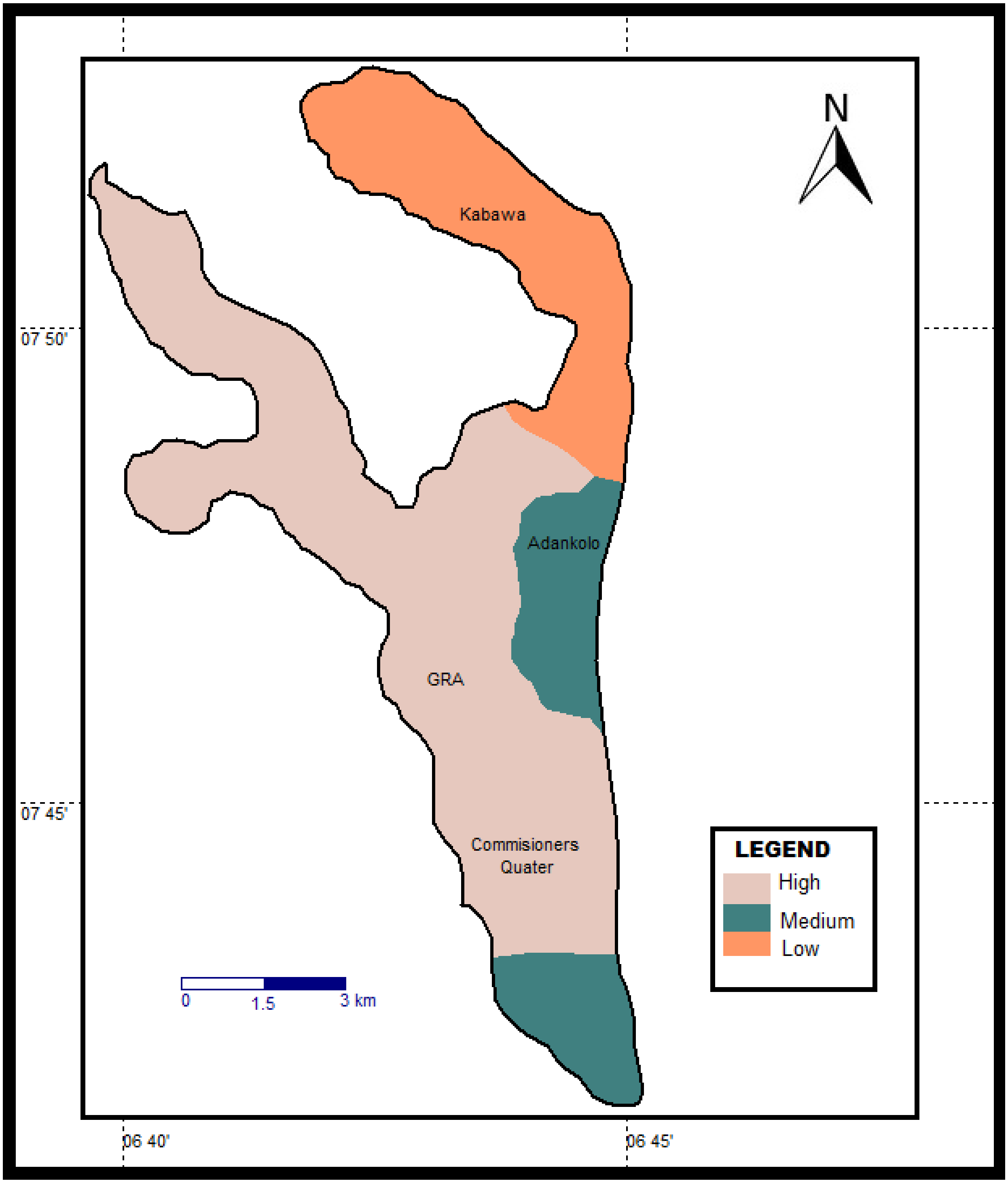

Fig 11: Lokoja showing socio-economic class

2.2.3 AREAS OF LOW WASTE GENERATION

These areas include the commissionersô quarters, Adankolo GRA, House of Assembly quarters, Governors lodge and environs. This area is characterized with high living standard where buildings are spaced meters away from each other; well managed lawn, functional drainage system, mean family size of 4 and average of 25 houses or less per hectare sq. Equally, there exists buildings in these areas with no occupants, except in some cases, where only guard(s), gardeners or gate keepers occupy some of the buildings. In this regard, waste accumulation is usually low here.

The Relationship between city socioeconomic class and waste management lies in the response of waste management authority which tends to pay much attention to the high and middle class people. This accounts for concentration of drums in G.R.A. and part of Adankolo.

2.3. WASTE MANAGEMENT EVALUATION IN LOKOJA

From researcherøs observation point of view, wastes were seen dumped indiscriminately in major part of the city especially along the roads and some interior part of the city particularly Adankolo and Kabawa. The prevalence of illegal dumpsites in the interior part of the city is a source of worry to whoever cares about healthy living. In Adankolo, Kabawa, Felele refuse occupies several portions of land while in Ganaja, Lokongoma and even the G.R.A., patches of waste were seen around some open spaces but they are not as prevalent and voluminous as those in the kabawa and areas alike. On the other hand, the drums that were recently supplied in the city were located haphazardly without considering factors such as centrality, adequacy of space, and other neighbouring land uses etc. The various indiscriminate dumpsites areas as well as those areas served with drums within the city are illustrated in Fig.9 to 11. On the whole our respondents across the city were offered an opportunity to evaluate the performance of KSSWMB and their responses were summarized and analyzed in Table 6.

Table 7 Analysis of evaluation of KSSWMB

	Adankolo	Felele	Ganaja	Lokongoma	Kabawa	Secretariat
Low	61.5	65.6	42.6	43.5	63.1	57.4
Moderate	26.2	17.2	36.1	35.5	26.2	31.1
High	7.7	12.5	13.1	12.9	4.6	4.9
Very High	4.6	4.7	3.3	1.6	4.6	1.6

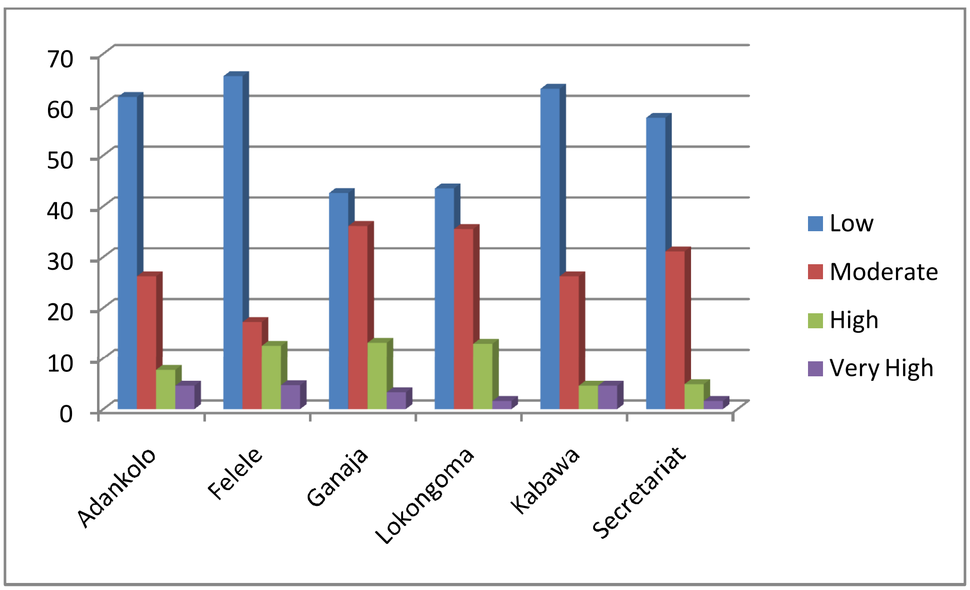

Figure 12: Analysis of evaluation of KSSWMB

The evaluation of KSSWMB shows clearly that in Figure 11 that the respondents evaluate the service delivery is low across the city.

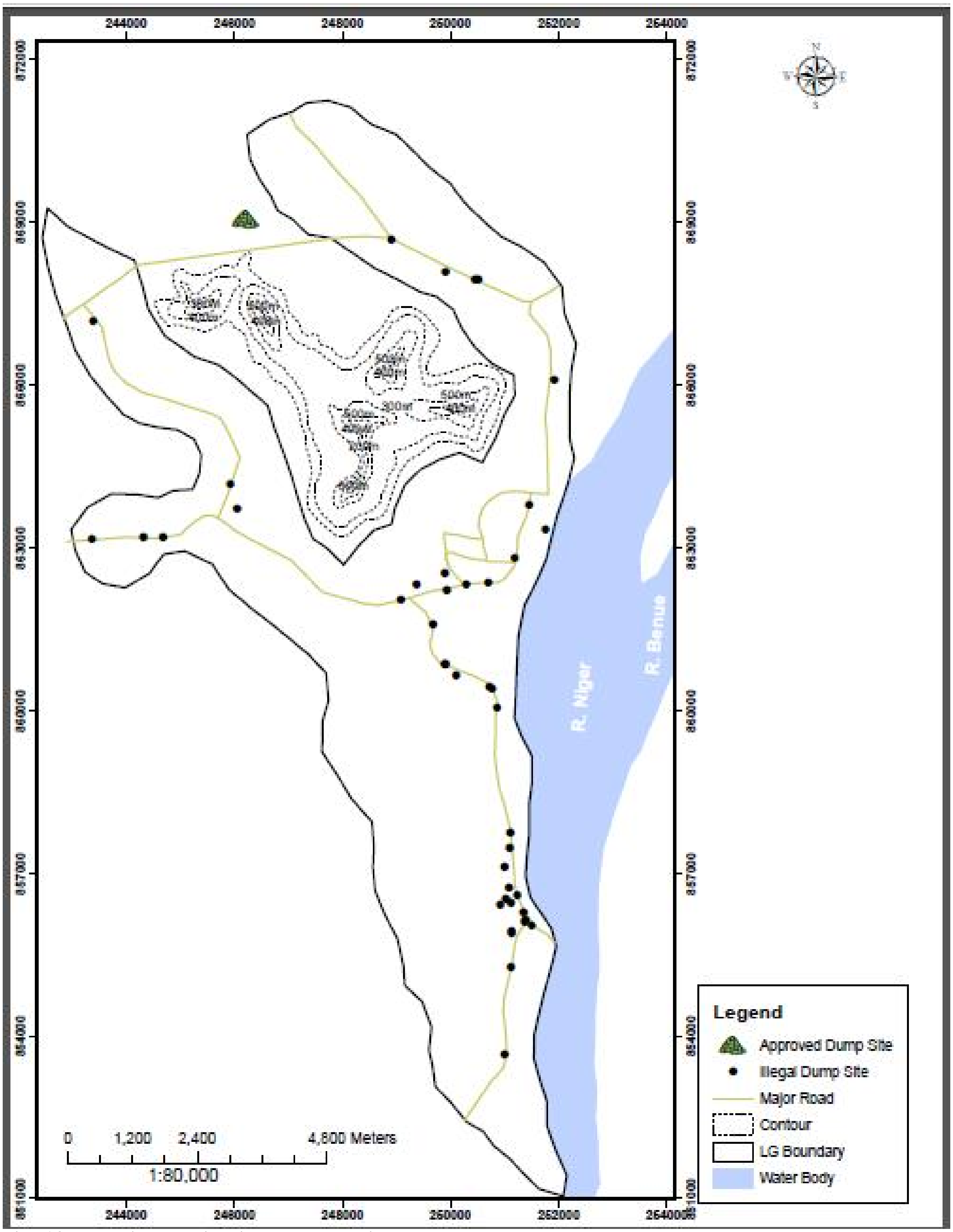

Fig. 13: Lokoja showing illegal dumpsites

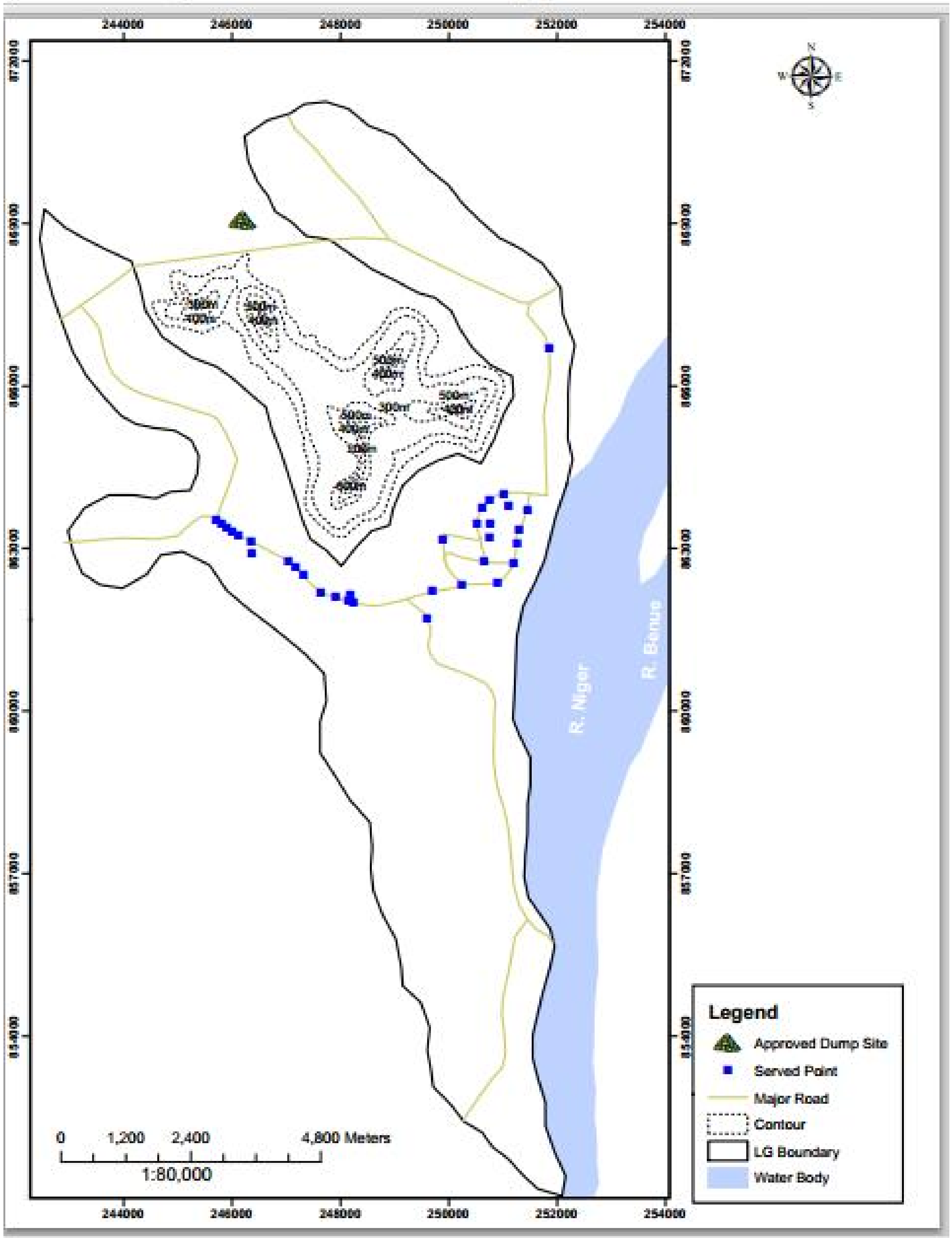

Fig. 14: Lokoja showing places served with drums

As shown in Figure 14, drums were only provided along major roads and in some certain areas of the city. As mentioned earlier, the drums were only concentrated around high and middle class zones of the city. Reason for concentration of limited drums in the selected areas, mainly along major roads, according to interview with some staff is to preserve the beauty of the city which happens to fall majorly within high and medium classes of the city. It is therefore evident that socioeconomic status plays a vital role in allocation of the drums that are currently in use for waste collection in the city.

CHAPTER THREE

3.0 FACTORS THAT INHIBIT REGULAR EVACUATION AND DISPOSAL OF SOLID WASTE IN LOKOJA

This chapter presents several factors affecting effective management of solid waste in Lokoja. These factors are as discussed below.

3.1 ACCESSIBILITY

Accessibility is vital to effective waste management system in any given area. Collection crews in Lokoja come on specified days to empty the bins for transfer to dumpsites. This system demands proper planning of infrastructure for accessibility and where this is not readily available the system readily collapses. Researcherӿs observation in the course of fieldwork reveals some areas in Lokoja are not easily accessible and as such pose serious threat to effective waste management in the city. Kabawa, part of Felele and Eastern part of Adankolo are grossly inaccessible following over aggregation of population in a poorly planned and poorly administered development manner in the area as well as proximity to the foot of the Patti ridge and Niger bank respectively. This problem prevents evacuation of waste in these areas and resultant effect is accumulation of waste in the area. Equally, areas behind Aniebo quarters, 500 unit and 200 unit estates have good but narrow road network which may not permit refuse collection trucks like compactors easy entry and exit. The implication of this means that waste collection vehicle will only evacuate wastes along the major roads where the trucks can make U turn where it deems necessary. This could cause several waste to be heaped up in the city without being attended to.

3.2 LIMITED NUMBER OF COLLECTING TRUCKS

Collection trucks especially compactors are limited in Lokoja as observation and visitation to the board reveals there are only two medium sized compactors in the whole city and in the whole state. Of the ten KSSWMB staff sampled, seven gave the number of trucks to be two (corroborating field observation) and two others gave four. This result accounts for 77.8% and 22.2% respectively. At the KSSWMB headquarters, there are two tippers, unserviceable pay loader and two tractors. Further oral interview with a senior staff of the board revealed that the tractors and tippers were used for waste evacuation in Lokoja until the two compactors (as shown in Plate 4) were recently acquired. Those who gave four as the number of trucks for waste collection at the KSSWMB are believed to have added the two tippers that were in use before the procurement of the two compactors to the number of trucks at the disposal of KSSWMB.

Plate 4: Top: One of the two compactors used for waste evacuation in Lokoja Metropolis
Bottom: An unserviceable pay loader used for clearing waste

3.3 POOR LEGISLATION AND IMPLEMENTATION OF ENVIRONMENTAL LAWS

Non implementation and poor enforcement of sanitation legislation in Lokoja undermines successful prosecution or fine for those who violate sanitation laws. It was gathered during an interview with some residents of the city at Adankolo that waste management authority pay lip service to waste law enforcement despite signing into recently the bill for the establishment, functions and powers of the board. This reflects the high magnitude of non-challant attitude that leaves the city besieged by heaps of solid waste indiscriminately dumped on open plots, drainage channels, along the roads in the road divides.

3.4 RELIEF

The relief of Lokoja is characterized by undulating topography with limited flat terrain. This is typical of Mount Patti and Agbaja plateau which are the two main highlands in the area (Omali, 2014). Mount Patti is a linear North West ï South East ridge parallel to Agbaja plateau with an altitude of about 450m both following the basing trend and perpendicular to the main axis of the Benue trough (Falconer, 1911 in Omali, 2014). The presence of river Niger on eastern side means there will be limited flat terrain for settlement and this accounts for extension of settlement to the foot of Mount Patti and Agbaja plateau. Field observation reveals that relief of the area poses a threat to effective waste management in the area following observed inability of waste collection trucks to access the area. Equally, rugged relief of this area could have hampered construction of roads in this area. Owing to the steepness of part of Kabawa and Felele, siting of dumpsters in the area becomes a great problem and this results in accumulation of waste in the area.

3.5 ABSENCE OF OTHER WASTE MANAGEMENT ALTERNATIVES

Open dumping of waste is the only waste management option carried out in Lokoja with no options of other management practices. As the situation stands, there is no incineration plant(s) to manage the ever growing waste in the city. Recycling as a preferred alternative could be vital in reducing ever increasing waste stream is not yet advocated in the city. Equally, engineered landfill waste management system is not in place

3.6 POOR ENVIRONMENTAL AWARENESS

There seems to be poor awareness and enlightenment on inherent dangers associated with indiscriminate refuse dumping in the drainages, open plots, along the road, in the river bodies etc. Consequent upon this, the public has turned the aforementioned points to where they dump their wastes.

3.7 UNDERFUNDING

TABLE 8: Appropriate Funding of Municipal Solid Waste Management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	1	11.1	11.1	11.1
	No	8	88.9	88.9	100.0
	Total	9	100.0	100.0	

TABLE 9: Source of Fund For Waste Management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Federal Government	3	33.3	33.3	33.3
	State Government	6	66.7	66.7	100.0
	Total	9	100.0	100.0	

Underfunding is one of the major issues KSSWMB contends with. It is worthy of notice that waste management is a task that requires huge capital outlay so as to function effectively but KSSWMB has been underfunded and has been facing a lot of challenges. This is evident in paucity of equipment they use for waste evacuation and the state of their general facilities such as dilapidated office building etc. Table 8 shows that 88.9% of the KSSWMB are of the opinion that waste management in Lokoja is not funded appropriately while 11.1% of the KSSWMB staff interviewed indicated that waste management is appropriately funded. Equally, Table 9 highlights the analysis of source of fund for waste management in Lokoja. From the analysis, 66.7% indicated that Kogi State Government funds waste management activities while 33.3% indicated funding from the Federal Government. Meanwhile, another senior administrative staff of KSSWMB reiterated during oral interview that only Kogi State Government funds waste management in the state.

CHAPTER FOUR

4.0. DETERMINATION OF SUITABLE SITES FOR LOCATION OF DUMPSTERS

This chapter shows the location of the proposed sites of dumpsters for Lokoja metropolis after a set of query and buffering analyses were performed on the rivers, public centres, roads, commercial centers, etc as depicted in figure 19. The distances for creating the buffer zones were adapted from the specifications of the United Nations Standard Criteria and as adopted by Iro, Okorondu, Mbano and Duru (2012). In the selection of solid waste collection points, the following selection criteria set based on the United Nations Standard and as adopted by Iro, Okorondu, Mbano and Duru (2012) were taken into consideration. They are:

- The collection point should be 10m or more away from roads (for easy collection and to prevent road blockage),
- The collection point should not be less than 70m away from water bodies e.g. rivers,
- They should be 40m or more away from public use areas,
- They should be 20m or more away from hospitals,
- They should be 20m or more away from commercial areas,
- They should be 20m or more away from the nearest residential areas (thus within the proximity of prospective users),
- A collection point must be at least 100m away from one another and it must be along the road or street junctions **(**Nathawat, and Shrivastava, 2001**)**

4.1. DATABASE QUERY

Spatial analysis in GIS involves three types of operations- attribute query (also known as non-spatial), spatial query and generation of new data sets from the original databases. Various spatial analysis methods viz: overlay; spatial modeling; geometric modeling; point pattern analysis; network analysis; surface analysis; etc. aid GIS analysis. GIS can interrogate geographic features and retrieve associated attribute information, called identification and it can generate new set of maps by query and analysis. Query was carried out to reveal spatial and non spatial information of Lokoja city land uses including roads. This shows the location and type of existing features in the city. Features like road type, number of roads, location of houses, market and other landmark features were shown in attribute table. Though this did not produce the final result, it gave an insight to the possible areas where the dumpsters can be placed. Selective display and retrieval of information from database was employed to perform analyses of the already stored information. Figure 15 shows the buffered roads of the city at 10 meters. This implies, among other factors that the dumpsters could be located at any convenient point 10m or more away from the road. As pointed out earlier, compliance to this buffer while locating the dumpsters will ensure among other things easy evacuation process and equally prevents road blockage. Figure 16 illustrates the commercial areas buffered at 30m. In the same manner, Figures 17, 18 and 19 show buffer of rivers/streams, public facilities at 70m, 40m and residential, commercial, buffered rivers, roads and public facilities respectively. After these buffers were carried out, proposed points became clearly defined. As shown in figure 20, points were aligned with the road network - a necessary condition for locating dumpsters. In the mean time, the areas served with drums were depicted in figure 22 and the buffer bands thereof show the extent of envisaged coverage each point can serve. Be it as it may, vast portion of the city is left out in the coverage process as shown in figure 22. In the event of this insufficient coverage, proposed sites were established in Figure 21 and integrated to aid NA in figure 26. With these proposal and integration, maximum service would definitely be guaranteed provided other conditions such as legislation against indiscriminate refuse dumps are not compromised. In figure 24 and 26, there are intersections of buffer bands in virtually all parts of the city. This indicates that the residents have the choice of using any of the dumpsters they wish to use at any particular point in time.

4.2. BUFFERING OPERATION

The operation performed by the buffer command generates one or more polygons ñBUFFER ZONEò surrounding geographic features. The buffer zone generated here depended on numerical values defined in map units according to the Coordinate Reference System (CRS) and as provided in the vector layer attribute table for each feature. In this study, buffering operation of 500m was carried out on the point entities. The location of dumpsters has been chosen following the aforementioned criteria of the UNO standard criteria adopted by Iro, Okorondu, Mbano and Duru(2012) in section 4.0. Prime target was to cover all the sections of the city road network in the optimization process. Mention has already been made about the sections of the road network, where the waste bins can be proposed (please refer to Figure 20). Here, two things have been observed. One is, whether the service areas are not overlapping much and the other is whether the service areas can cover most part of the city (Figure 24)

Figure 22 shows that much area of the city was not covered with waste storage facilities (drums). This was established after buffering operation of the served area shows the pattern and extent of service coverage by KSSWMB. Therefore, several areas fall off the buffered zones and as such revealed the vast unserved areas.

4.3. ANALYSIS

Several analyses were made to suggest improvement to the existing waste management system in Lokoja metropolis of Kogi state Nigeria. The results of the analysis made from the available data helped in the decision support for planning the allocation or relocation of the existing bins with their presence at any given location causing inconveniences to the city inhabitants. Equally, integration of existing data could aid generation of another feature and would ensure maximum coverage. The first analysis is studying the proximity to roads, schools, hospitals, public places water bodies, residential areas. For this, a buffer analysis of 20 meters or more; 40 metres and 30 metres were carried out respectively around these three land uses.

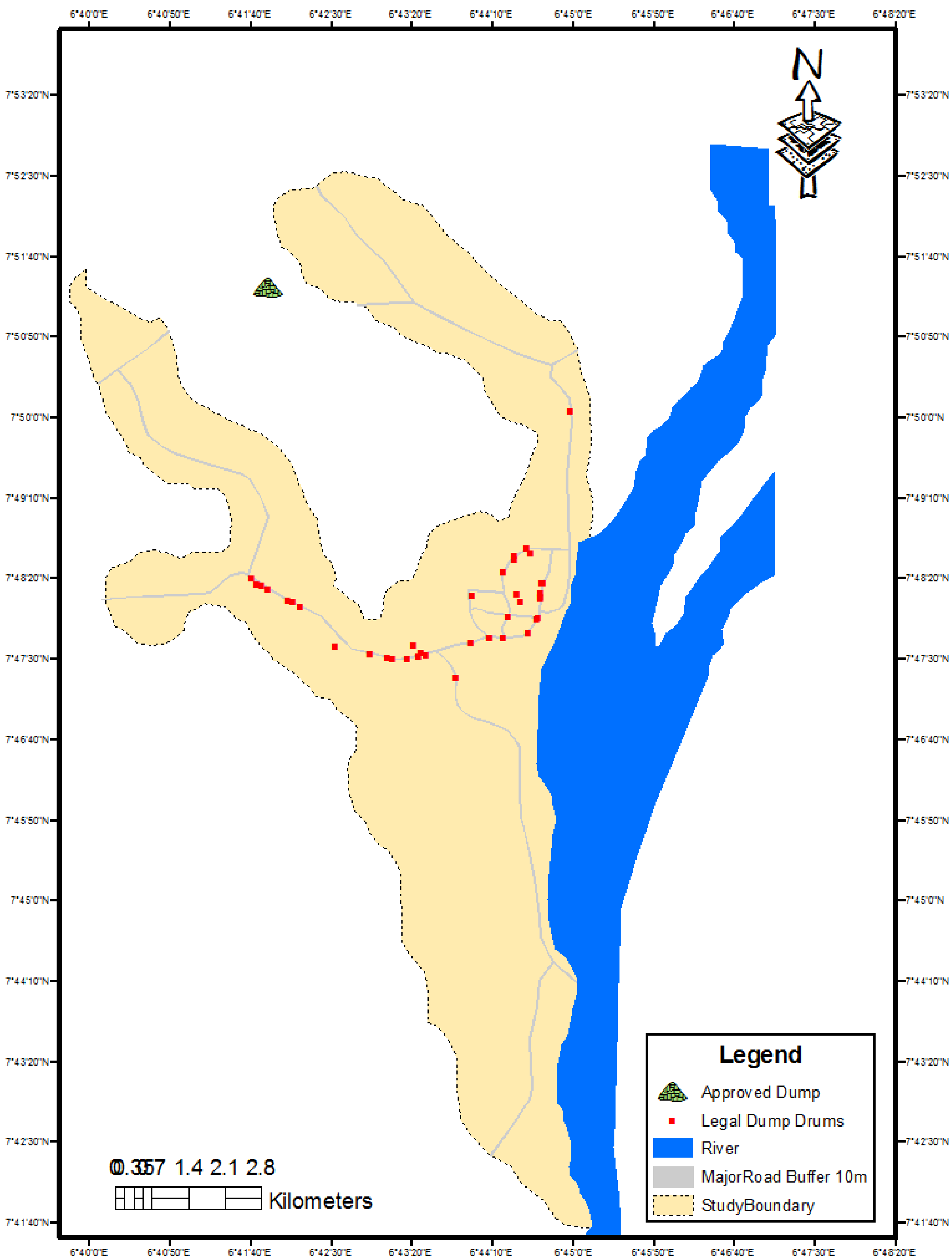

Fig 15:Lokoja showing buffered road with drums

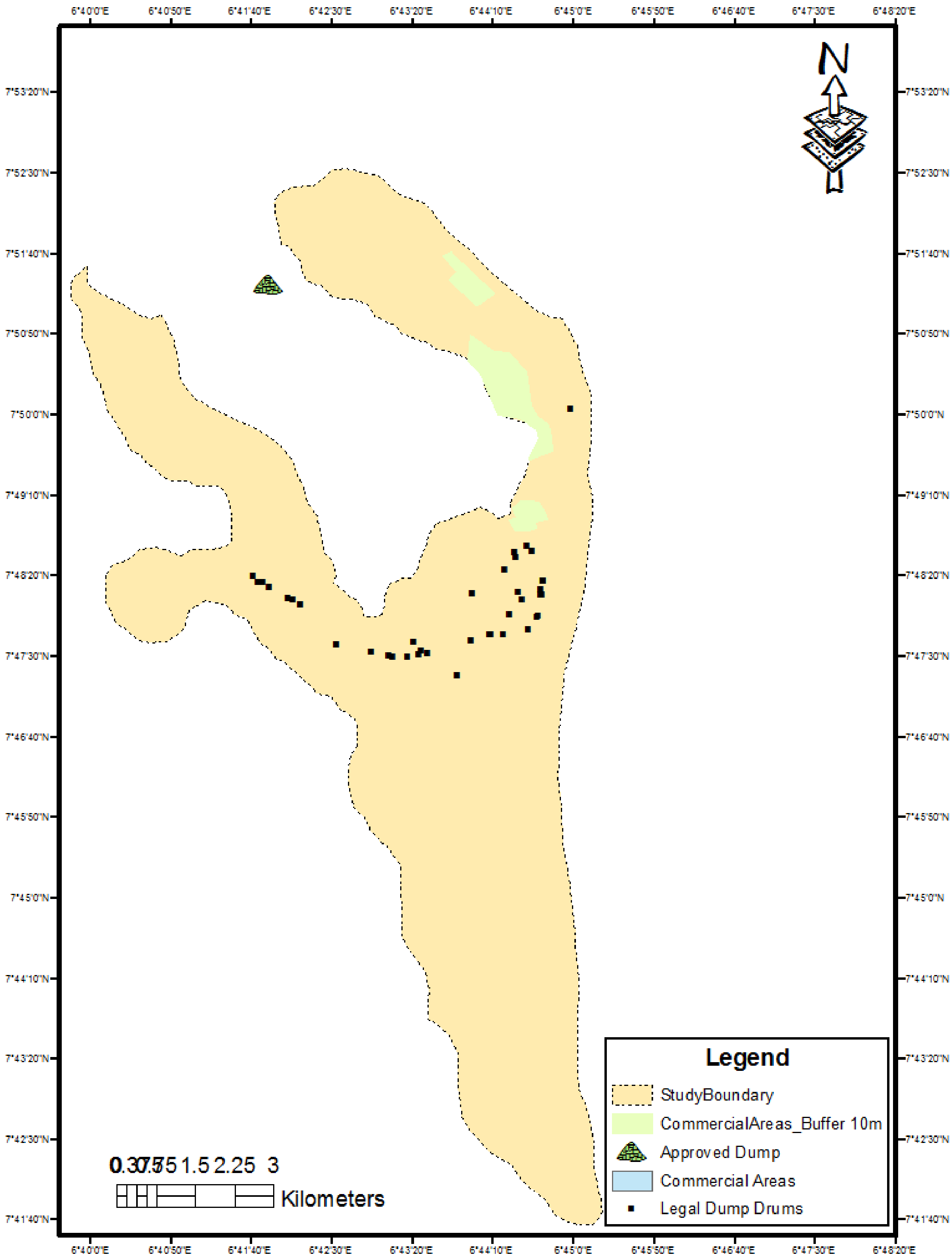

Fig 16:Lokoja showing commercial areas

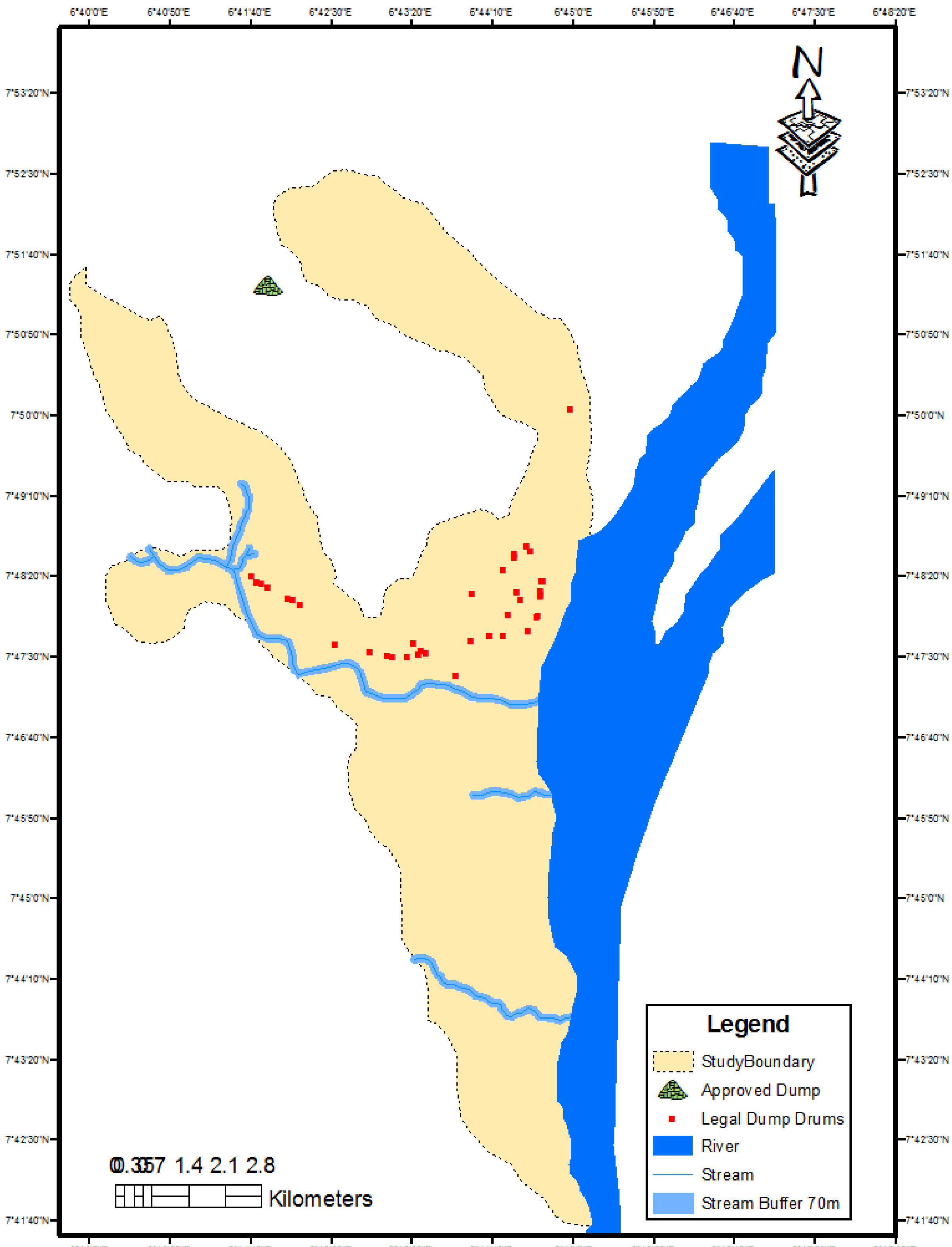

Fig. 17:Lokoja showing buffered rivers.

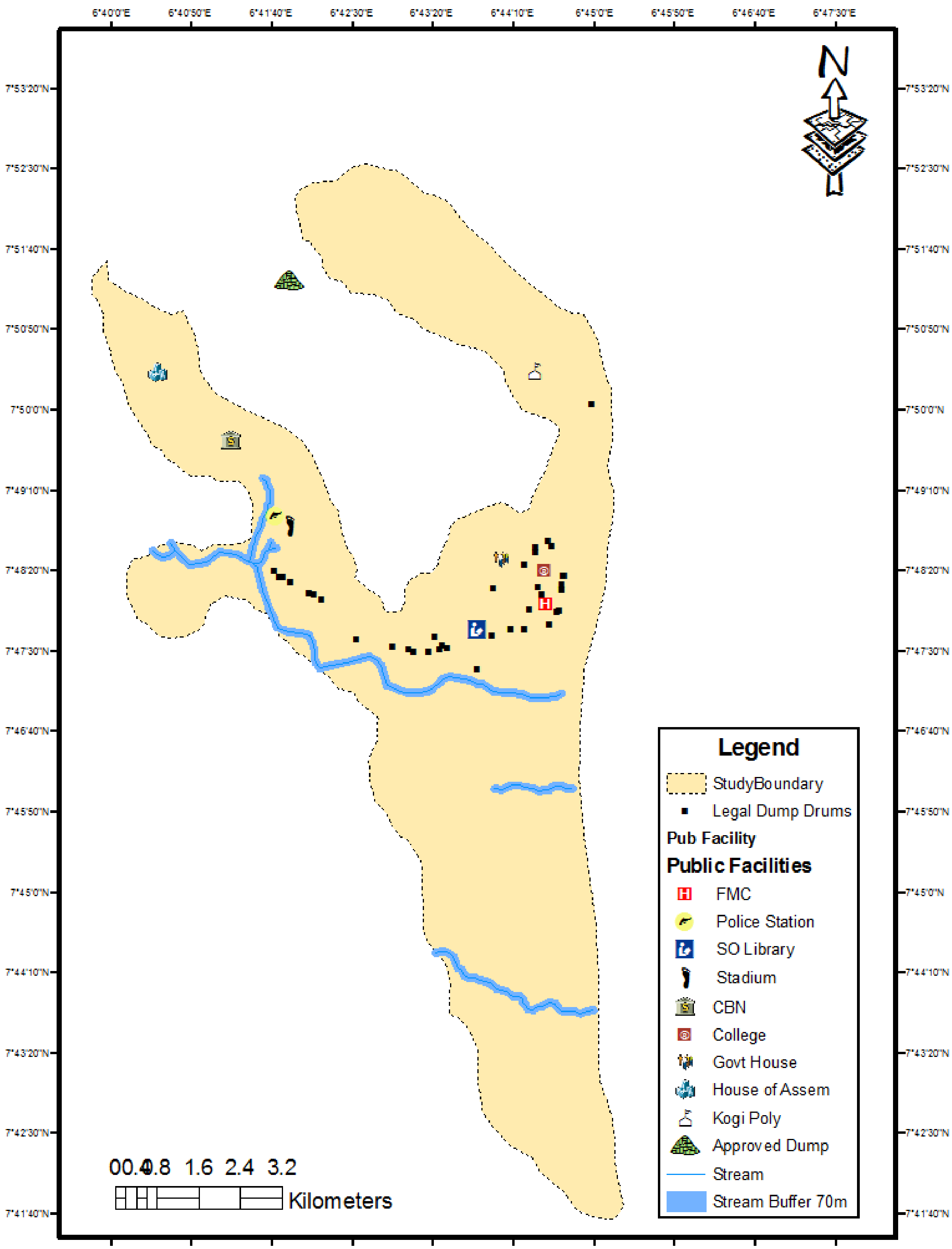

Fig 18: Lokoja showing location of public facilities and buffered river

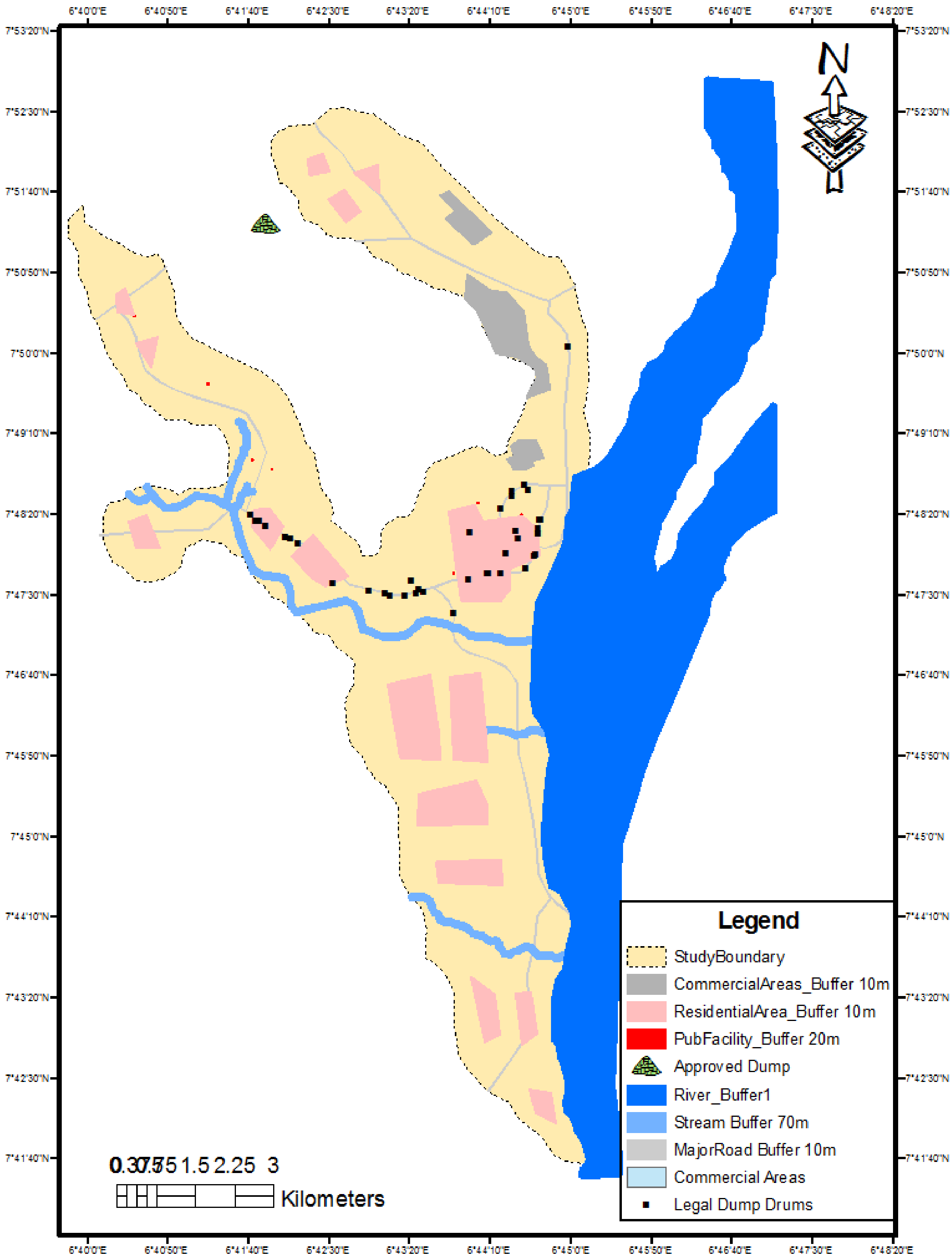

Fig 19: Lokoja showing residendial, commercial, buffered rivers, buffered roads Public facilities

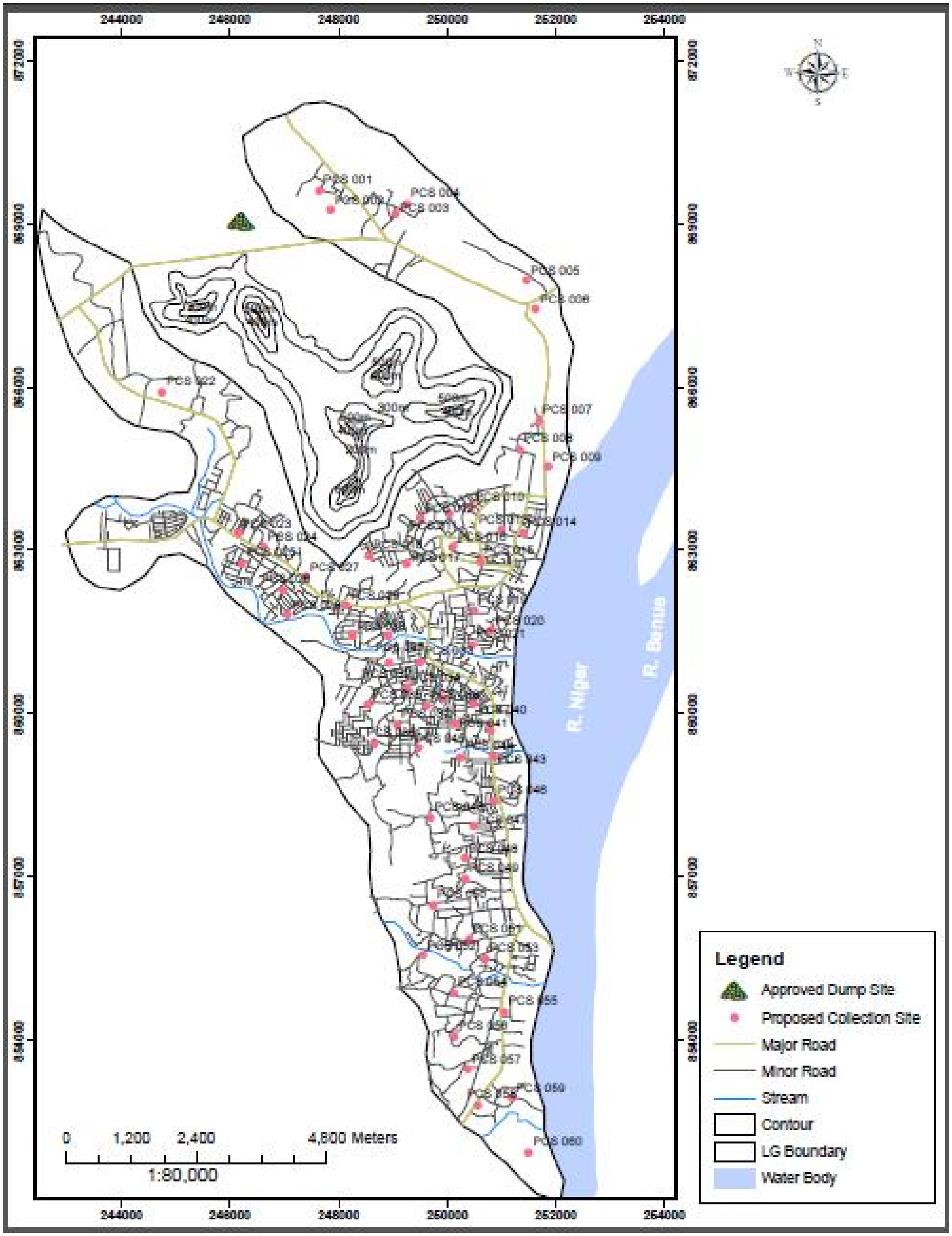

Fig 20: Lokoja showing proposed collection points along road networks

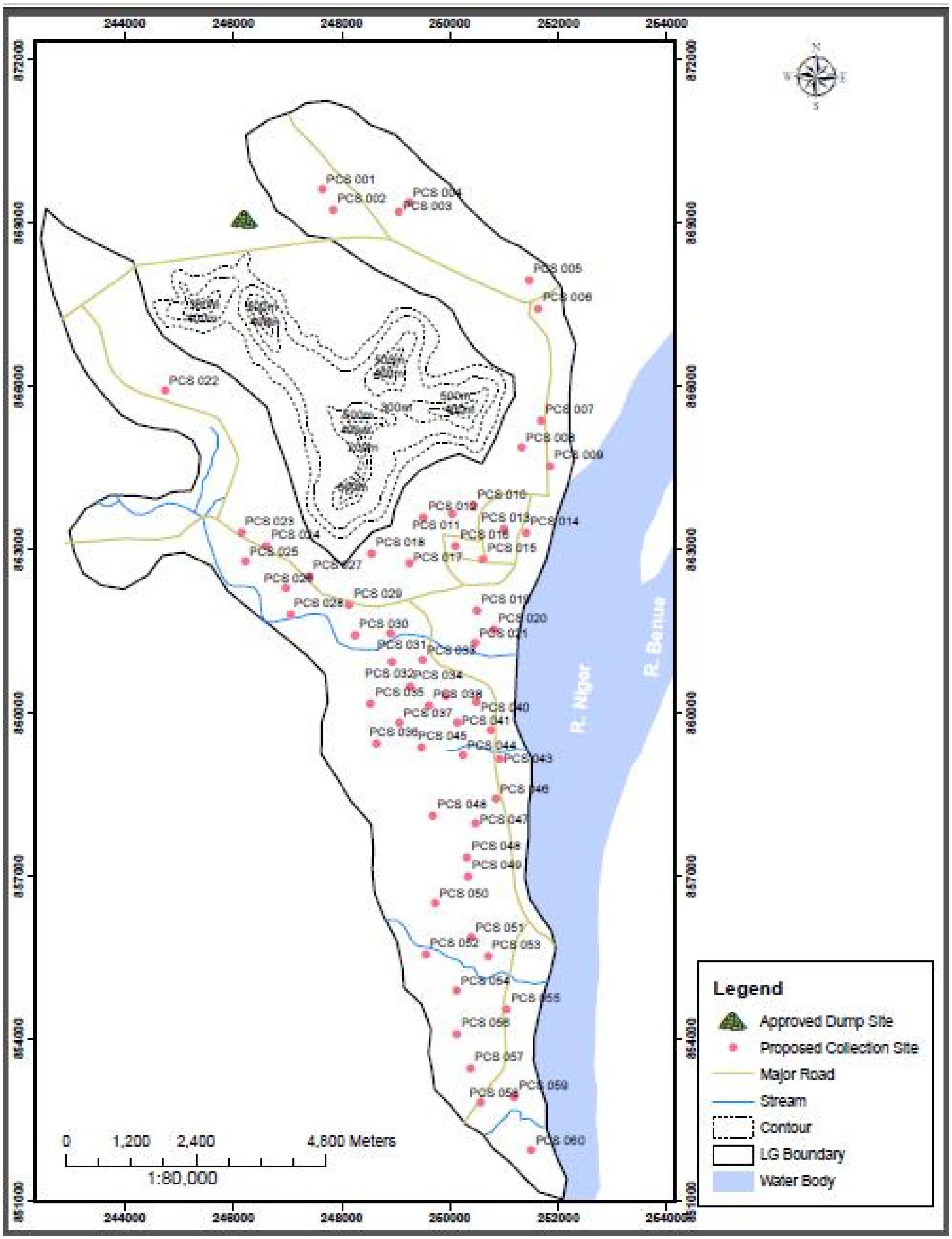

Fig 21: Lokoja showing proposed points of waste collection

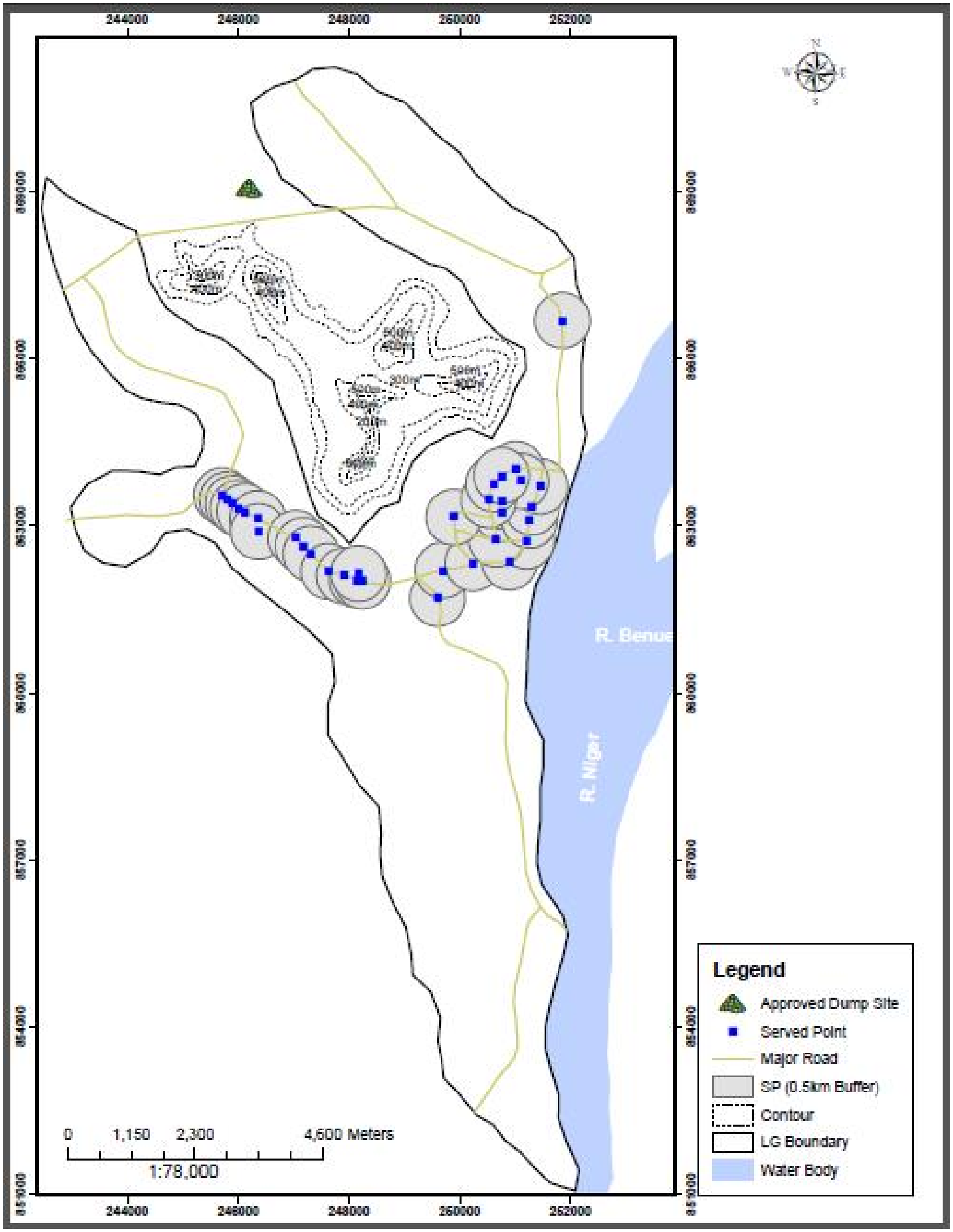

Fig 22: Lokoja showing buffered points served with drums

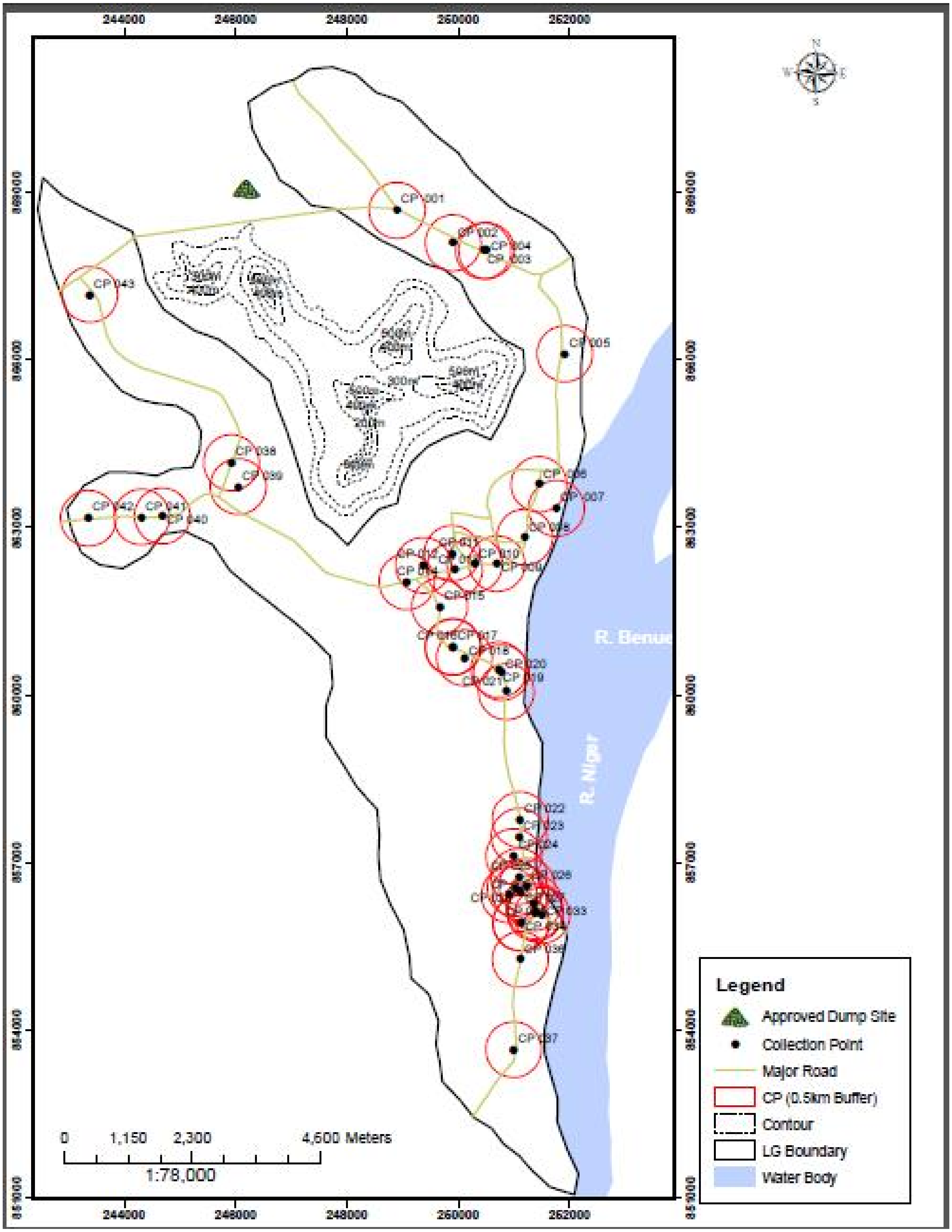

Fig 23:Lokoja showing buffered indiscriminate points.

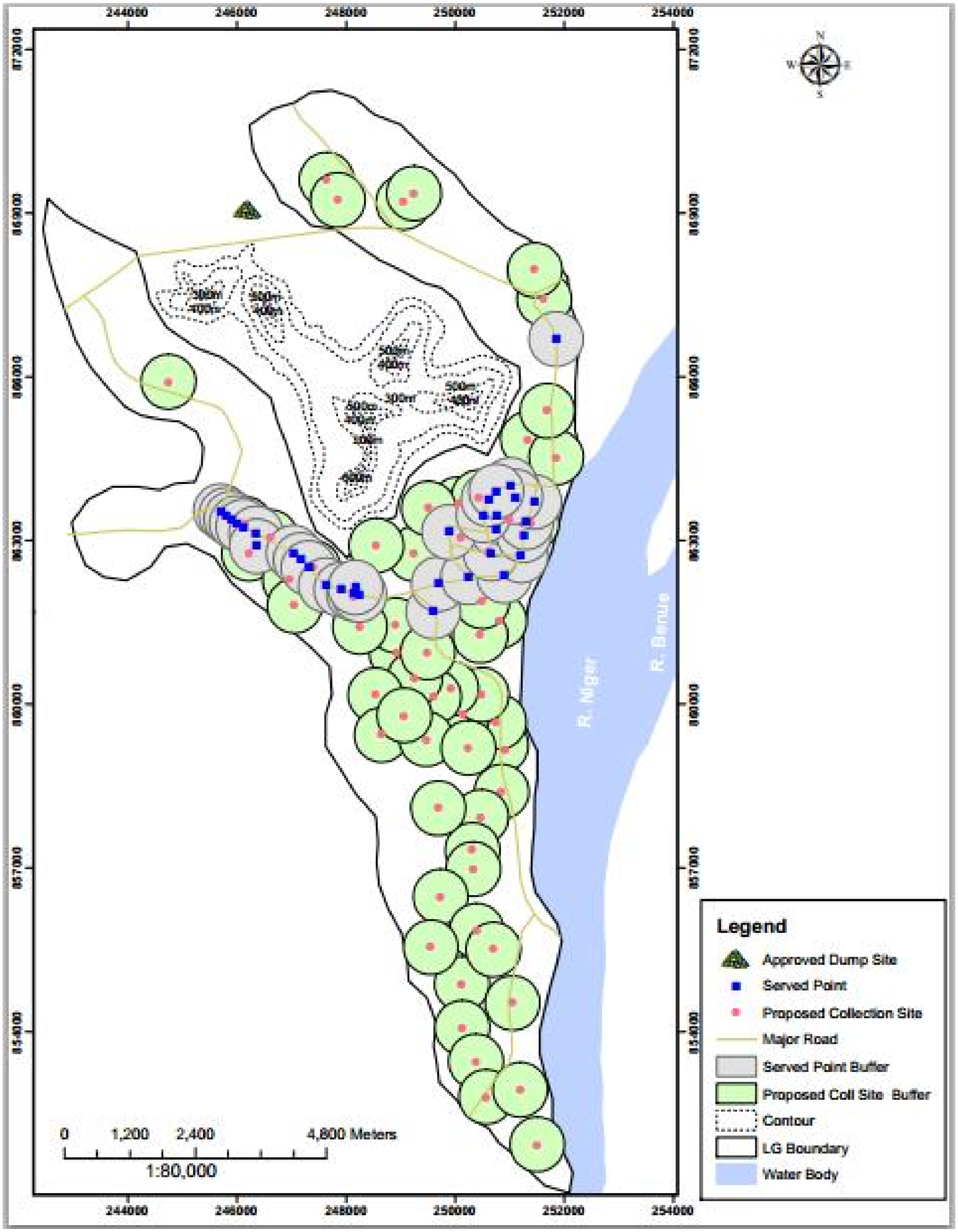

Fig 24: Lokoja showing buffered proposed collection and served points

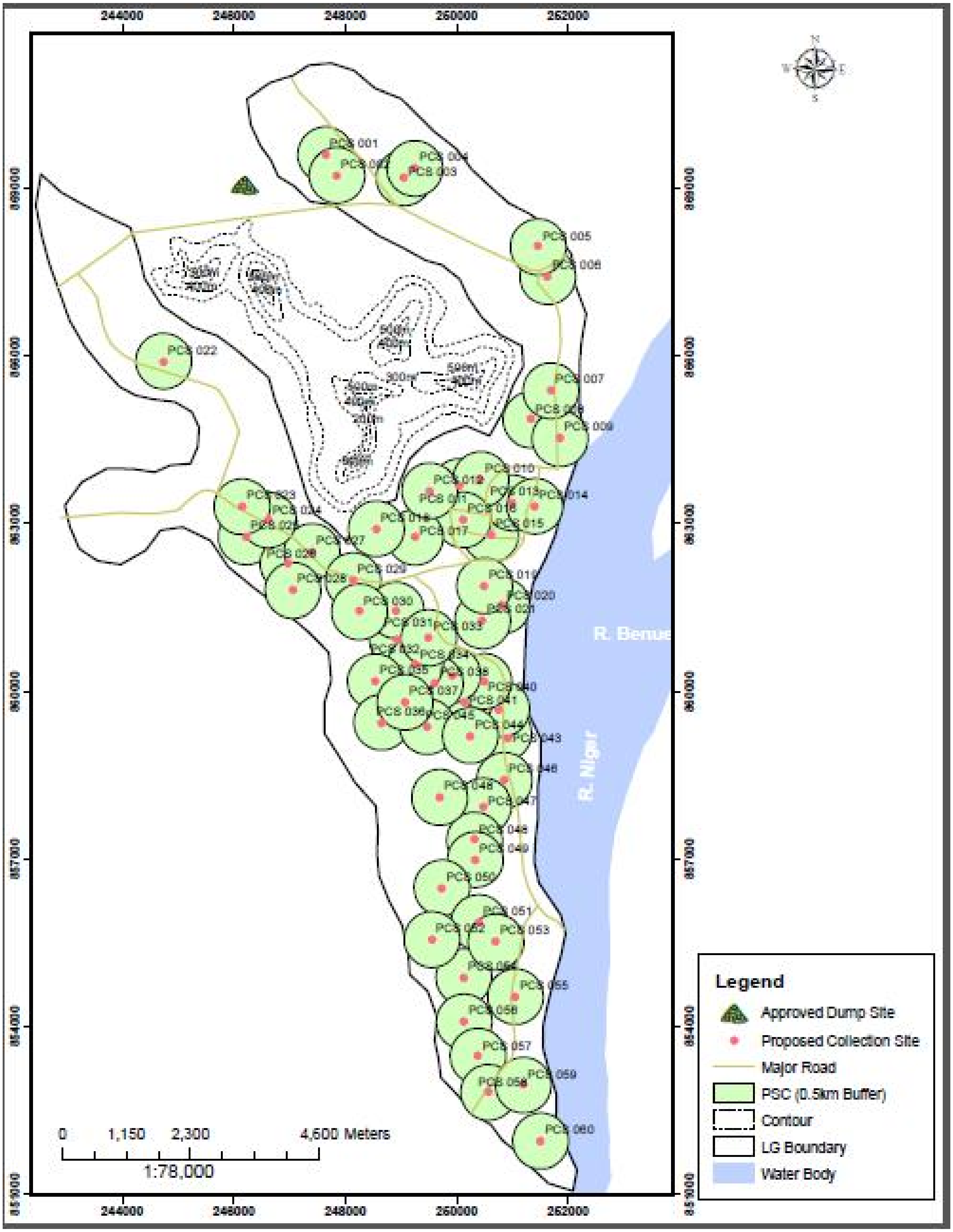

Fig 25:Lokoja showing buffered proposed collection points.

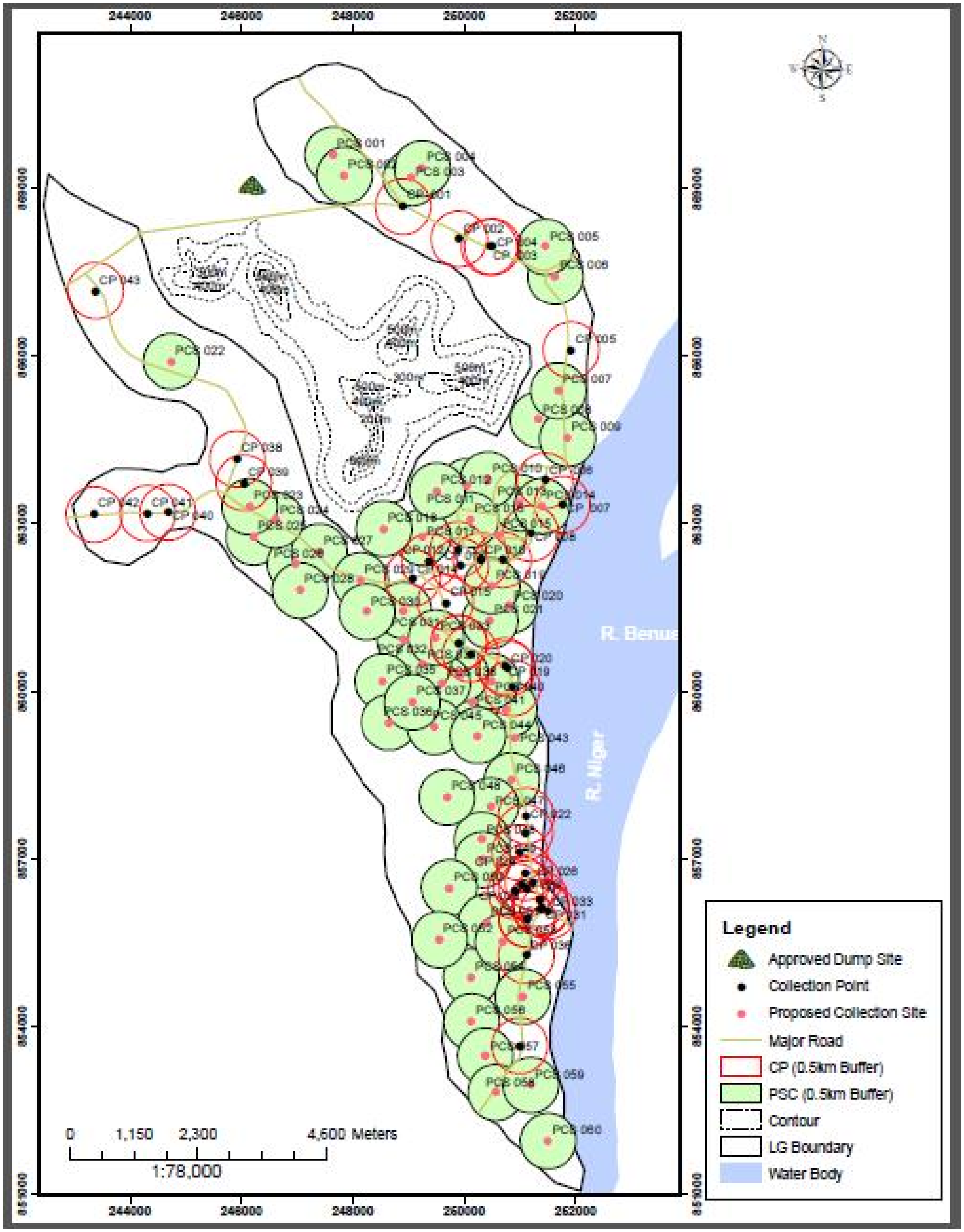

Fig. 26:Lokoja showing buffered zones of integrated site for dumpsters

CHAPTER FIVE

5.0. WASTE COLLECTION ROUTES OPTIMIZATION

In this chapter, GIS is used to model an optimal routing network that minimizes distance and cost for transporting MSW from a network of collection points to the approved dumpsite at *Crusher, Felele*. The network was developed to inform and optimize collection plans for the capital city of Kogi State, Lokoja. The work comprises three phases, following Tavares, Zsigraiova, Semiao and Carvalho(2009) : phase I creates a road network ñDATASETò using ArcGIS Network Analyst; phase II analyses and calculates the length of arcs along the road network that participated in the network; and phase III performs the optimisation of MSW collection for best routes and alternative routes by applying the ArcGIS Network Analyst. The application takes into account all the required parameters for waste collection so as to enable its desktop users model realistic network conditions and scenarios (Bhambulkar, 2011). In this case, the simulation consists of scenarios of visiting loading spots in Lokoja metropolis in order to collect Municipal Solid Waste that could not be collected by the KSSWMB waste collection crew due to location and other prohibitive factors. It also possesses a rich network attribute model that helps model impedances, restrictions, and hierarchy for the network. Hence, a thorough understanding of the problem scenario is essential for addressing this issue.

Following the application of Network Analyst to solid waste evacuation and disposal in Lokoja metropolis, three scenarios of waste management evacuation were produced. They are enumerated and analyzed below.

5.1. SCENARIO I : In the case of waste evacuation from Barracks, house of Assembly quarters and environs, to the approved refuse dumpsite at crusher, Felele, the best route from this points is shown in Fig 27. The route determines the quickest, shortest or most scenic route to the approved refuse dumpsite. Best route details and driving direction for KSSWMB crew are shown in Table 10.

Table 10: Best route analysis for scenario I

S/N	Driving Directions	Track Length
1	Start at Litered point (LP 042)	
2	Go east on Kabba Road Major Road	2.3 km
3	Arrive at Litered point (LP 041), on the left	
4	Depart Litered point (LP 041)	
5	Continue east on Kabba Road	0.9 km
6	Arrive at Litered point (LP 040), on the right	
7	Depart Litered point (LP 040)	
8	Continue east on Kabba road	2.8 km
9	Continue on Murtala Mohammed road	1.9 km
10	Turn right to stay on Murtala Mohammed road	0.2 km
11	Turn right to stay on Murtala Mohammed road	0.2 km
12	Turn left to stay on Murtala Mohammed road	0.1 km
13	Turn right to stay on Murtala Mohammed road	0.1 km
14	Depart Litered point (LP 025), on the left	
15	Depart Litered point (LP 025)	
16	Go back east on Murtala Mohammed	0.1 km
17	Turn left to stay on Murtala Mohammed road	0.1 km
18	Turn right to stay on Murtala Mohammed road	0.2 km
19	Turn left to stay on Murtala Mohammed road	0.2 km
20	Turn left on Murtala Mohammed way to stay on Muritala Mohammed road	0.1 km

21	**Arrive at Litered point (LP 024), on the left**	
22	**Depart Litered point (LP 024)**	
23	**Continue northwest on Murtala Mohammed way**	**1 km**
24	**Turn right**	**< 0.1 km**
25	**Arrive at Litered point (LP 023), on the right**	
26	**Depart Litered point (LP 023)**	
27	**Continue northeast**	**0.2 km**
28	**Turn left**	**0.3 km**
29	**Arrive at Litered point (LP 039), on the left**	
30	**Depart Litered point (LP 039)**	
31	**Continue northwest**	**0.2 km**
32	**Turn right**	**0.3 km**
33	**Arrive at Litered point (LP 038), on the right**	
34	**Depart Litered point (LP 038)**	
35	**Continue northwest**	**2.7 km**
36	**Turn right**	**0.6 km**
37	**Arrive at Litered point (LP 022), on the right**	
38	**Depart Litered point (LP 022)**	
39	**Go back northwest**	**2.2 km**
40	**Arrive at Litered point (LP 043), on the right**	
41	**Depart Litered point (LP 043)**	
42	**Continue northwest**	**0.3 km**
43	**Turn right**	**1.2 km**
44	**Finish at approved disposal site on the right**	
Total distance		**18.1 km**

Table 10 shows the analysis of driving direction for Best route for scenario I. Each of the arcs in this scenario map was analyzed in terms of direction and distance and the total distance to cover. The total distance of best route of waste evacuation for scenario I is 18.1km.

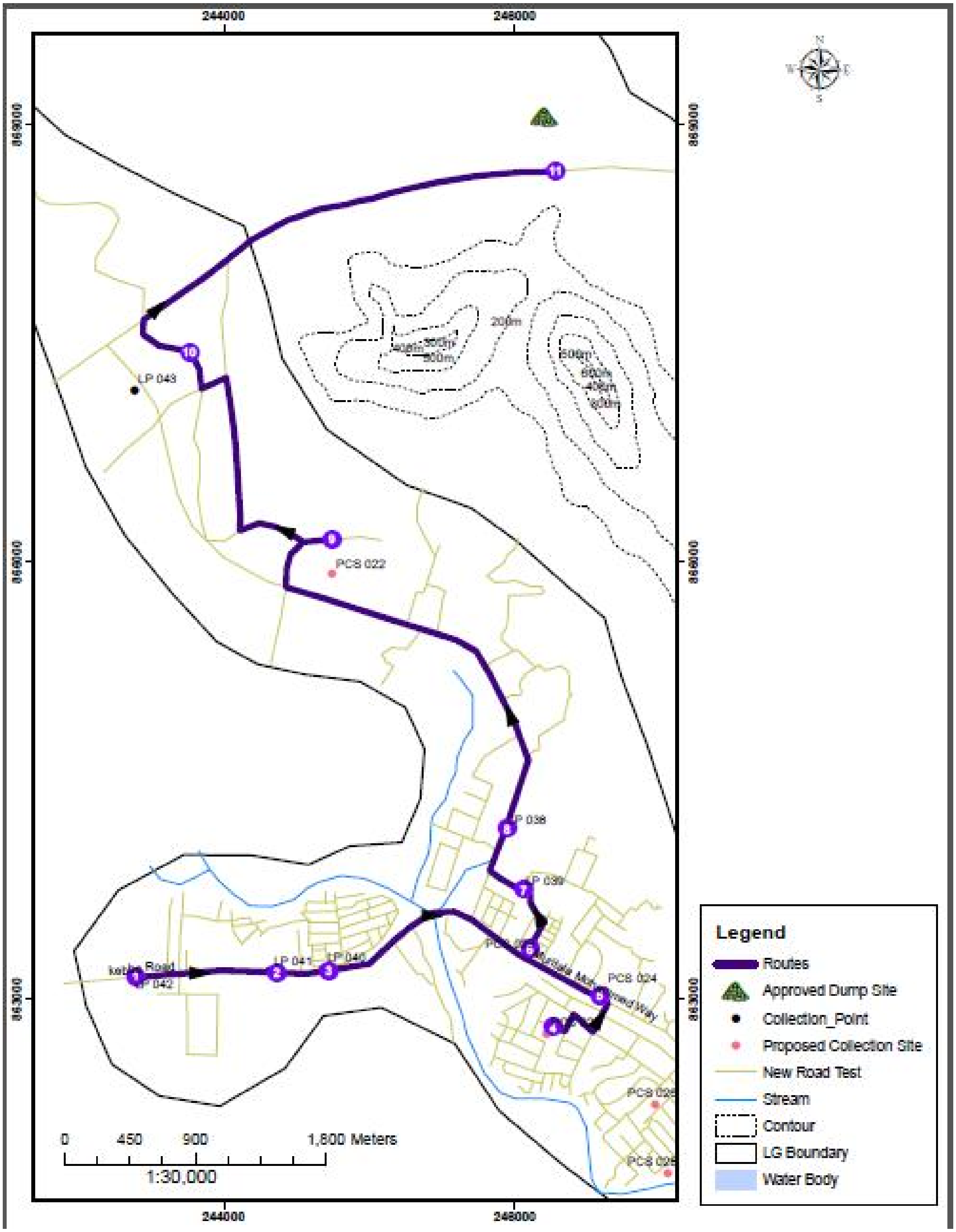

Fig 27: Lokoja showing Best Route for waste collection for Scenario 1

Conversely, there are situations whereby there are barriers on best route to a particular location. Barriers could be in the form of traffic, obstruction such as fallen trees, accident, as well as road maintenance that could lead to road closure. This therefore, would prompt the need for an alternative route. Peradventure, there is a traffic jam at Hassan Kastina junction when coming from Barracks and environs the alternative route to be taken will be to take through secretariat road to link up with Hassan Kastina road. Figure 28 shows the alternative route to be taken by KSSWMB crew to the approved dumpsite location. Alternative route details and driving directions for waste evacuation crew are shown in Table 11 where the summary of the total distance of the route is 18.5 km.

Tabe 11: Alternative route analysis for scenario I

S/N	Driving Directions	Track Length
1	Start at Litered point (LP 042)	
2	Go east on Kabba Road Major Road	2.3 km
3	Arrive at Litered point (LP 041), on the right	
4	Depart Litered point (LP 041)	
5	Continue east on Kabba Road	0.9 km
6	Go to stay on Kabba road	<0.1 km
7	Arrive at Litered point (LP 040), on the left	
8	Depart Litered point (LP 040)	
9	Go south on Kabba road	<0.1 km
10	Go at Kabba road to stay on Kabba road	2.7 km
11	Turn left	0.2 km
12	Turn right	0.5 km
13	Turn left on Murtala Mohammed way	1.5 km

14	**Turn right to stay on Murtala Mohammed way**	**0.2 km**
15	**Turn right to stay on Murtala Mohammed way**	**0.2 km**
16	**Turn left to stay on Murtala Mohammed way**	**0.1 km**
17	**Turn right to stay on Murtala Mohammed way**	**<0.1 km**
18	**Arrive at Littered point (LP 025), on the left**	
19	**Depart Littered point (LP 025)**	
20	**Go back east on Murtala Mohammed**	**<0.1 km**
21	**Turn left to stay on Murtala Mohammed way**	**0.1 km**
22	**Turn right to stay on Murtala Mohammed way**	**0.2 km**
23	**Turn left to stay on Murtala Mohammed way**	**0.2 km**
24	**Turn left at Murtala Mohammed way to stay on Murtala Mohammed way**	**0.1 km**
25	**Arrive at Littered point (LP 024), on the right**	
26	**Depart Littered point (LP 024)**	
27	**Continue northwest on Murtala Mohammed way**	**1 km**
28	**Turn right**	**<0.1 km**
29	**Arrive at Littered point (LP 023), on the right**	
30	**Depart Littered point (LP 023)**	
31	**Continue northaest**	**0.2 km**
32	**Turn left**	**0.3 km**
33	**Turn right**	**<0.1 km**
34	**Arrive at Littered point (LP 039), on the right**	
35	**Depart Littered point (LP 023)**	
36	**Go back southwest**	**<0.1 km**
37	**Turn right**	**0.3 km**

38	**Turn right**	**0.3 km**
39	**Arrive at Litered point (LP 038), on the right**	
40	**Depart Litered point (LP 038)**	
41	**continue northwest**	**2.7 km**
42	**Turn right**	**0.5 km**
43	**Arrive at Litered point (LP 022), on the left**	
44	**Depart Litered point (LP 022)**	
45	**Go back west**	**0.7 km**
46	**Make sharp right**	**1.1 km**
47	**Turn left**	**0.2 km**
48	**Turn right**	**0.3 km**
49	**Arrive at Litered point (LP 043), on the left**	
50	**Depart Litered point (LP 043)**	
51	**Go northwest**	**0.4 km**
52	**Turn right**	**0.9 km**
53	**Finish at approved disposal site on the left**	
Total distance		**18.5 km**

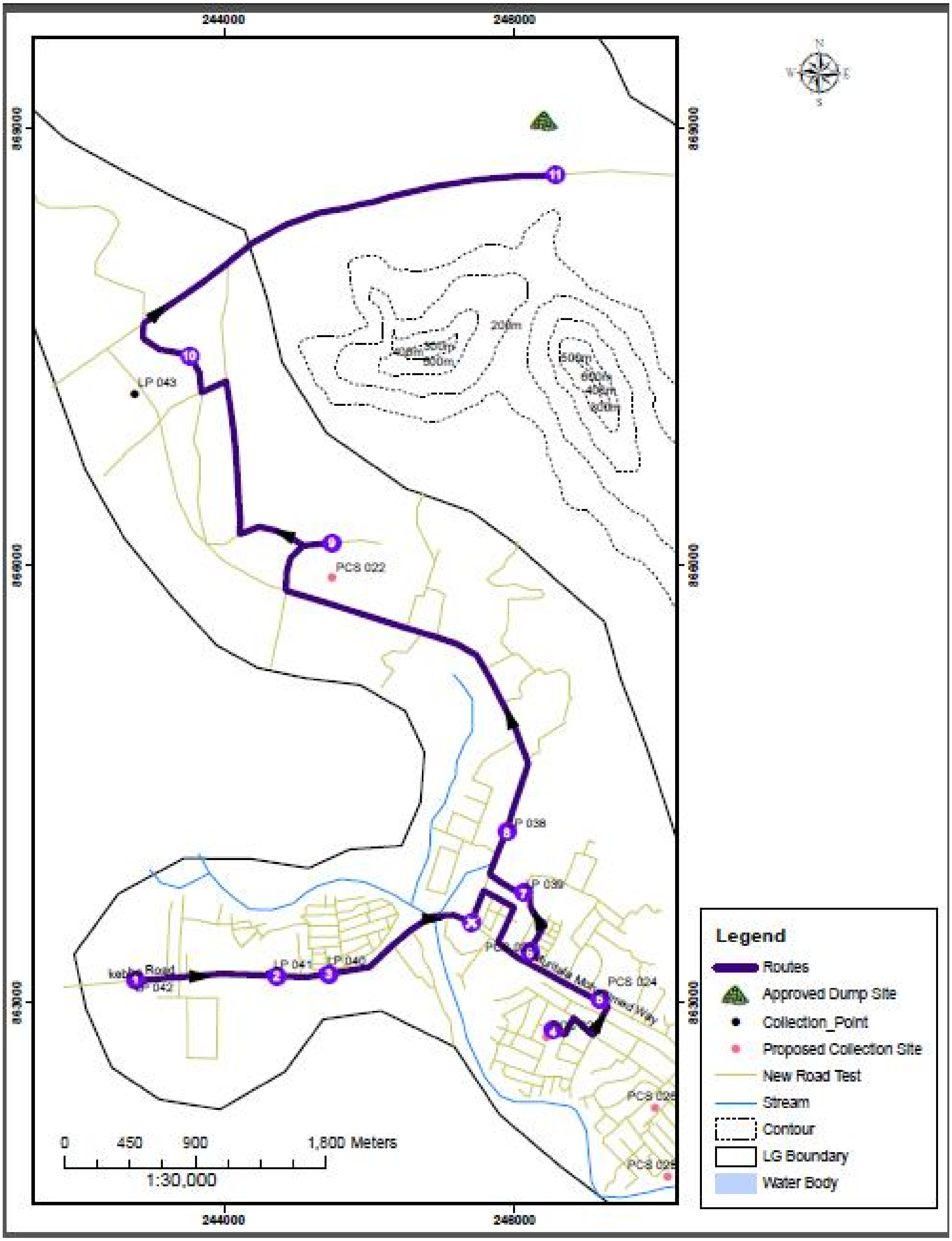

Fig 28: Lokoja showing Alternative Route for waste collection for Scenario 1

5.2. SCENARIO II: There is need to evacuate solid waste from Taiwo road, Kupoloti street and environs through Lokoja-Ankpa road using an appropriate route to the approved dumpsite. Figure 29 shows the best route to be taken by KSSWMB crew linking this location. Incidentally, traffic (barrier) could be at Taiwo road junction following closeness to old market and aggregation of north-east-bound vehicles in the area. Thus, this will necessitate the need for alternative route. The alternative route to be taken will be to take through new layout road through Rafiu Kupoloti street and then link up with Hammed Bello way. Figure 30 shows the alternative route to be taken by KSSWMB linking this location.

Table 12: Best Route analysis for scenario II

S/N	Driving Directions	Track Length
1	Start at proposed point (PCS 011)	
2	Go south east on Ado Ibrahim Patti road	0.3 km
3	Turn left on new layout road	0.8 km
4	Make sharp right	0.2 km
5	Arrive at proposed point (PCS 010), on the right	
6	Depart proposed point (PCS 010)	
7	Go back northeast	<0.1 km
8	Turn right	0.1 km
9	Turn right on Taiwo road	0.5 km
10	Turn left on Lugard road	0.5 km
11	Turn left on Rafiu Kupoloti street	<0.1 km
12	Arrive at proposed point (PCS 013), on the right	
13	Depart proposed point (PCS 013)	
14	Go back south on Rafiu Kupoloti strret	<0.1 km
15	Turn left on Lugard road	0.2 km

16	**Bear right on Aliu Close**	**0.2 km**
17	**Turn left**	**<0.1 km**
18	**Arrive at proposed point (PCS 014), on the left**	
19	**Depart proposed point (PCS 014)**	
20	**Continue north**	**0.2 km**
21	**Turn left**	**0.1 km**
22	**Turn right on Lokoja Ankpa road**	**0.2 km**
23	**Arrive at proposed point (PCS 006), on the left**	
24	**Depart proposed point (PCS 006)**	
25	**Go south on Lokoja Ankpa road**	**<0.1 km**
26	**Go on LGA Secretariat road**	**0.4 km**
27	**Turn right on beach road**	**1.6 km**
28	**Arrive at Litered point (LP 007), on the left**	**1.6 km**
29	**Depart Litered point (LP 007)**	
30	**Go back north on beach road**	**1.6 km**
31	**Turn left on LGA secretariat road**	**0.4 km**
32	**Turn right on Lokoja Ankpa road**	**0.2 km**
33	**Turn right at Taiwo Road / Muritala Mohammed way to stay on Lokoja Ankpa road**	
34	**Turn left on Hammed Bello way**	**0.7 km**
35	**Arrive at proposed point (PCS 009), on the right**	
36	**Depart proposed point (PCS 009)**	
37	**Continue north on Hammed Bello way**	**0.8 km**
38	**Turn left on Sadauna street**	**0.7 km**
39	**Arrive at proposed point (PCS 008), on the left**	

40	Depart proposed point (PCS 008)	
41	Go back northeast on Sadauna street	0.6 km
42	Turn left	0.2 km
43	Turn right	<0.1 km
44	Turn left on Hammed Bello way	<0.1 km
45	Arrive at proposed point (PCS 007), on the right	
46	Depart proposed point (PCS 007)	
47	Continue north on Hammed Bello way	1 km
48	Arrive at Litered point (LP 005), on the right	
49	Depart Litered point (LP 005)	
50	Continue north on Hammed Bello way	2 km
51	Turn right	<0.1 km
52	Arrive at proposed point (PCS 006), on the right	
53	Depart proposed point (PCS 006)	
54	Continue northeast	0.3 km
55	Turn left	0.4 km
56	Arrive at Proposed Point (PCS 005), on the right	
57	Depart proposed point (PCS 005)	
58	Go back south east	0.4 km
59	Turn right	1.5 km
60	Arrive at Litered point (LP 003 and LP 004), on the left	
61	Depart Litered point (LP 003 and LP 004)	
62	Continue northwest	0.5 km
63	Arrive at Litered point (LP 002), on the right	

64	**Depart Litered point (LP 002)**	
65	**Continue northwest**	**1.2 km**
66	**Bear right on Abuja road**	**<0.1 km**
67	**Arrive at Litered point (LP 001), on the right**	
68	**Depart Litered point (LP 001)**	
69	**Go northwest on Abuja road**	**0.5 km**
70	**Turn right**	**0.4 km**
71	**Turn right**	**0.3 km**
72	**Turn right**	**0.1 km**
73	**Arrive at Proposed Point (PCS 016), on the left**	
74	**Depart proposed point (PCS 016)**	
75	**Go back north**	**0.1 km**
76	**Turn right**	**0.2 km**
77	**Arrive at Proposed Point (PCS 017), on the left**	
78	**Depart proposed point (PCS 017)**	
79	**Go back northwest**	**0.5 km**
80	**Turn left**	**0.4 km**
81	**Turn right on Abuja road**	**0.5 km**
82	**Arrive at Proposed Point (PCS 002), on the left**	
83	**Depart proposed point (PCS 002)**	
84	**Continue northwest on Abuja road**	**0.3 km**
85	**Make sharp left to stay on Abuja road**	**0.2 km**
86	**Turn right to stay on Abuja road**	**0.1 km**
87	**Turn left to stay on Abuja road**	**0.3 km**
88	**Arrive at Proposed Point (PCS 001), on the left**	

89	**Depart proposed point (PCS 001)**	
90	**Go back east on Abuja road**	**0.3 km**
91	**Turn right to stay on Abuja road**	**0.1 km**
92	**Turn left to stay on Abuja road**	**0.2 km**
93	**Make sharp right at Abuja road to stay on Abuja road**	**0.8 km**
94	**Turn right**	**0.4 km**
95	**Turn right**	**0.6 km**
96	**Finish at approved disposal site on the left**	
Total distance	**25.1 km**	

Table 13: Alternative route analysis for scenario II

S/N	**Driving Directions**	**Track Length**
1	**Start at proposed point (PCS 011)**	
2	**Go south east on Ado Ibrahim Patti road**	**0.3 km**
3	**Turn left on new layout road**	**0.8 km**
4	**Make sharp right to stay on new layout road**	**0.2 km**
5	**Arrive at proposed point (PCS 010), on the right**	
6	**Depart proposed point (PCS 010)**	
7	**Go back northeast on new layout road**	**0.2 km**
8	**Turn right at new layout road to stay on new layout road**	**0.1 km**
9	**Turn left on Taiwo road**	**0.4 km**
10	**Turn right on Rafiu Kupoloti street**	**0.6 km**
11	**Arrive at proposed point (PCS 013), on the left**	
12	**Depart proposed point (PCS 013)**	

13	continue south on Rafiu Kupoloti strret	<0.1 km
14	Turn left on Lugard road	0.2 km
15	Bear right on Aliu Close	0.2 km
16	Turn left	<0.1 km
17	Arrive at proposed point (PCS 014), on the left	
18	Depart proposed point (PCS 014)	
19	Continue north	0.2 km
20	Turn left	0.1 km
21	Turn right on Lokoja Ankpa road	0.2 km
22	Arrive at Litered point (LP 006), on the left	
23	Depart Litered point (LP 006)	
24	Go south on Lokoja Ankpa road	<0.1 km
25	Go on LGA Secretariat road	0.4 km
26	Turn right on beach road	1.6 km
27	Arrive at Litered point (LP 007), on the left	
28	Depart Litered point (LP 007)	
29	Go back north on beach road	1.6 km
30	Turn left on LGA secretariat road	0.4 km
31	Turn right on Lokoja Ankpa road	0.2 km
32	Turn right at Taiwo Road / Muritala Mohammed way to stay on Lokoja Ankpa road	0.3 km
33	Turn left on Hammed Bello way	0.7 km
34	Arrive at proposed point (PCS 009), on the right	
35	Depart proposed point (PCS 009)	
36	Continue north on Hammed Bello way	0.8 km

37	Turn left on Sadauna street	0.7 km
38	Arrive at proposed point (PCS 008), on the left	
39	Depart proposed point (PCS 008)	
40	Go back northeast on Sadauna strret	0.6 km
41	Turn left	0.2 km
42	Turn right	<0.1 km
43	Turn left on Hammed Bello way	<0.1 km
44	Arrive at proposed point (PCS 007), on the right	
45	Depart proposed point (PCS 007)	
46	Continue north on Hammed Bello way	1 km
47	Arrive at Litered point (LP 005), on the right	
48	Depart Litered point (LP 005)	
49	Continue north on Hammed Bello way	2 km
50	Turn right	<0.1 km
51	Arrive at proposed point (PCS 006), on the right	
52	Depart proposed point (PCS 006)	
53	Continue northeast	0.3 km
54	Turn left	0.4 km
55	Arrive at Proposed Point (PCS 005), on the right	
56	Depart proposed point (PCS 005)	
57	Go back south east	0.4 km
58	Turn right	1.5 km
59	Arrive at Litered point (LP 003 and LP 004), on the left	
60	Depart Litered point (LP 003 and LP 004)	

61	**Continue northwest**	**0.5 km**
62	**Arrive at Litered point (LP 002), on the right**	
63	**Depart Litered point (LP 002)**	
64	**Continue northwest**	**1.2 km**
65	**Bear right on Abuja road**	**<0.1 km**
66	**Arrive at Litered point (LP 001), on the right**	
67	**Depart Litered point (LP 001)**	
68	**Go northwest on Abuja road**	**0.5 km**
69	**Turn right**	**0.4 km**
70	**Turn right**	**0.3 km**
71	**Turn right**	**0.1 km**
72	**Arrive at Proposed Point (PCS 016), on the left**	
73	**Depart proposed point (PCS 016)**	
74	**Go back north**	**0.1 km**
75	**Turn right**	**0.2 km**
76	**Arrive at Proposed Point (PCS 017), on the left**	
77	**Depart proposed point (PCS 017)**	
78	**Go back northwest**	**0.5 km**
79	**Turn left**	**0.4 km**
80	**Turn right on Abuja road**	**0.5 km**
81	**Arrive at Proposed Point (PCS 002), on the left**	
82	**Depart proposed point (PCS 002)**	
83	**Continue northwest on Abuja road**	**0.3 km**
84	**Make sharp left to stay on Abuja road**	**0.2 km**
85	**Turn right to stay on Abuja road**	**0.1 km**

86	**Turn left to stay on Abuja road**	**0.3 km**
87	**Arrive at Proposed Point (PCS 001), on the right**	
88	**Depart proposed point (PCS 001)**	
89	**Go back east on Abuja road**	**0.3 km**
90	**Turn right to stay on Abuja road**	**0.1 km**
91	**Turn left to stay on Abuja road**	**0.2 km**
92	**Make sharp right at Abuja road to stay on Abuja road**	**0.8 km**
93	**Turn right**	**0.4 km**
94	**Turn right**	**0.6 km**
95	**Finish at approved disposal site on the left**	
Total distance		**25.2 km**

Tables 12 and 13 show the analysis of driving directions and distances for best route and alternative route. The total distance for the best route is 25.1 km and alternative route distance is 25.2 km. Relatively, a difference of 0.1 km (100 m) shows that in the event of obstruction along the best route, this alternative route is preferred since it is only in excess of 100 metres.

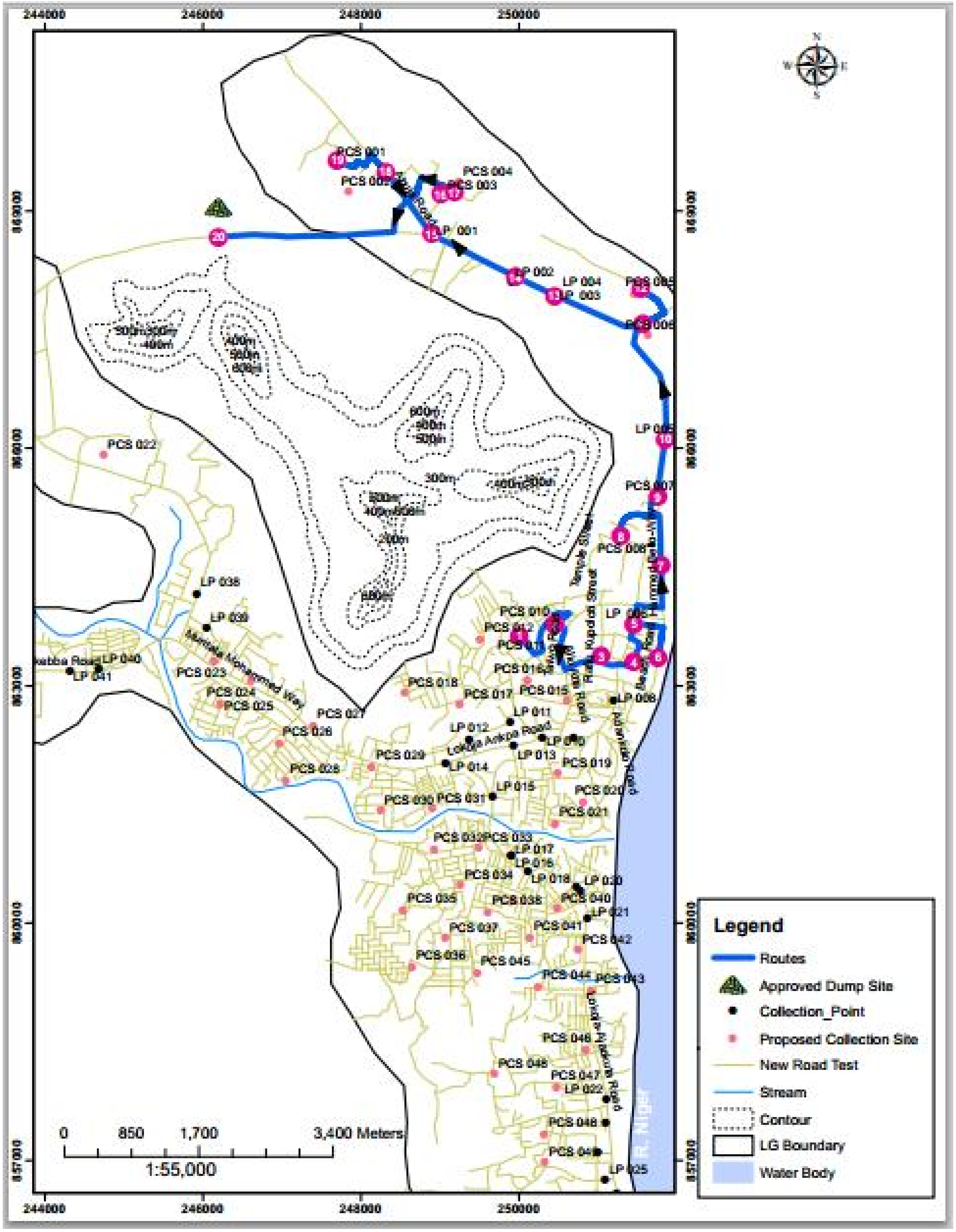

Fig 29: Lokoja showing Best Route for waste collection for Scenario II

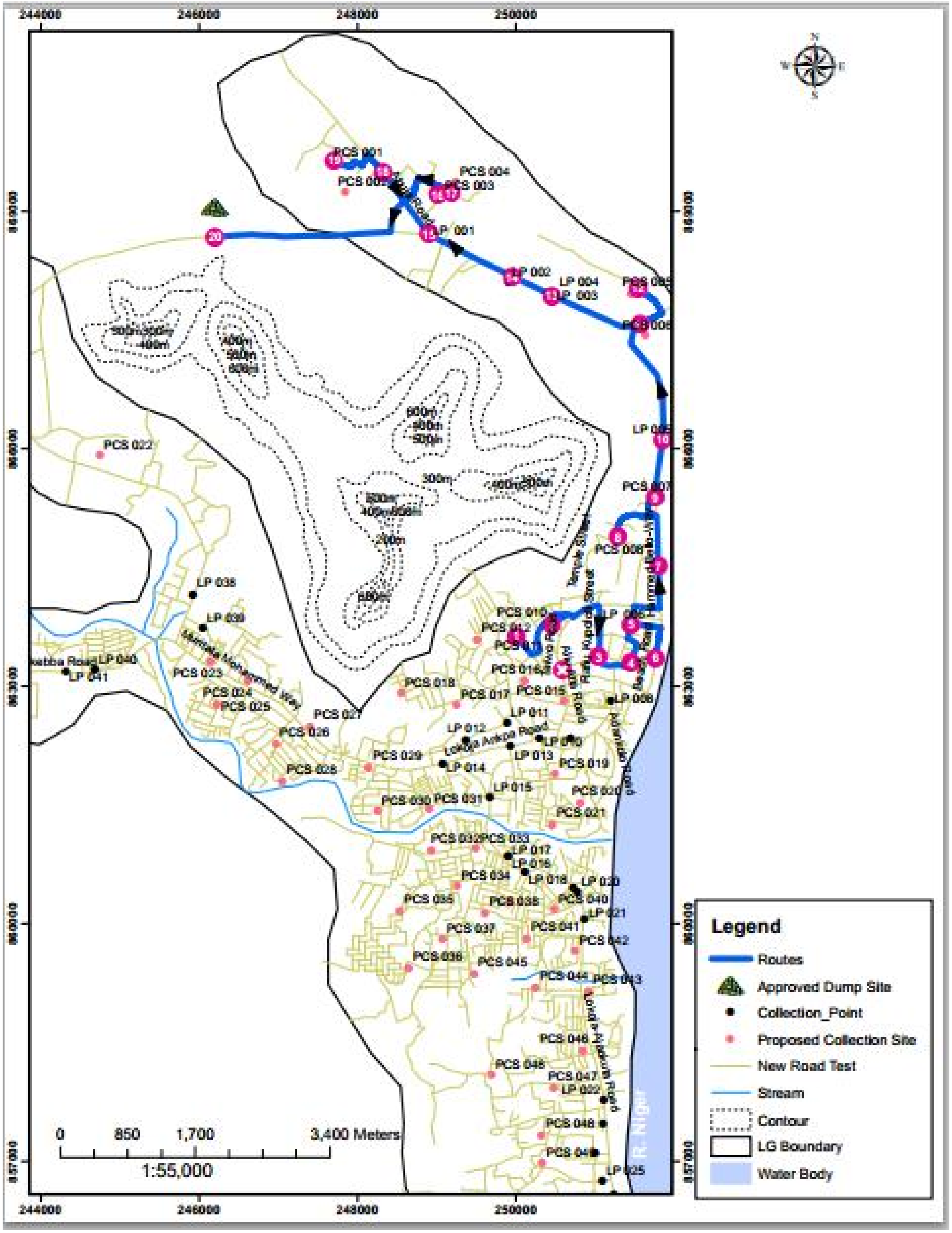

Fig 30. Lokoja showing Alternative Route for waste collection for Scenario II

5.3. SCENARIO III: In the case of evacuating solid waste from locations in the Ganaja axis, best route was optimized for easy transfer of waste. Figure 31 shows the best route to be taken by KSSWMB crew linking locations along the route. Best route details and directions for KSSWMB crew are analyzed in Table 14. Again, Traffic congestion (barrier denoted by red star on the alternative route map) could be at Ganaja junction following business activities, location of park at the junction. Thus, this will necessitate the need for alternative route. The alternative route to be taken will be to link through new layout road through Adankolo road and then link up with Hammed Bello way as illustrated in Figure 32. with driving details spelt out in Table 15.

Table 14: Best Route analysis for scenario III

S/N	Driving Directions	Track Length
1	Start at proposed point (PCS 058)	
2	Go northeast	0.2 km
3	Turn right	0.7 km
4	Arrive at Proposed point (PCS 059) on the right	
5	Depart Proposed point (PCS 059)	
6	Go back west	0.4 km
7	Turn right	0.2 km
8	Turn left	0.2 km
9	Turn right	0.8 km
10	Turn left	0.2 km
11	Turn left	<0.1 km
12	Turn right	0.2 km
13	Turn left	0.3 km

14	**Turn right**	**0.2 km**
15	**Arrive at Proposed Point(PCS 057), on the left**	
16	**Depart Proposed point (PCS 057)**	
17	**Go back east**	**0.2 km**
18	**Turn left**	**0.3 km**
19	**Turn right**	**0.2 km**
20	**Turn left**	**<0.1 km**
21	**Turn right**	**0.2 km**
22	**Turn right**	**0.4 km**
23	**Arrive at Litered point (LP 037), on the left**	
24	**Depart Litered point (LP 037)**	
25	**Go back north**	**0.4 km**
26	**Turn left**	**1.4 km**
27	**Turn right**	**<0.1 km**
28	**Arrive at proposed point (PCS 056),on the left**	
29	**Depart proposed point (PCS 056)**	
30	**Go back west**	**<0.1 km**
31	**Make sharp right**	**0.5 km**
32	**Turn right**	**0.2 km**
33	**Turn left**	**0.1 km**
34	**Turn right**	**0.5 km**
35	**Turn right**	**<0.1 km**
36	**Arrive at proposed point (PCS 056),on the left**	
37	**Depart proposed point (PCS 056)**	
38	**Go back north**	**<0.1 km**

39	**Turn left**	**0.5 km**
40	**Turn righ**	**0.1 km**
41	**Make sharp left**	**0.5 km**
42	**Turn right**	**<0.1 km**
43	**Arrive at proposed point (PCS 054),on the right**	
44	**Depart proposed point (PCS 054)**	
45	**Go back southwest**	**<0.1 km**
46	**Turn left**	**0.5 km**
47	**Turn left**	**<0.1 km**
48	**Turn right**	**0.4 km**
49	**Turn left**	**0.5 km**
50	**Arrive at proposed point (PCS 036),on the right**	
51	**Depart proposed point (PCS 036)**	
52	**Continue north**	**<0.1 km**
53	**Turn left**	**0.3 km**
54	**Turn left**	**0.1 km**
55	**Arrive at proposed point (PCS 053),on the left**	
56	**Depart proposed point (PCS 053)**	
57	**Go northwest**	**0.6 km**
58	**Turn left**	**0.4 km**
59	**Turn right**	**0.5 km**
60	**Turn left**	**0.5 km**
61	**Arrive at proposed point (PCS 036),on the right**	
62	**Depart proposed point (PCS 036)**	
63	**Go back northeast**	**0.5 km**

64	**Turn right**	**0.5 km**
65	**Turn left**	**0.4 km**
66	**Make sharp left**	**<0.1 km**
67	**Arrive at proposed point (PCS 051),on the right**	
68	**Depart proposed point (PCS 051)**	
69	**Go back southeast**	**<0.1 km**
70	**Turn left**	**0.6 km**
71	**Arrive at Litered point (LP 035), on the right**	
72	**Depart Litered point (LP 035)**	
73	**Continue east**	**0.2 km**
74	**Turn left**	**0.3 km**
75	**Turn left on Ajaokuta road**	**6.2 km**
76	**Bear right**	**0.6 km**
77	**Turn left on Sule Oyidi street**	**0.2 km**
78	**Turn right on Lokoja Ankpa road**	**2.8 km**
79	**Continue on Muritala Mohammed way**	**0.8 km**
80	**Turn left on Temple street**	**0.3 km**
81	**Turn right on Sadauna street**	**0.6 km**
82	**Turn left**	**0.2 km**
83	**Turn right**	**<0.1 km**
84	**Turn left on Hammed Bello way**	**3.1 km**
85	**Turn left**	**4 km**
86	**Finish at Approved disposal site**	
Total distance	**35 km**	

Table 15: Alternative route analysis for scenario III

S/N	Driving Directions	Track Length
1	Start at proposed point (PCS 058)	
2	Go northeast	0.2 km
3	Turn right	0.7 km
4	Arrive at Proposed point (PCS 059) on the right	
5	Depart Proposed point (PCS 059)	
6	Go back west	0.4 km
7	Turn right	0.2 km
8	Turn left	0.2 km
9	Turn right	0.8 km
10	Turn left	0.2 km
11	Turn left	<0.1 km
12	Turn right	0.2 km
13	Turn left	0.3 km
14	Turn right	0.2 km
15	Arrive at Proposed Point(PCS 057), on the left	
16	Depart Proposed point (PCS 057)	
17	Go back east	0.2 km
18	Turn left	0.3 km
19	Turn right	0.2 km
20	Turn left	<0.1 km
21	Turn right	0.2 km
22	Turn right	0.4 km
23	Arrive at Litered point (LP 037), on the left	

24	Depart Litered point (LP 037)	
25	Go back north	0.4 km
26	Turn left	1.4 km
27	Turn right	<0.1 km
28	Arrive at proposed point (PCS 056),on the left	
29	Depart proposed point (PCS 056)	
30	Go back west	<0.1 km
31	Make sharp right	0.5 km
32	Turn right	0.2 km
33	Turn left	0.1 km
34	Turn right	0.5 km
35	Turn right	<0.1 km
36	Arrive at proposed point (PCS 056),on the left	
37	Depart proposed point (PCS 056)	
38	Go back north	<0.1 km
39	Turn left	0.5 km
40	Turn righ	0.1 km
41	Make sharp left	0.5 km
42	Turn right	<0.1 km
43	Arrive at proposed point (PCS 054),on the right	
44	Depart proposed point (PCS 054)	
45	Go back southwest	<0.1 km
46	Turn left	0.5 km
47	Turn left	<0.1 km
48	Turn right	0.4 km

49	**Turn left**	**0.5 km**
50	**Arrive at proposed point (PCS 036),on the right**	
51	**Depart proposed point (PCS 036)**	
52	**Continue north**	**<0.1 km**
53	**Turn left**	**0.3 km**
54	**Turn left**	**0.1 km**
55	**Arrive at proposed point (PCS 053),on the left**	
56	**Depart proposed point (PCS 053)**	
57	**Go northwest**	**0.6 km**
58	**Turn left**	**0.4 km**
59	**Turn right**	**0.5 km**
60	**Turn left**	**0.5 km**
61	**Arrive at proposed point (PCS 036),on the right**	
62	**Depart proposed point (PCS 036)**	
63	**Go back northeast**	**0.5 km**
64	**Turn right**	**0.5 km**
65	**Turn left**	**0.4 km**
66	**Make sharp left**	**<0.1 km**
67	**Arrive at proposed point (PCS 051),on the right**	
68	**Depart proposed point (PCS 051)**	
69	**Go back southeast**	**<0.1 km**
70	**Turn left**	**0.6 km**
71	**Arrive at Litered point (LP 035), on the right**	
72	**Depart Litered point (LP 035)**	
73	**Continue east**	**0.2 km**

74	**Turn left**	**0.3 km**
75	**Turn left on Lokoja Ajaokuta road**	**6.0 km**
76	**Turn right**	**0.3 km**
77	**Turn left**	**0.3 km**
78	**Turn right**	**<0.1 km**
79	**Turn left on Sule Oyidi street**	**0.3 km**
80	**Turn right**	**1 km**
81	**Turn left at Adankolo road**	**0.5 km**
82	**Bear right on Lokoja Ankpa road**	**1.7 km**
83	**Continue on Muritala Mohammed way**	**0.8 km**
84	**Turn left on temple street**	**0.3 km**
85	**Turn right on Sadauna Street**	**0.6 km**
86	**Turn left**	**0.2 km**
87	**Turn right**	**<0.1 km**
88	**Turn left on Hammed Bello way**	**3.1 km**
89	**Turn left**	**4 km**
90	**Finish at Approved disposal site, on the right**	
Total Distance		**35. 1 km**

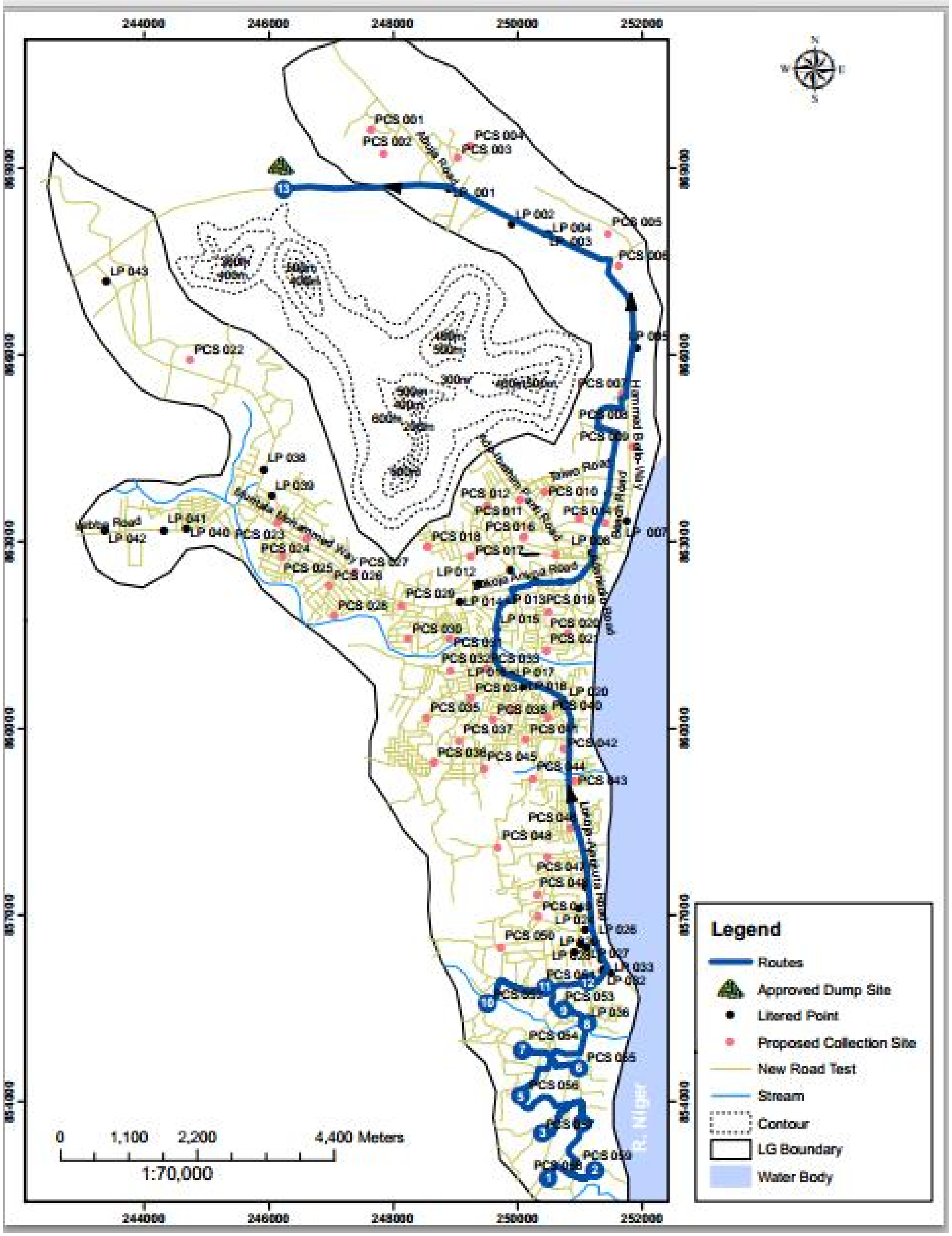

Fig 31: Lokoja showing Best Route for waste collection for Scenario III

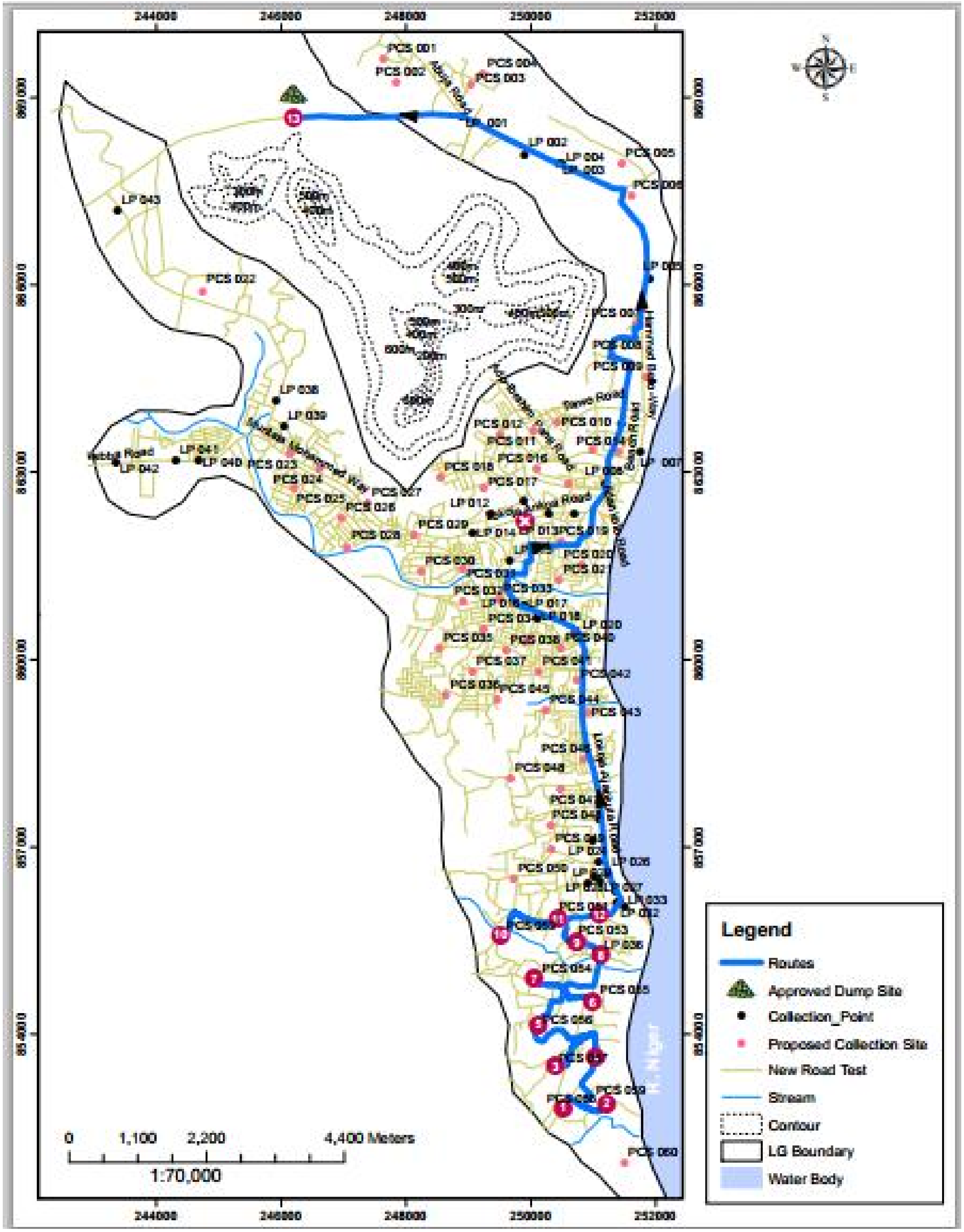

Fig 32. Lokoja showing Alternative Route for waste collection for Scenario III

CHAPTER SIX

6.1 SUMMARY, RECOMMENDATIONS AND CONCLUSION

The investigation of optimization of municipal solid waste collection and disposal for Lokoja metropolis, Kogi State, Nigeria has, no doubt revealed insights into the existing waste management practices in the city. The summary of the findings of waste management practices in Lokoja are presented below.

- Results of waste management system in Lokoja metropolis indicates that waste management in Lokoja is still at rudimentary stage. Result of availability of dumpsters in the city indicates that only 12.6% of the respondents betokened availability of dumpsters while 81.3% objects to availability of dumpsters.
- Equally, on disposal system, the result of waste disposal method shows that open dumping method is the final disposal method in the city. Furthermore, the results of the study show that despite daily evacuation of waste between 6.00am ï 11.30am by KSSWMB, the whole city is not covered even where there are drums.
- In addition, it was found that waste volume differs from zones to zones even though waste litter incidence was found everywhere but the situation is much worrisome in Kabawa, part of Adankolo than other Zones and least in GRA, Commissionersô quarters and House of Assembly quarters.
- Again, it was found out that the drums provided for waste storage in the city were arbitrarily located and concentrated within certain parts of the city leaving vast part of the city uncovered.
- In addition, factors discovered to have inhibited effective waste management system in the city. Accessibility, limited number of waste collection trucks, poor legislation of

environmental laws, relief of the city are, absence of alternative waste management alternatives and poor environmental awareness of the public.

- Criteria for locating dumpsters in the city follow the adoption of Iro, Okorondu, Mbano, and Duruõs (2012) of United Nations Single criterion standard which set required distance of the dumpsters from roads (10m), water bodies(70m), public areas(40m), commercial areas(20m), residential areas(20m) and from one another not to be less than(100m). Buffering operation was carried out on the geographical features of the city and unioned results were clipped with boundary to show the potential position of the dumpsters.
- Finally, ARCGIS 9.3NA aided driving directions and showed the total distances to be covered in the course of waste evacuation in each of the scenarios. The total distance to be covered along scenario I best route is 18.1km while alternative route covers 18.5km. Scenario II best route has a distance of 25.1km while scenario II alternative route has 25.2km. And scenario III best route is 35km while its alternative route covers 35.1km. It should be noted that the differences between the best route and alternative routes of each scenarios are not significant and as such making the alternative routes good choices in the event of impedance.

6.2. RECOMENDATIONS

Based on the findings of this research, the following recommendations have been made to improve the deplorable condition of Lokoja waste management.

6.2.1. PROCUREMENT OF MORE COMPACTORS

Following the availability of just two compactors that operate between 6.00am-11.30am daily in Lokoja metropolis, many wastes are left uncleared in the city. In this regard, the state government should procure about 9 compactors (3 compactors for each scenario) to serve the city optimally as addition of compactors would improve the rate of evacuation of waste within the city

6.2.2. ENFORCEMENT OF URBAN DEVELOPMENT CONTROL LAW

It is recommended that urban development law be strengthened in order to forestall chaoses that are associated with unplanned urban structure which in turn affects urban waste management system. Over aggregation of buildings in Kabawa, Felele, part of Adankolo is indicative of poor enforcement of urban development law. The implication of this is the resultant accumulation of waste in those areas mentioned. Efforts of urban and regional planners should therefore take into account urban renewal in this area and equally implement all provisions of the cityǿs master plan. Illegal structures that fall within the buffer zones of dumpsters should be demolished. Compensation should however be paid by Kogi State government to legal property owners within the buffer zone.

6.2.3. OPENING UP OF THE CITY

In relation to the aforementioned, it is worthy of notice that accessibility plays vital role in ensuring effective waste management system. Much desired results would be guaranteed if there could be more road expansion projects in the entire city to enhance easy entry and exit of waste collection vehicles. Expediently, construction of more roads especially in Kabawa and Felele that have no intra-city roads would not be out of place especially now that there is heightened waste issue in the city. In Adankolo equally around the NIWA dock, it would be pertinent to construct more roads as one of the residents in the area attributed their choice of dumping refuse in the area to poor accessibility. While in Ganaja, 200-unit, 500-unit, estates and environ, the existing roads in those areas, if widened, would ensure much desirable results.

6.2.4. PROPER IMPLEMENTATION OF ENVIRONMENTAL POLICIES

Stringent environmental policies would no doubt address the case of indiscriminate waste disposal along the road, inside the drainage system, in the river, on open plots and other areas that waste are indiscriminately disposed. Strict implementation of these laws would not only help in prosecuting the environmental law defaulters but serve as deterrent to several others within any given environment in perpetrating such acts. Though it is believed that perpetrators of indiscriminate waste dumping carry out this act at night and during heavy rainfall, environmental law enforcement agents should be on duty at night to apprehend those who dump refuse indiscriminately. Equally, environmental law enforcement agents should keep abreast weather forecast to know when it is likely to rain so as to devise strategy on how to ambush those who might want to take advantage of rainfall to illegally dump refuse.

6.2.5. PROVISION OF STANDARD DUMPSTERS.

Apparently, absence of hoist-away dumpsters in the city is part of the cause of accumulation of waste on open plots, drainages, along the road. It therefore becomes expedient that dumpsters are procured and positioned at the various proposed locations in order to guarantee the anticipated result in the city. In a more synergetic form, individual home should be encouraged to procure waste storage tools and either pays for the services of house ï to ï house collectors who transfer the wastes to the dumpsters or they transfer themselves.

6.2.6. IMPROVED AWARENESS AND CAMPAIGN AGAIN INDISCRIMINATE REFUSE DUMP

Much sensitization needs to be made on adverse effects inherent in the abuse of our environment through indiscriminate refuse disposal system. There should be public awareness and participation in the planning and implementation of solid waste management. Different avenues like media, school symposia, workshops, seminars should be explored by the government. Several cases of environmental disasters like flooding, erosion, etc have been traced to indiscriminate dumping of refuse along the drainage channels and had caused siltation of these drainage channels and thereby causing diversion of water away from its natural course to result in erosion and flooding. So sensitization on implication of indiscriminate refuse dumping and adequate provision of dumpsters in the proposed points across the city cannot be overemphasized.

6.2.7. DIVESTMENT OF WASTE MANAGEMENT SYSTEM BY THE GOVERNMENT

It is highly recommended that government hands over waste management system to the private sectors. Private sector participation is proven to have yielded results in advanced countries. It therefore behoves on government to restrict or limit itself to standard setting, monitoring and ensure enabling environment for private sectors to thrive.

6.2.8. ESTABLISHMENT OF RESEARCH DEPARTMENT

It was discovered that KSSWMB lacks data, publications and researches on waste characteristics and management. It is important for establishment of research department in the board in order to make data available on waste characteristics, composition, volume of waste generation as well as spatial characteristics of waste in the city.

6.2.9. APPLICATION OF 4Rs

The 4Rs of resource management should be adopted and encouraged at all times. These 4Rs are Reduce, Reuse, Recycle, and Recovery of damaged resources. It should be noted that sizeable part of the wastes in the city are reusable and recyclable. It is therefore pertinent for government to allow investors come into recycling of wastes that has taken its toll on our environment. Recycling would in no doubt reduce waste stream and in a related manner, sorting of waste into various category should be encouraged.

6.2.10. HEIGHTENED FUNDING REQUIRED

For waste management to be effective in Lokoja, there should be adequate funding of waste management in the state. Present situation shows that the sector is poorly funded and it has spelt doom on the cityộs landscape.

6.2.11. THE PLACE OF GIS

Application of GIS for solid waste collection needs to be institutionalized and introduced to the contractors, municipal and city councils officials in order to ease information management for both spatial and non-spatial data. On the other hand, the spatial and non-spatial data for cities should be updated from time to time in order to support decision making. Application of GIS in waste management should be accorded prominence in environmental management planning. This is borne out of the proven ability of the tool to display the holistic view of the entire city at a glance; its ability to guarantee precision and its ability to help in planning and managing waste and other terrestrial related matters. Based on these proven abilities, it is recommended that GIS be employed for waste management in Lokoja by taking into consideration route analysis of various proposed sites in the previous analyses. More importantly, KSSWMB crew should have about three regional offices across the city from where they could commence waste evacuation based on the three scenarios proposed for waste collection routing in the city. This will no doubt ensure service efficiency and maximum practicable results.

6.2.12 ADOPTION OF ADVANCED WASTE MANAGEMENT OPTIONS

Open dumping of refuse is presently the only waste management practice in place in Lokoja and the system is found to be a harbor for rodents and other disease vectors. Integrated waste management options like recycling and injection are preferred options. It is therefore pertinent for the government of Kogi State to adopt these options in order to generate wealth from recycling waste and useful gases that could be generated from integrated waste injection.

6.3. CONCLUSION

Conclusively, it could be established that waste management in Lokoja metropolis is still at rudimentary stage. This is against the backdrop of incessant spate of indiscriminate refuse dumping on the streets, open plots, uncompleted buildings and drainages without prosecuting the defaulters of the environmental laws. This suggests that waste management system in the city is poor and lacks planned evacuation system. Equally, absence of required size or specification of dumpsters in the city should be addressed. Further, the study demonstrated the value of GIS technology as a waste collection optimization tool, capable of guiding decision making. Future work should therefore focus on sectorization of wider waste collection areas, based on spatial analysis and empirical approaches. Equally, adaptation of the collection system to the introduced separate collection schemes for different zones in the city will ensure efficiency.

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Appendix A

DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF NIGERIA, NSUKKA.
QUESTIONNAIRE FOR RESEARCH WORK (KOGI STATE SANITATION AND WASTE MANAGEMENT BOARD)

Dear Respondent,

I am a post graduate (PG) student of Environment Management in the Department of Geography, University of Nigeria, Nsukka, who is embarking on an academic research on optimization of municipal solid waste collection and disposal for Lokoja, Kogi State, Nigeria.

Could you please supply objective answers to the questions contained herein. All your answers will be treated with confidentiality as your answers will not only assist me in carrying out an objective research but also assist your organization in providing efficient means of tackling municipal solid waste management problems within the study area.

JOSEPH, SIJI
PG/M.Sc/11/60004

Mark õXô in the appropriate column

1. Sex : Male [ ] Female[ ]
2. Age
   Below [ ] 18-24years [ ] 25-34years [ ] 35-44years [ ] 45years and above [ ]
3. Educational attainment
   Primary school [ ] Secondary school [ ] Tertiary [ ]
4. What category of worker are you in Kogi State Sanitation and Waste Management Board?
   Senior [ ] Junior [ ] Casual Staff [ ] contractor [ ]
5. What is the major source of municipal solid waste in Lokoja?
   Commercial source [ ] Domestic source [ ] Institutional source [ ]
6. Whose duty to evacuate solid waste?
   Staff [ ] Casual staff/ Ad-hoc staff [ ] Contractor[ ]
7. In which of these ways do you dispose of solid waste?
   Just anyway and anywhere [ ] by composting [ ] Landfill [ ]
   Incineration[ ]
8. How many trucks do you use in solid waste collection and disposal?
   One [ ]Two [ ] Three [ ] Four [ ] More than five [ ] none[ ]
9. What kind of trucks do you use in collecting and disposing of waste?
   Compacting truck [ ] Cart [ ] Tipper [ ] Wheel Barrow [ ] Basket [ ]
10. From what points do you collect waste?
    Public refuse dump[ ] Residential houses [ ] Offices [ ] Communal bins [ ]
    All of the above [ ] Schools[ ] None of the above[ ]
11. Is municipal solid waste management funded appropriately?
    Yes [ ] No[ ]
12. Who funds solid waste collection and disposal?
    Federal government [ ] State government [ ] Local government [ ]
    Voluntary organization [ ] Individual [ ]

13. How often do you collect and dispose solid waste from dumpsite?
    Everyday[ ] Twice a week[ ] Every Saturday[ ] Every month end[ ]
14. How many dumpsites do you have in each zone?
    One [ ]Two[ ] Three[ ] Four [ ]Five [ ] More[ ]
15. Do you sort solid waste before disposal?
    Yes [ ] No [ ]
16. Do you have data on the quantity of municipal solid waste generated daily/ weekly/ monthly?
    Yes [ ] No [ ]
17. What is the volume of solid wastes collected per day, week or month? Less than 150kg [ ] 150-200kg [ ] 200kg-250kg [ ] 250-300kg [ ]
    300kg and above [ ]
18. What are the problems encountered by Kogi State and Sanitation Waste Management Board in the discharge of its duty in Lokoja?
    Cooperation from the staff [ ] Cooperation from the pubic [ ] Accessibility[ ]
    Funding [ ] insufficient personnel [ ] All of the above [ ]
    Othersé é
    é ..
19. How do you evaluate the problem posed by municipal solid waste evacuation in Lokoja?
    Very high [ ] High [ ] Moderate [ ] Little[ ] No problem [ ]
20. Do you use dumpsters for solid waste collection? Yes [ ] No [ ]
21. Are the dumpsters sited at satisfactory walking distance to the neighbourhood? Yes [ ] No[ ]
22. Is there any appropriate type of containers and door-to-door collecting vehicles?
    Yes [ ] No [ ]

Appendix A2

DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF NIGERIA, NSUKKA.
QUESTIONNAIRE FOR RESEARCH WORK (GENERAL PUBLIC)

Dear Respondent,

I am a post graduate (PG) student of Environmental management in the Department of Geography, University of Nigeria, Nigeria, who is embarking on an academic research in municipal solid waste management in Lokoja.

Could you please supply objective answers to the questions contained herein. All your answers will be treated with confidentiality.

Your answers will help the researcher in advising the government and environmental management bodies in Kogi State on the ways of handling solid waste management problems in Lokoja.

JOSEPH, SIJI
PG/M.Sc/11/60004

Mark ōXô in the appropriate column

A) Socio-Economic characteristics:

1. Which area do you reside in Lokoja?
   é é é é é é é é é é é é é é é é é é é .
2. Age
   Below 15years[ ] 16-24years [ ] 25-34years [ ] 35-44years [ ] 45years and above[ ]
3. Educational attainment:
   Primary [ ] Secondary[ ] Tertiary [ ] Others[ ]
4. Occupation:

Student [ ] Civil servant [ ] Farmer [ ] Trader[ ] Artisan[ ]

5. Number of persons in household?...

B Waste collection

6. How long have you lived in the area?
   Less than 5yrs [ ] 6-10yrs [ ] 11-15yrs [ ] 16-20yrs [ ] More than 20yrs [ ]

7. What do you use to store wastes in your house?
   Carton[ ] Basket [ ] Bucket [ ] Waste bin[ ]
8. Who disposes solid wastes in your house?
   House maid [ ] Boys [ ] Girls[ ] Adult [ ]
9. At what time of the day is solid wastes removed?
   Morning [ ] Afternoon [ ] Night [ ]
10. What constitutes the bulk of your solid wastes?
    Food waste [ ] Paper waste [ ] Polythene Glass [ ] waste [ ]
    Yard waste[ ] miscellaneous waste[ ]
11. Do you sort solid waste into different categories in your house?
    Yes [ ] No [ ]
12. Which sector undertakes solid waste collection service in city?
    Private sector [ ] Public sector [ ] Informal sector [ ]

C SOLID WASTE DISPOSAL

13. Where do you dispose solid waste?
    Backyard [ ] Gutter [ ] Along the road [ ] Dumpster [ ]
14. How often do you dispose of your solid waste?
    Once daily [ ] Twice daily [ ] Once a week [ ] Twice a week [ ]
15. Do you have a dumpster near your house?
    Yes [ ] No [ ]
16. What problems do you encounter when you go to the dumpsite to dispose solid waste?
    Accessibility [ ] ill-defined dump [ ] littering of solid waste[ ]
    Odour/Rodent/insect/Flooding [ ] All of the above[ ]
17. How long does it take the KSSWMB to dispose of the solid wastes?
    Everyday [ ] Twice a week [ ] Every Saturday [ ] Once a month[ ]
    None[ ]
18. How do you assess the effectiveness of KSSWMB in Lokoja
    Low [ ] Moderate [ ] High [ ] Very high
19. How can you assess the sanitary condition of Lokoja?
    Satisfactory [ ] Moderate [ ] poor[ ]
20. What should be done to improve or solve the problem of solid waste in Lokoja? (Indicate your answer by using 1-5 with 5 being your strongest point and 1 your least point).
    Provision of more public bins[ ]
    Improving the frequency of evacuations of bins[ ]
    Improving existing road condition [ ]
    Introduction of weekly sanitation and sanitary court[ ]
    By promoting environmental awareness on indiscriminate dumping of solid waste[ ]
    Othersé é

Appendix B
RECOMMENDED DUMPSTERS DETAILS

- Name: Roll off Dumpster
- Size: 40 cubic yard open top, 22 feet long, 8 feet wide and $7^{1/2}$

UNIT FOR CONVERSION

1ft = 0.3048m

No of proposed dumpsites = 60

No of integrated dumpsites = 43

Total No of sites = 103

Area to be covered by each of the dumpsters:

Length of the proposed dumpster = 6.7056m

Breadth = 2.4m

Area = L*B

A = 6.7056*2.4m

A = 16.1 m^2

Total land area to be used for dumpster Location in the city:

16.1*143= 2,302.3m^2

Appendix C

[DataSet1] C:\Users\siji\Desktop\Validity.sav

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	30	100.0
	Excluded[a]	0	.0
	Total	30	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.697	16