REDESIGNING CADASTRAL SURVEY METHOD IN LIBERIA

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DECLARATION

I Kortimai, Charles N., declare that this thesis is my own work and that it contains neither material previously published by any other person nor material which has been accepted for the award of any other degree of any University, except where due acknowledgement has been made in the text.

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ABSTRACT

The concept of formal documentation of land information through a cadastre based on an accurate survey of land for the purposes of tenure security has remained relatively undeveloped in Liberia. Much of the earlier documented land records and infrastructure for survey works has been destroyed by years of conflict. This thesis has examined the existing cadastral regulations, methods, infrastructure and equipment used for cadastral surveying and the proposed new methods based on improvements in technological developments. The use of the GPS measurement technology and its proliferation in the surveying and mapping industry within a well-defined framework was explored. The development and use of a consistent spatial Reference framework is proposed. The investigation reveals that clear guidelines and regulations for cadastral surveys would ensure accurate and integral data that will improve security and reduce land conflicts and litigation. Consequently, new rules and procedures for boundary definition and demarcation and comprehensive datasets in the form of the cadastral plan and the use of more accurate measuring surveying equipment are proposed as improvements to the existing cadastral system. As the measurement information from GPS is already in digital form it can provide useful inputs into cadastral information systems. A cadastral survey was conducted as a case study using the proposed DGPS survey method specifically the Post-Processing Kinematic Survey Method. The results were used in the designed application software that was developed by this thesis to produce modified and standardized Cadastral Survey Plan.

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ACRONYMS OR ABBREVIATIONS

BLS	Bureau of Lands and Surveys
BLM-US	Bureau of Land Management of the United States
CNDRA	Center for National Documents and Records/Archives
CORS	Continuously Operating Reference Stations
DGPS	Differential Global Positioning System
DLSC	Department of Land Survey and Cartography
FIG	International Federation of Surveyors
FAO	Food and Agriculture Organization
GNSS	Global Navigational Satellite System
GPS	Global Positioning System
GIS	Geographic Information System
HARN	High Accuracy Reference Network
ICAO	International Civil Aviation Authority
IHO	International Hydrographic Organization
IOCRF	International Office of the Cadastre and Land Registry
ITRS	International Terrestrial Reference System
IUGG	International Union of Geodesy and Geophysics
IERS	International Earth Rotation Service
LTRS	Land Title Registration System
LPIS	Land Policy and Institutional Support Program
LTRS	Land Title Registration System
LCS	Liberian Cartographic Service
MLME	Ministry of Lands, Mines, & Energy
PLSS	Public Land Survey System
PPK	Post-Processing Kinematic Survey Method
PRC	People Redemption Council
PLSS	Public Land Survey System
TTS	Torrens Title System
UTM	Universal Transverse Mercator
WB	World Bank
WGS84	World Geodetic System of 1984

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Chapter 1

INTRODUCTION

1.1 Background

Land is fundamental to all forms of human activity such as providing space to live and ultimately the backbone of all economic activity. However, the often-destructive impact of human activity on land and conflicts of use has led to the need for more careful stewardship of the land.

Land includes a range of physical and abstract attributes, from rights to build upon the land to rights to use and exploit natural resources on it and beneath its surface. These systems are needed to provide information about land rights and responsibilities in land, including public administration of land, land use planning, land development monitoring and the support of land markets, particularly in an age of a rapidly expanding population.

According to (FIG, 1999), the proposed re-engineering of land administration systems by endorsing policies in cadastral benchmarks such as the *Bogor Declaration on Cadastral Reforms* (UN, 1996). The insecurity of land tenure has caused the movements of people from rural areas to urban areas, thereby increasing the need for a contemporary cadastral model or system for managing the recording of all interests in land and their interrelationships to support Government and community expectations in land holdings and security of such holdings.

The concept of linking man with the use of land and its attributes by the formal documentation of information evolved through Napoleon I. (Larsson, 1991) into a cadastre based on a systematic survey of each parcel. However, these attributes include parcel identification number (PIN), size of the parcel, land use and land values are prominent in the proper identification of the land documentation in the cadastre information for any country. For such cadastre to be useful for legal purposes, they must include accurately surveyed cadastral plans and large-scale maps (Ting, and Williamson, 1999)

The cadastre as defined by the International Federation of Surveyors (FIG) is *"A parcel based and up-to-date land information system containing a record of interests in land (for example rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of these interests, and often the value of the parcel and its improvements* (FIG, 1995)

Fundamentally, the cadastre must include an unambiguous definition of parcel boundaries both in map form and on the ground prepared through cadastral surveys (Ting, 1999). The most common method of carrying this out is to permanently monument the parcel boundaries, which are then surveyed by ground methods with the corresponding measurements being displayed on technical maps and plans. In such a system then, the boundaries of each parcel can be precisely defined and re-located on the ground even if the boundary monuments are missing or disturbed (Ting, and Williamson, 1999).

The cadastral survey unit used in positioning property boundaries (parcels) must ensure that conflicts in the position of these boundaries are avoided by making the variously independent surveys integral in a uniform cadastral framework for adaptation to meet up with the needs of title registration (Dale, 1988).

The functions of cadastral mapping, cadastral indexing and maintenance of the local coordinate reference framework are carried out by the Department of Land Survey and Cartography (DLSC). This is meant to support the public administration of land by providing information that can be used to formulate, implement and monitor land policies. However, such as those concerning land redistribution, land consolidation, land acquisition and allocation and land markets (Pichel, 2011).

Demands for accurate surveys in the past were usually not high as in those times physical parcel demarcations were distinguished mainly for providing actual notice of the boundaries to the landowners. The property documentation in registers and for re-establishment of boundaries was not necessary at the time. Nevertheless, man-land relationships at the parcel level have changed due to the nature and complication of rights and interests in the land. With these complexities, the community and native levels need faster and easier access to information about their natural resource and public infrastructure, also monitoring of impacts of man's activities, require information systems that are flexible, reliable and responsive to user requirements. Accuracy requirements for conflict resolutions, for example, may demand that systems overall allow the relative positioning of points on the ground to be determined to within a few centimeters in Easting, Northing and height (McLaughlin, 1999).

1.2 Problem Statement

Current survey methods and guidelines in Liberia do not result in the production of uniformly accurate cadastral plans for indexing, legal land registration and for the development of multipurpose cadastre. Survey standards were not specified within the People Redemption Council (PRC) Degree 23, 1980 regulations, and legislation, but rather this regulation provides a standard of professional conduct and accountability for surveys. The cadastral survey system in existence does not record survey data like coordinates

(Northing and Easting) of the property boundary corners (parcel) positions over physical locations of beacons on the ground, so if these markers were missing, or they are disputed, they cannot be accurately retraced. The inaccuracies in existing surveys in Liberia comes from the conditions of using obsolete equipment whose results are not particularly comparable with modern surveying techniques like Differential Global Positioning System (DGPS), photogrammetry, or total stations. With the availability of accurate measuring equipment the need to redesign cadastral survey method is increasingly on the rise as it is causal to assisting proper positioning of property boundaries to be easily traced or retraced in the country.

1.3 Research Aim and Objectives

The primary aim of this thesis is to examine the feasibility and benefits of, introducing a re-designed cadastral survey method and plan preparation suitable for the development of a modern Multipurpose Cadastre in Liberia.

The specific objectives of the research project are followed:

- To analyse the current cadastral system and the historical development of its various components;
- To examine the central role of spatial data, standards and procedures, in the operation of a Multipurpose Cadastre in the context of national policy trends.
- To consider the relationship between cadastral surveying, rules and procedures for land parcel boundary definition and demarcation and re-arrangement of property boundaries to facilitate better land management was considered.
- To investigate of current trends and factors impacting on the current system and the development of an appropriate vision and cadastral model.
- To investigate cadastral survey standards and the application of modern positioning technology such as the Global Positioning System (GPS).
- To introduce an appropriate cadastral survey method selected for redesigning cadastral survey in Liberia.

As this thesis is primarily concerned with cadastral reform, a number of suggested solutions were proposed which can be integrated as part of a larger institutional reform agenda or implemented incrementally according to political, institutional and economic settings.

1.4 Scope

The scope of the project focuses on the examination and possible adoption of "best practice" cadastral systems to the Liberian situation. Accepted, successful cadastral concepts and their suitability for adaptation to improve the current system are investigated, and recommendations made.

1.5 Relevance

The need to utilize and manage land to promote increased and sustainable economic development require an appropriate cadastral system to record rights, interests and responsibilities to provide secure title.

The advent of modern technology has allowed cadastral systems to evolve into parcel based land information systems capable of providing a framework for local government administration, planning, collection of rates and taxes and management of public infrastructure such as utilities and transport systems. The application of successful modern cadastral concepts can provide substantial social benefits in terms of better access to land related information and a simpler system for the recording of interests in land. A consistent and comprehensive geodetic network makes it possible to establish spatial linkages between all relevant land information so that any features can be related spatially.

This thesis is focused on selecting an appropriate cadastral survey method that is able to produce spatial data that will assist in positioning properties (parcels) boundaries in Liberia. And it is also focused; on the improvement of the product of the Cadastral Survey by designing modify cadastral plan, and application to assist in title registration and adjudication.

1.6 Research Questions

The process of selecting the appropriate modern method to accomplish the research aims, requires these critical questions to be answered:

1) What cadastral survey method could be provided and produced standardised and modern cadastral plans of parcel boundaries in Liberia?
2) What are the setbacks of the existing cadastral survey methods?
3) What suitable survey technique could be useful in redesigning the present method?
4) How can the appropriate method be useful in producing modern cadastral plan application for Liberia?

1.7 Study Area

The Camp Ramrod/72nd Military Barrack lies further north of the district of Sinkor within the Paynesville City near Monrovia which is the capital City of Liberia, West Africa's oldest country. Camp Ramrod/72nd Military Barrack has its geographical location in the northern hemisphere between latitudes Latitude of 6° 17 49" N and 6°17 04" N and on the west of the Greenwich meridian between longitudes 10° 42' 10" W AND 10° 41' 31" W. The Camp Ramrod/72nd Military Barrack is presently hosting few members of the deformed Armed Forces of Liberia (AFL) whose population is a little more than 1000 (personal communication, 2013); the Camp has an approximate area of 11 acres (0.0445 sq. km).

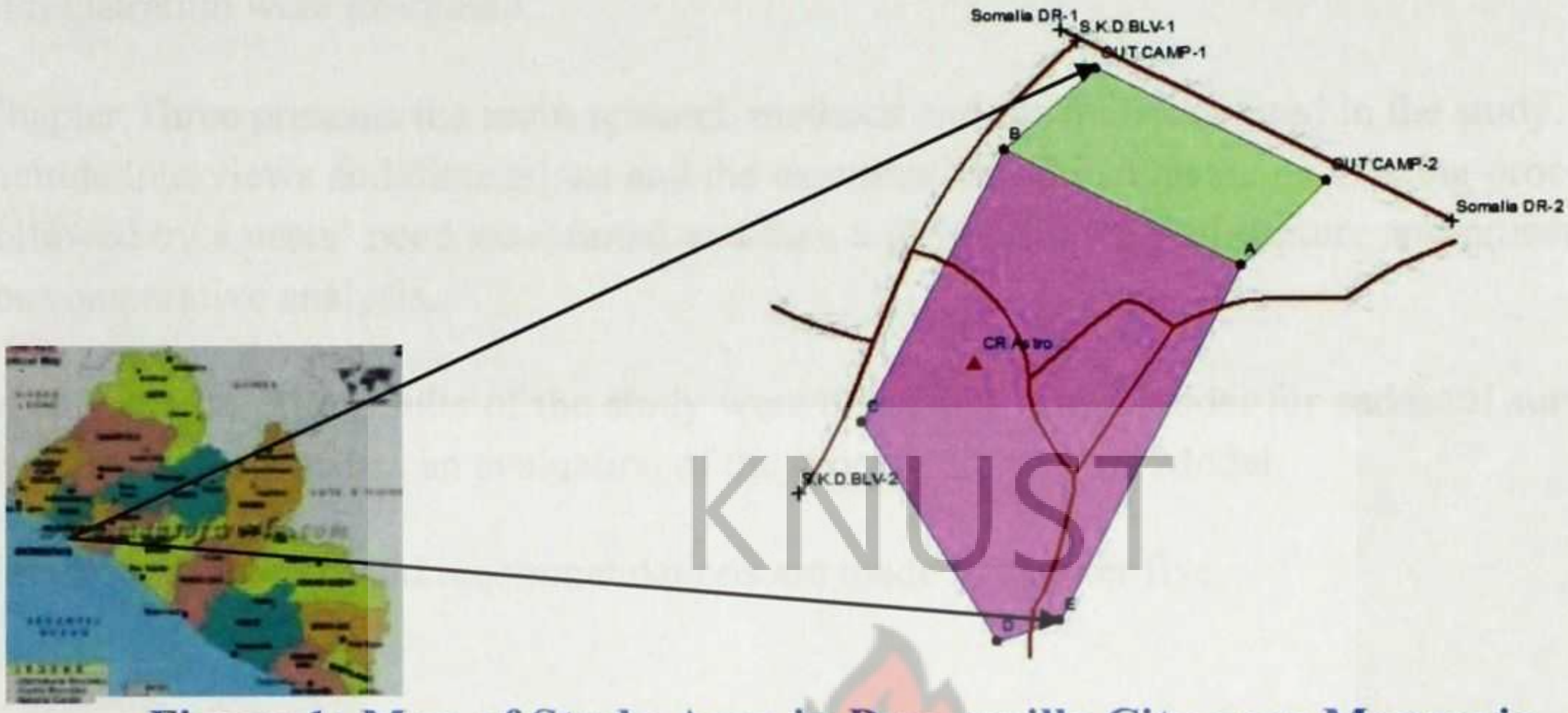


Figure 1: Map of Study Area in Paynesville City near Monrovia

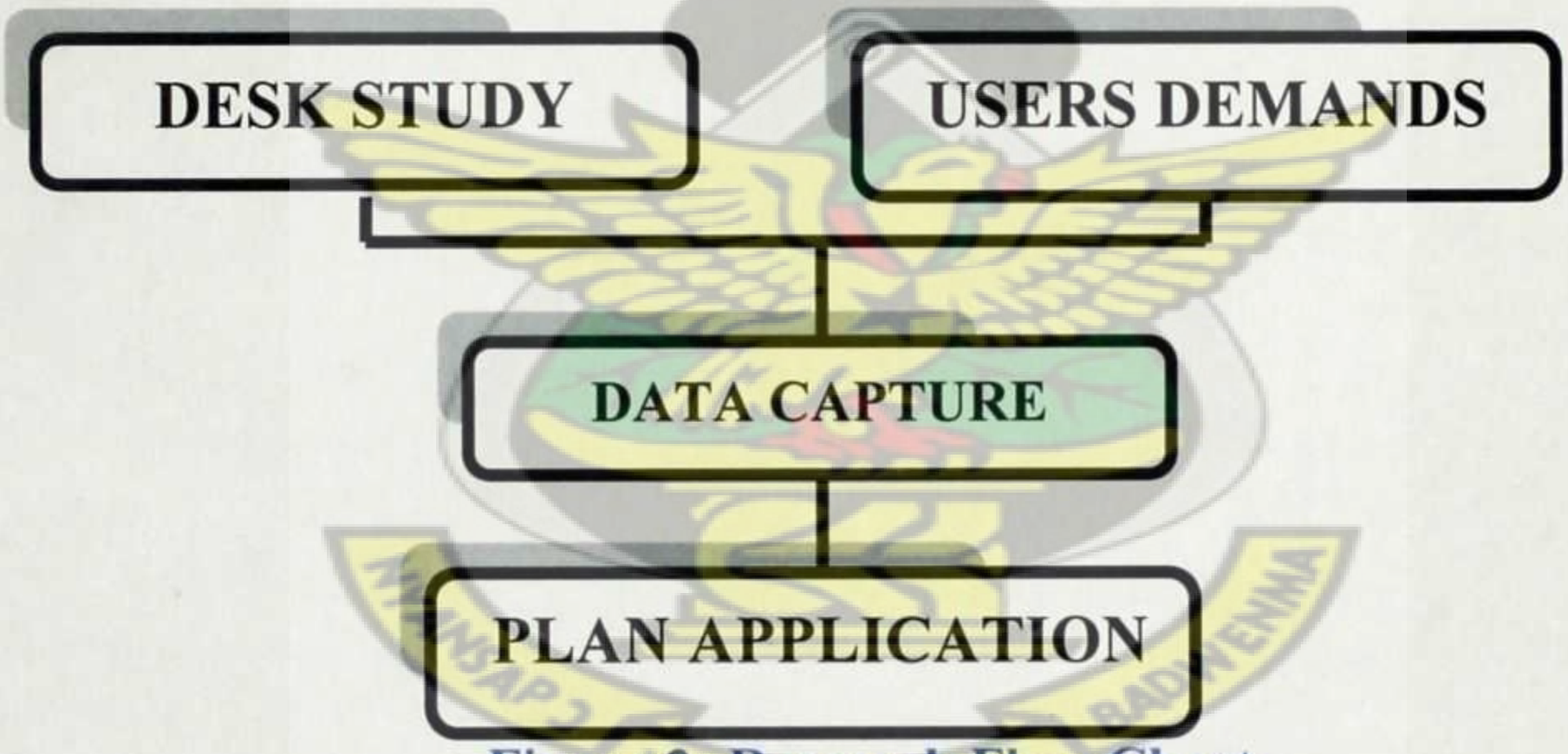


Figure 2: Research Flow Chart

1.8 Thesis Structure

The thesis is structured into the following five chapters:

Chapter one is embodied with the introductory it contains a background to the cadastral surveys in Liberia and shares the problem statement, the main objectives and scope of the current study as well as the research questions and the layout of the thesis.

Chapter Two reviews various literature related to the current study. This study covers the cadastral survey methods of the United States and Ghana and contrasts these with methods

currently used in Liberia. The discussion of the advantages and disadvantages of the compass and Differential Global Positioning System (DGPS) methods, error sources inherent in the methods; the Land Laws in Liberia, concept of GPS and its components, the operations of DGPS and the status of DGPS in Liberia, and the types of the cadastral plans used in support of registration were examined.

Chapter Three presents the main research methods and the materials used in the study. These include interviews and discussions and the examination of documents on existing procedures followed by a users' need assessment and then a physical survey to capture and process data for comparative analysis.

In chapter four, the results of the study were discussed, and a model for cadastral surveying has proposed as well as an evaluation of the proposed Cadastral Model.

Finally, conclusions and recommendations are made in chapter five.

Chapter 2

INVESTIGATION OF CADASTRAL SYSTEMS AND SURVEY METHODS

2.1 Land Ownership and Land Laws in Liberia

Land ownership in Liberia is based on Common Law, which requires an owner to have a land deed. A similar system of customary law, based on a verbal agreement, is also popular with most Liberians being more accustomed to the customary law and regarding the common law as a system imposed by the central Government in Monrovia (World Bank, 2008).

The approved land law of 1956 refers to the Amero-Liberian settlers were allocated lands under a deed system and considered as freehold properties. All other lands especially in the interior were considered public lands and are commonly used by the Indigenes under customary land tenure. The 1974 amendment to the Public Lands Law which deals with land registration system permits lands in the settler areas of Liberia. These permits can be held as fee simple rights to such Settlers who were entitled to either a town lot or ten acres of farm land (or even twenty-five if they were married) upon naturalization given by the land commissioner or register of deeds and signed by the President.

According to the law, land could only be transferred after the Title was obtained, but use-right could be transferred to heirs if the Title had not been obtained before death. It is clear then that Land can only be held by Liberian citizens who have to be of black ethnic heritage. In terms of access by Indigenous Africans, public lands in setter areas would only, by law, be deeded fee simple to "educated indigenous people" if they either erected a house, like to settlers or planted trees bearing marketable products, in the case of farm lands. Thus, African indigenous people, who constitute the majority of Liberian society, could not normally access public lands for ownership under fee simple or deed, but their access to land was through customary land tenure unless he/she became "civilized".

In terms of customary land tenure, there is no formal written customary land law in Liberia, though all lands in the designated indigenous areas fall under a system of ownership based on traditional customary law. Within that system, there is no individual ownership, but rather the government recognizes the collective (communal) right to the land. Individuals could own land use rights but cannot own land. The land is under the control of the chieftain who has a communal deed to tribal areas and administers its distribution.

Amero-Liberian settlers can still take public lands held by rural communities, but first have to go to the traditional head to get approval and pay a symbol of good intention. The lack of

secure tenure in Liberia as revealed in the laws has resulted in several problems including the following (World Bank, 2008):

- The legal distinction between public lands and tribal lands lack clarity, resulting in tensions between government, which has long asserted ownership of and the right to isolate large areas of land occupied by traditional communities, and those communities, who consider this land as their own.
- Citizens fled due to war and abandoned their property and occupied by squatters who can claim rights to the property through the law of adverse possession'.
- The existing deed registration process before the war did not adequately document property transactions. It has made land (property) sales difficult to follow as the conflict has resulted in lost deeds, deed records and databases, resulting in high risk in the property market. This epidemic has also made illegal property deed and other documents, allowing sales of the same piece of land to different people.
- Decision-making control over land is fragmented among several state agencies, without a strong coordinating body.
- Key land management agencies have lost man and technological assets that needed rebuilding for any effective land management.
- The customary law of Liberian ethnic groups is poorly documented, and studies to establish a central typology and parameters are required as there are large deviations between officially recognized practice administrations from original models on the ground. This would provide stronger awareness and protection to customary rights to land and re-orient Liberian legal education to address customary land law.

2.2 Land Registration Requirements and Administration in Liberia

Liberia has both a system of Deed Registration and a more recently introduced Land (Title) Registration System. The land title registration was intended to replace the deeds system, but this has not occurred due to various logistical reasons. However, the existing Deeds Registration System is in shambles. Records under that means have been scattered, damaged and in many cases destroyed, and there is the need to re-collect and preserve these records, exclusively digital format for easy access in both estate management and estate organization.

Land registration (land titling) "is the official recording of legally recognized interests in land and is usually part of a cadastral system. From a legal perspective a distinction can be made between deeds registration, where the documents filed in the registry are signs of title, and registration of title, in which the record itself serves as the earliest evidence" (FIG, 1995) Land titling, the process of registering titles to land, is considered superior to deeds registration as it provides in principle, greater security of tenure and more reliable information. It provides attributes like parcel identification number, owner's name, parcel corners coordinates, street name, etc.

The Torrens system, devised in 1857 by Sir Richard Robert Torrens, involves the registration and transfer of titles of any real property together with restrictions and charges and the name of the proprietor. The fundamental qualities of this system were for reliability, simplicity, low cost, speed and suitability of registration. Three fundamental principles are usually followed, namely the mirror principle, where the register is supposed to reflect the correct legal position; the curtain principle, which means that, no further (historical) investigation beyond the record is required except overriding interests, and the security or government guarantee principle where the government guarantees that what is registered is legal for third parties in good faith and that a bona fide rightful claimant who is contradicted by the record is reimbursed from an insurance fund maintained by the state (Mugnier, 2011).

The state must be active in analyzing transactions, due to the guarantee principle and documents to minimize fraud, damages and compensation. The defining characteristics of a Land Title Registration System (LTRS) are:

- The Register is organized by parcel, and each parcel bearing an identifier making it easier to connect the parcel with related information.
- The coverage is comprehensive, with the Register for a locality being created through a systematic and participatory field process in which all claims in the specified area must be brought forward and are vetted for inclusion in the Register.
- A very strong, often decisive legal result is given by law to a right shown in the Title Register such that the right is unchallengeable by other claimants except in very narrowly defined circumstances.

Cadastral surveys are the foundation upon which title to all land rests. Cadastral surveys are the result of surveys, identifying the property owner, lot number and interest in land, as well as measuring the site's dimensions, area and boundaries with adjacent sites. Cadastral surveys also include: the preparation of maps, books from where these measurements are prepared from cadastral surveys are submitted to official registration offices (Williamson, 1998).

Through cadastral surveys, the cadastre (the most fundamental level of information on land) is clarified for land-transactions. Also, by clarifying individual rights and interests over land, cadastral surveys, contribute to the protection of land-based assets. At the same time, cadastral information captures detailed figuration and field measurements regulatory agencies are able to produce basic maps for GIS purposes, thus to employ cadastral surveys as base information for drafting plans involving land, for various services to the general public. Cadastral surveys deal with one of the oldest and most elemental facets of human society-ownership of land. They are the surveys that generate, mark, define, retrace, or reestablish the boundaries and subdivisions of public lands (BLM, 2012).

Currently, there is no cadastre and no valid and responsible land information system in Liberia. The cadastral survey and title adjudication activities of the Bureau of Lands & Surveys were disrupted since the late 1970s and have not been resumed. The activities of the Liberian Cartographic Service (LCS) which before then has included the national topographic base mapping, the national geodetic control establishment, and the national geographic studies have all ceased since the conflict. The full responsibility of defining the cadastral surveying methods that trained and experienced surveyors can provide accurate and integrated cadastral information for developing the National cadastre.

2.3 Cadastral Systems and Survey Methods

2.3.1 Cadastral Systems

Cadastral surveying is the definition, identification, demarcation, measuring and mapping of new or changed legal parcel boundaries. It usually includes the process of re-establishing lost boundaries and sometimes resolving disputes over boundaries or other interests in real property (FIG, 1999).

The most vital function of cadastral surveys in any country is to make exact spatial locations, sizes and shapes of land parcels specifically for land registration (Silayo, 2005). Cadastral survey data is paramount in the transferring and processing of interests in the land that is being surveyed levying land tax, supporting land markets, and land development planning, among others. Competent acquisition of such survey data is a vital issue for the accomplishment of appropriate city and rural land use.

Zanzibar cadastre authority was overwhelmed by the simple land (property) boundaries to use in defining reference to the names of adjoining owners with no survey plan attached to the deeds. The use of such 'social cadastre' in that sense supported the idea of (Farverque & Wallace, 1991). They suggested that the identity (ID) of land parcels, particularly in the Third World countries like Liberia, could be without survey and also without locating the parcel on a map. Furthermore, they recommended that the initial recording of land data depended on the status of ownership and local/community knowledge attributed to a parcel. However, he takes a considered position by recommending a similar but more elaborate cadastral system that provides security of tenure for foreign investors in Africa (Anderson, 1998). He pointed out that the record on the original land grants in the United States was once based on a social cadastre. However, as the country developed and the land became more expensive, the issue of land litigation became frequent and social cadasters were unable to help in the processes of adjudication and establishment of boundaries. Therefore, that form of land recording was abandoned in support of the mathematically based descriptions using metes and bounds and co-ordinate systems.

In all modern cadastre, the Cadastral plan or survey plan is the basic building block of the cadastre (McLaughlin, 1975). There is growing interest worldwide for clearer, more secure rights in land as many countries move towards new economic structures and require legal sustainable resource management. Simple, but effective cadastral structures must be available to support the operation of land markets and the provision of land-related services, land use planning and cope with demand for resources and facilities while ensuring that there is minimal damage to the environment.

The World Bank (WB) and the Food and Agriculture Organization (FAO) have argued the importance of the legal recognition of property rights in land supported by appropriate cadastral systems for the delivery of improved agricultural productivity, strong and markets and economic development. It is recognized globally that, the formal recording of rights, responsibilities and restrictions in land are important for:

- Improved sustainable resource management
- The promotion of increased investment in agriculture
- More effective stewardship of the land
- Facilitating the design and development of national cadastral infrastructures so that they may easily check the escalating needs of greatly increased urban populations.

Recognition of these trends and needs were addressed through the United Nations Interregional Meeting of Experts on the Cadastre, who met in Bogor, Indonesia (UN, 1996). The outcomes of that meeting are known as "The Bogor Declaration". The meeting identified a number of justifications for cadastre and cadastral reform among which are to:

- ***Support Land Management and Economic Development*** by providing better information for the land use planning, land administration, and support for socially desired land use and environmental considerations.
- ***Improve Protection of Land Rights*** including the reduction and avoidance of land and boundary disputes; the increase in productivity of property transfers and dealings; increased protection of property rights and dealings and fraud prevention.
- ***Support the Creation or Development of an Efficient Land Market*** through the provision of secure title for economic development; increasing revenue for central and local government by accurate identification of land use activity and property values; and combination of different systems.
- ***Simplify Processes*** through the standardization and, automation of procedures and elimination of duplication between institutions.
- ***Computerize*** to provide fast, cost effective approach to information and improve the integrity of data.

A vision for the cadastre was to develop advanced cadastral infrastructures that enable efficient land and property markets, protect the land rights of all, and support long term sustainable development and land management (Ting, and Williamson, 1999).

Arising from the *Bogor Declaration* was the Bathurst *Declaration* (Grant, 1999) which calls for a global commitment to halve the number of people around the world without access to secure property rights by the year 2010. This declaration identifies the need for policy and institutional reform to promote sustainable development and proposes a number of recommendations as follows:

1. Providing effective legal security of tenure and access to property for all men and women, including indigenous peoples, those living in poverty and other disadvantaged groups.
2. Promoting the land administration reforms essential for sustainable development and facilitating full and equal access for men and women to land-related economic opportunities, such as credit and natural resources.
3. Investing in the necessary land administration infrastructure and in the dissemination of land information required to achieve these reforms.
4. Encouraging all those involved with land administration to recognize the relationships, and inter-dependence between different aspects of land and property. In fact, there is needed for basic co-operation and co-ordination between surveying and mapping, the cadastre, valuation, physical planning, land reform, land consolidation and land registration.
5. Encourage the flow of information relating to land and property between different government agencies and between these agencies and the public. Whilst access to data, its collection, custody, and updating should be facilitated at the local level the overall information infrastructure should be recognized as belonging to a national uniform service to promote sharing within and between nations.
6. Improve the security of tenure, access to land and to land administration systems through policy, institutional reforms and appropriate tools with specific attention paid to gender, indigenous populations, the poor and other disadvantaged groups.
7. Recognize the incidents of violent dispute over land rights can be reduced through proper land tenure institutions that have quality land information data.
8. Encourage national and local government bodies to document and manage their own land and property assets.
9. Recognizing the difficulties in interpretation of the various land management related terms, establish an easily accessible thesaurus, to promote a better understanding of the terminology used.
10. In view of the crucial importance of human resources in the management of land, ensure that there is sustained education and training in land administration.
11. Undertake analyses and improve performance indicators that can monitor the effectiveness of land administration and land tenure systems in relation to sustainable development and poverty alleviation. (FIG, 1999).

The Declaration makes recommendations for the re-engineering of existing systems reflect

on changing priorities in society and the following considerations:

- Statutory survey requirements need to be more flexible and relate to the character of the information and the use of information for multiple purposes. Co-ordinates of boundary points should form the fundamental geo-reference.
- Systems need to be able to accommodate a range of information that may not be exclusively parcel-based, such as Native title, water rights and overlapping rights.

2.3.2 Cadastral Survey Methods

Cadastral survey methods are the basic technical methods used to undertake ground surveying like Compass Method, Theodolite, Total Station, GPS, et cetera. The cadastral survey is the scientific method used to carry out ground surveying for purposes of obtaining spatial data. Regrettably, technology is increasingly advancing and developing countries are lacking behind in the technical knowhow and personnel training processes of modern techniques.

In Liberia, Cadastral information is currently collected in a largely unregulated manner using a variety of surveying equipment of different accuracies. There are several situations of "isolated surveys", that is, surveys only connected to adjoining surveys and not to any consistent spatial framework (or geodetic reference). Surveyors have traditionally been preoccupied with Compass and other manual terrestrial technologies. Advances in survey technology such as Electronic Total Stations and the Global Positioning System (GPS) in recent years mean that relative and absolute accuracy of centimeters can be achieved relatively easily over large properties. Total station technology is commonly used, particularly for small parcels and subdivisions, with the Global Positioning System (GPS) also being employed for larger projects.

Even though the plane tables, tapes with transit or optical theodolites methods were used previously in the execution of cadastral surveys, there are sophisticated methods that have been developed to produce higher accuracies like electronic distance measuring equipment or "Total Stations". Moreover, satellite position fixing using the Global Positioning System (GPS) could now be used with more calm and high accuracy at a relatively low cost (Nichols, 1993).

Global Positioning System (GPS) technology can be used to capture spatial information and other attribute information relating to natural resources or the "as built" environment. GPS is also a powerful tool for completing and densifying geodetic networks. An advance in the provision of Differential GPS services through the establishment of additional Continuously Operating Reference Stations (CORS) makes it possible for positioning to accuracies of a few centimeters (Seeber, 1994).

Compass Survey Method

One of the methods widely used in cadastral survey in Liberia is the Compass Survey method. This method measures bearings and distances around a piece of the property boundary with the use of a magnetic compass and tape. As the compass measures magnetic bearings, unless these are appropriately corrected for convergence of meridians, they are not easily integrated with other surveys on National grid maps. Another limitation of the compass is the low precision in its design. Its accuracy is less than one degree if used carefully in the survey execution. This error of one degree will lead to one unit in sixty which is 2m error over a distance of 120m. Another limitation to the use of the compass is the errors due to local attraction to the proximity of ferrous deposits within the traverse area, magnetic changes in the atmosphere due to magnetic storms. With the compass method, one crucial problem is that, it has to be used with tape for linear distance measurements and Inter-visible lines usually can cause the survey to begin and continue or discontinue. In addition, one limitation can also be the inability for the compass to produce spatial information on parcels boundary like Differential Global Positioning System (DGPS) producing ground coordinates (X, Y) of the parcel boundary. However, its usage is simple, and the equipment is cheap in terms of cost. Bearings and linear distances key to this process are referenced to "witness" marks used as a monument for a property to be traced or re-traced by Cadastral Surveyors (Nichols, 1993).

2.3.4 Theodolite and Total Station Survey Methods

A Total Station integrates an electronic theodolite with an electronic distance meter thus making it possible to measure both direction and distance measurements simultaneously. The theodolite uses a movable telescope to measure angles in both the horizontal and vertical planes. A total station using electronic transit theodolites will read distance from the instrument to any spot of the surveyor's choice. They are hence two essential surveying instruments in one.

2.4 Geometric Framework Requirements for Cadastral Surveys

Any Land-Information System requires some method of spatial reference for the data it would record or store. An accurate mapping project requires the establishment of a system of survey controls. Survey control consists of a framework of points whose horizontal and vertical positions have been accurately established by field surveys. These survey controls can be checked against the map details. For multipurpose application, it is essential that survey control systems meet two basic criteria if the maps are to be effective planning and management tools. First, it must permit correlation of real property boundary-line data with topographic and other land related data. Second, it must be permanently monumented on the ground so that lines on the maps may be reproduced in the field (Ziemann, 1976). In the past, establishment of control systems was costly; in terms of precision and resources needed. GPS

technology has improved, and increased accuracy and reduced time and, therefore, cost of surveys quite reasonably, also these do not need inter-visible lines of sight between controls (Silayo, 2005).

The cadastral survey systems nationwide ought to be initiated from a control framework of permanent reference marks that have been accurately fixed in two or three dimensions, coordinates. Such a framework must be densified to a network of points in areas where such cadastral surveys are to be executed in the country. The key point of such a framework is to provide national consistency in supporting ground survey of land parcels boundaries so as to provide the following (Brinker & Minnick, 1987):

- A basic spatial data framework which will assist in unifying parcels boundaries.
- Support in quality control, for example, facilitate in detecting mistakes and checks against the accumulation of errors in survey measurements, hence maintaining consistency, improving accuracy and giving greater degree of reliability of survey data.
- Aid to speed up fieldwork and decrease survey costs when it is readily available.
- Provide scale and correct orientation for producing plans and maps, and
- Reduce uncertainties in boundary surveys, for example, checks against encroachments or overlapping surveys, thus avoiding confusions of boundaries, which may cause conflicts among parcels owners.

2.4.1 Geodetic Control Framework

The cadastral survey systems nationwide ought to be initiated with a control framework of permanent reference marks, with accurately fixed coordinates. This would afford the definition of both a National datum and projection system for cadastral surveys. In Liberia, the geodetic datum used was the Liberia 1964 Datum based on Clarke 1880 ellipsoid with the origin at the intersection of longitude 9° 25′ W and latitude 6° 35′ N. the false origin values are 0.000 feet for Northing and 1500000 feet for Eastings and scale on the central meridian being 0.99992 (Hager, 2005). The National Imagery and Mapping Agency (NIMA) have determined transformation between this and the WGS84 ellipsoid from four satellite points as DX= -90 ± 15 m., DY=. , and DZ= 80 ±15m. (Stein, Malys , 2000). The key points of such a framework are:

- To provide National consistency in supporting ground survey to facilitate definite descriptions, and identifications of land parcels.
- To provide a basic spatial data framework which will assist unifying parcels boundaries.
- Support in quality control, for example, facilitate in detecting mistakes and checks against the accumulation of errors in survey measurements, hence maintaining

consistency, improving accuracy and, therefore, giving greater degree of reliability of survey data.

- Aid to speed up fieldwork by providing controls close to properties and thus decrease survey costs.
- Provide scale and correct orientation for producing plans and maps, and
- Reduces uncertainties in boundary surveys, for example, checks against encroachments or overlapping surveys, thus avoiding confusions of boundaries, which may cause conflicts among parcels owners.

Records on the monuments of the original framework, as well as the monuments themselves, are currently not available hence most surveys done are processed in UTM zone29n from standalone static results. The absence of control networks to act as base Referencing for Differential GPS for post processing makes the results of these surveys uncertain in terms of accuracy and integrality with other surveys.

2.4.2 The Central Role of Spatial Data in a Multipurpose Cadastre.

The integration of spatial and textual databases containing all interests in the land will facilitate a complete spatial view and understanding of land use. A *Cadastre must show the complete legal situation of land, including all rights, restrictions and responsibilities. Such interests could* include those that extend to three dimensions, such as mining interests and also indigenous rights such as Native Title, which extends over, areas defined by natural landmarks. The primary datasets in such a cadastre is the cadastral parcel information.

Spatial Data infrastructure (SDI) comprises the fundamental data sets required to underpin economic growth and social and environmental policy development (Nowak, & Craglia M J., 2006). The infrastructure includes the materials, the technology, the organizational arrangements and the people necessary to acquire, process, store and distribute those datasets.

One of the basic datasets identified as fundamental to the operation of the SDI is the cadastre and in particular, the digital representation of the spatial cadastre or Digital Cadastral Database. The cadastre, as a land information system containing interests in land, forms part of that infrastructure. (Ting, 1999) Included a conceptual model of a parcel based geographic information system based on a legal cadaster as part of an SDI.

The comprehensive recording and management of all rights and interests in land as a component of the national SDI is increasingly needed as means of accessing and navigating through the virtual world recreated through the SDI (Ting, 1999).

A Digital Cadastral Database can also contain a number of thematic layers such as administrative boundaries, State Forests, National Parks, and Proclaimed Survey Areas. .A

multipurpose cadastral model is hence an information system model that conceptualizes the relationships between various databases, data flows and users.

The model must be flexible to accommodate changing technology such as the inevitable changing community expectations as overlapping rights and restrictions become imminent due to changing societal needs. For such a system to be developed there, is a need for functional co-operation and co-ordination between surveying and mapping, valuation, physical planning, land consolidation and land registration. The application of GIS and Internet technologies will allow distributed databases to be connected, accessed and presented in a seamless fashion to users.

2.5 Implementation of Cadastral Surveys in Some Countries

2.5.1 The United States of America

In the United States, the Public Land Survey System (PLSS); which is sometimes referred to as "rectangular survey" was the cadastral survey method that originated from the 1785 legislation. Survey methods were used spatially to identify parcels boundaries before the title of final ownership, mostly for rural lands in the country. It was one of "the first mathematically designed system and nationally conducted cadastral survey in any modern country" and is been cited as "an object of revision by public officials of nameless countries for land reform. As a nation growing, it was faced with "an overwhelming task of surveying of over 1.8 billion acres of public province lands acquired through the Louisiana Purchase, the Alaska Purchase, and other acquisition proceedings" (BLM, 2012).

The Rectangular Survey System provides for a unit of land approximately 24 miles square, bounded by base lines running east and west, and meridians running north and south. This 24 mile square is divided into six miles square areas called townships. The townships were then mainly divided into 36 sections, and each section was set at mile square.

The Base Line and Principal Meridian determinations were the first step in implementing this survey system and followed the establishment for an initial point. This initial point is adopted for all government surveys in United States. The Latitude and longitude for this point were fixed by means of astronomical observations and from the initial point a Principal Meridian is run north and south on a line that intersect the poles; while the Base Line is run east and west on a parallel of latitude (BLM, 2012). The Principal Meridian controls survey lines east and west, and the Base Line is the north and south controls (BLM, 2012). The Bureau of Land Management of the United States has for some centuries successfully surveyed 1.5 billion acres into townships, sections were also monumented. However, the position of the meridian has changed a few times during history. The United States has adopted the WGS84 as the positioning system, and this new Datum is known as NAD83.

2.5.2 Cadastral Systems of Australia.

The development of cadastral systems was aimed at rapid land settlement, and economic expansion of primary production to support domestic and global markets. All Australian states adopted cadastral principles that included inter-alias what is now universally known as the Torrens Title System (TTS), a system of licensing surveyors and a system of "running surveys" by traversing. The defining characteristics of the Torrens system are:

- The Register is organized by parcel, each parcel bearing it own unique identifier, like parcel identification number.
- The coverage is comprehensive, with the Register for a locality being created through a systematic field survey process followed by an adjudication resolution in the case of conflicting claims.
- The survey of each parcel is rigid within a national framework for integration.
- Very strong, often conclusive legal effect was given by law to a right shown in the Title Register, that right being unchallengeable by other claimants.

The shortfalls in the Australian system include its complete reliance on traverse methods of running surveys which could cause errors to be propagated as a result of the "running survey" approach, and that existing procedures do not fully take advantage of modern survey equipment such as satellite methods, which are becoming increasingly, coordinate based (Kentish, 1994).

2.5.3. Ghana's Cadastral Survey Method

The method operative in Ghana, until the reformation, to include land title registration has been a Registration of Deeds, under the Republic of Ghana Land Registry Act 122, of 1962. A deed is a written instrument recording a transaction, usually the sale or transfer of property which is registered in the interest of private persons. Under this Act, no rigid proofs of title were required hence even a tracing from a general layout map at a scale of 1:2500, certified by a licensed surveyor was enough proof of the existence of a parcel due for registration (Ndoye, 2008). However, registration of deeds have had inherent inaccuracies; which gave rise to litigation over land, fraud from purchasers and mortgagees of land among other problems identified. These led to the adoption of the Land Title Registration with the promulgation of land Title Registration Law PNDCL 152 of 1986. They gave power to the Chief Registrar of Lands progressively to declare areas for compulsory title registration with a view of eventually converting all deeds into Titles. "In order to regulate survey of plans to accompany title certificate a survey regulatory instrument called LI1444 was also passed in 1989 which sought to convert any plans accompanying instruments for title registration into specially designed cadastral plans only." These plans are prepared by Licensed Surveyors which must be submitted together with survey field records to the Director of Surveys for checking and authentication (LN. , 1994 & 1999).

The title registration is only piloted in Accra and Kumasi and does not cover the whole country for which Deeds Registration is still carried on alongside. Another complaint with implementation was the cost of field survey and the duration of completion of the registration process from the time of initiation coupled with the fact that several Agencies or Departments were involved in various aspects of the registration process such as the Land Title Registration office of Ghana, the Survey Department and the then Lands Commission Secretariat which used to register deeds. Recently, all these Departments were put together under a re-structured Lands Commission. New survey guidelines were also prepared to enable the use of faster and straightforward technologies. Technologies like GPS and other suitable satellite methods for cadastral surveying methods in land surveying sector in Ghana.

2.5.4. Kenya's Cadastral Survey Method

Kenya's scenario is somewhat bendable using both graphical and numerical survey methods. According to (Osterberg, 2001) Kenya has invested extremely in a well-known European-like cadastral system for land registration through adjudication of existing traditional rights in a systematic pattern using simple methods that can keep the costs for the registration low and reasonable. The process of conveying fixed boundary surveys for the alienation of Crown lands to Europeans on white highlands prior to the Second World War was expensive in terms of time and procedure (Wayumba & Ogalo, 2002). After the Second World War, the areas that were under Land Consolidation and Adjudication programs had been surveyed by identifying existing boundaries of individual fragments on uncertified photographs (adjudication). Preplanning plots to produce demarcation maps (consolidation) then followed (Wayumba & Ogalo, 2002).

2.5.5 Existing Cadastral Methods in Liberia

Cadastral surveys in Liberia are executed by both Government and private Licensed Surveyors. Liberia has seventy one registered and licensed surveyors in the country according to the report of (Pichel, 2011). The Surveys are not based on any existing monumented framework as these were all destroyed during the conflict years. Most surveys are executed by compass traverses using magnetic compasses and low quality cloth tapes, which are not necessarily connected to any control frameworks but may be tied to any identifiable object for the purposes of plan preparation. However, there are some surveyors who have acquired total stations and GPS machines for use. These are from investors companies that are contracting roads, mines etc in Liberia.

Survey accuracies are, therefore, not only often low but inconsistent since minimum accuracy standards and methods for the survey are not specified (Pichel, 2011). There is currently no available National geodetic control framework for use in guiding cadastral surveys. As the country lies in the Northern Hemisphere, some few surveyors who have access to GPS and can produce their maps projected in UTM zone 29N. The Liberian nation

depended mainly on the Clarke 1880 map projection to produce maps before and even now. Maps producers (cartographers) relied on old topographic maps to develop these maps (personal communication, 2013). However, this simply means that grid systems on the maps themselves may also vary because there was no specific projection to be used till now.

The number of deeds being registered is taking a downward trend as with fewer properties being registered. The numbers for Montserrado County support this, with 1800 transactions occurring in 2008, 1683 in 2009, and 287 in 2010. This may seem counter-intuitive based on the amount of litigation involving land disputes (Pichel, 2011).

All aspects of the existing cadastral survey method need to be reviewed and redesigned for better productivity in the country. However, the existing method has assisted and contributed to the beginning of land surveying over a few centuries in Liberia. Nevertheless, as technology is increasing in the profession of land surveying, compass survey method is not effective for surveys now. The overwhelming development going on Liberia will need a survey method that will bring economic and social growth to the country. Therefore in the following sections discussion will be on survey method that will change the cadastral survey method of Liberia (Pichel, 2011).

2.5.6 Merits and Demerits of existing Cadastral System

The cadastral method in Liberia, though having survived since the 1850s and having graduated from one stage to another; has lots of weaknesses.

- Cadastral surveys are still executed with equipment like the magnetic compasses in conjunction with Cloth tapes being used for the measurements of distances between points in a traverse loops;
- Cadastral Surveys are entirely not based on monumentation;
- Surveys accuracies are usually very low and incompatible because they are not specified;
- There is no proper record of a National geodetic control framework; which could form the basis of cadastral survey integration in the country;
- The Cadastral system is presently unable to be integrated into modern surveys because of the lack of standards.

Land Laws in Liberia

Cadastral surveys or legal surveys are often regulated by land laws. However, the Liberian scenario has no Land Laws that make reference to cadastral surveys. The Land Law carved by the People Redemption Council "PRC Degree 23 in 1980" was specifically for licensing and registration of Surveyors. It was carved to provide a standard for professional conduct, accountability, control and regulate survey methods. Furthermore, it was to protect survey monuments, markers, beacons and other appurtenances on land. The Law did not consider

which surveying methods to be applied for Cadastral Surveys. It made reference to the fact that it can be regulated by the Surveyors in the country. However, current there is a reform land law before the legislators in Liberia for passage.

2.6 The Cadastral Plan

The basic building block of a cadastre in every country is the cadastral plan or legal parcel. Cadastral plan is produced by a registered and licensed surveyor who defines and measures the boundary of the land (parcel) by the use of an accurate survey method. The c records the boundary of the property (parcel) that had been surveyed. Each cadastral plan is static in time, and it represents the shape and status of the cadastre at the time of survey (Dale, 1988).

Figure 3: Certified Cadastral Plan of Ghana

Cadastral plan can contain different pieces of information, but there should be some basic important features that should be visible on all them. In the Ghana, cadastral plans are

patterned to match the methods used in the survey and the locality of such survey that has been executed in said area. The description of the cadastral plan for the Ashanti Region as shown in Figure 3 has following content:

- Plan shows the owner of the land (Title)
- Plan shows Plot number, community and the region where the land is located.
- It shows the area of the property (parcel) in acreage and hectare.
- The scale of the plan is normally for large scale, which is, 1:2500 and the notation of lines that surround the property (parcel) is in Pink.
- The cadastral plan shows the locality, District and Region where land (parcel) can be found.
- The parcel of interest is edged pink and adjoining parcels in the layout region are also indicated. There are also connecting lines showing how the survey was initiated and also where it closed.
- Grid lines running from north- south t and west-east are also shown on the plan with at least two adjacent lines to enable to proper scaling to be checked.
- Parcel's Plan Data in a chat form showing the Bearing and Distances of each edge is also shown.
- There is also a certification of the Licensed Surveyor that the survey was properly done together with his Signature, licensed number and stamp.
- There is finally, a Space for the Approval Seal of the Director of surveys and also approval signature.

In the current Liberian scenario, the Cadastral plans are patterned as following:

- The plan shows the name of the owner parcel within plot itself
- It shows the area of the property (parcel) under the owner's name;
- The scale of the plan is not standardized and the notation of lines that surround the property (parcel) is in Red;
- Parcel shows the shape of the land on the ground;
- Metes and bounds are indicated on the parcel;
- A sign of the north is shown on the plan such as magnetic North;
- Adjacent parcels and roads shown on the plan
- Licensed Surveyor signature with his license number attached and the date the survey was executed by him.
- The Assistant Minister of DLSC attest with a stamp, signature and date of attested.

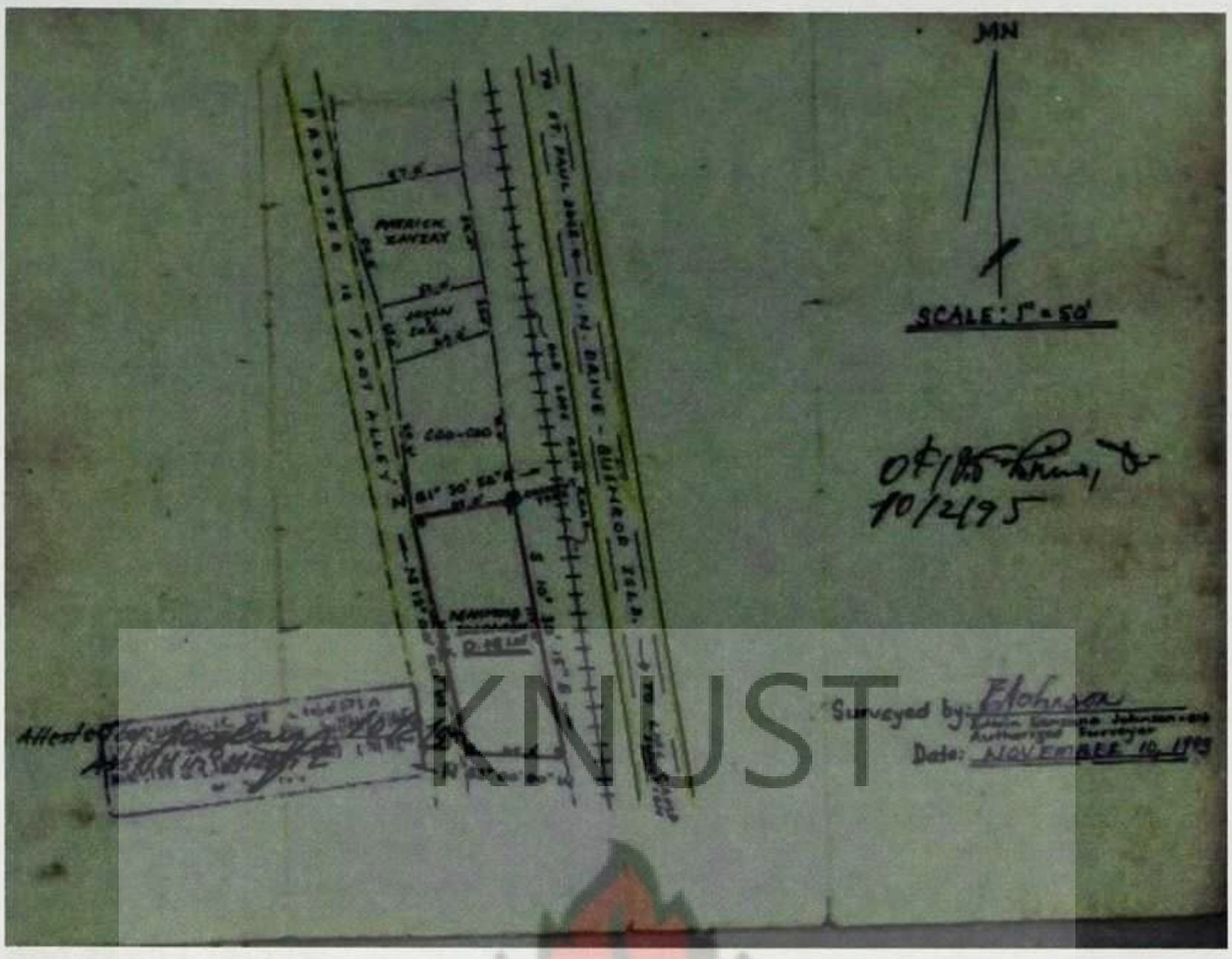


Figure 4: Certified Cadastral Plan of Liberia

A comparison between the Ghanaian and Liberian cadastral plans show the following similarities:

- Both have the names of the owner on the plans;
- They both show the size of the property;
- They are both edged pink along boundary lines;
- They show adjoining parcels and roads on the plans
- The signature of a Licensed Surveyor is affixed, and the approval signature of the Surveyor General or person responsible to approved such plans is on the certified plans.

In contrast the cadastral plans of Ghana and Liberia have a number of differences among which are:

- The Liberian plan is not arranged by plot numbers, but the Ghanaian plan has plot numbers
- The Liberian cadastral plan has no geo-code/locality on it but the Ghanaian plan has the region and the community in with the property was surveyed;
- There is no standard scale for the Liberian large scale plans; while there is a standard large scale for all Ghanaian cadastral plans;
- The provision of grid lines is not presented on the Liberian plan, but it is on the Ghanaian plan and allows the correctness of scale checking in cases of paper shrinking and also for proper georeferencing.

Chapter 3

MATERIALS AND METHODOLOGY

3.1 Materials and Equipments

The materials utilized for the successful completion of this project are as follows:

- Digital base map of Camp Ramrod/72nd Military Barrack
- Questionnaires
- ArcGIS 10.0
- Leica GPS receivers
- Microsoft Office
- Computer Hardware and accessories
- Microsoft Visual Studio 2008

3.2 Research Methodology

For this research to address it require specific objectives, the following research methods were used:

1 Desk study and Data Capture
2 Investigating Users Demands
3 Designing and Printing Cadastral Plan

3.2.1 Desk Study and Data Capture

The desk research was one of the core factors of this entire research. It was the medium through which the research was able to gather important pieces of literatures in assisting the compilation of the cadastral survey process in Liberia. It gives a holistic perspective of the existing method in Liberia and what problems it is faced with as opposed to the scenarios of other countries survey methods. An understanding of the existing methods provides the basis for recommending the appropriate cadastral survey method for the country. To compare existing plans with those captured with modern equipment, some data was captured through field survey using the Post-Processing Kinematic Survey Method (PPK) (it is a kind of DGPS method). There were also interviews with some senior staff at the DLSC. The process of questions and answers and review of documentation of the existing method which responds to the first two research questions.

3.2.2 Investigating Users Demands

Given that the project was engaged in finding suitable method for cadastral surveying to assist authorities in the Land sector in reforming cadastral survey laws in the country, the proceeding portion of this research would be a users' need assessment for cadastral surveying. A cataloging of the users' demands from the benchmark for method and standards specifications.

3.2.3 Designing and Printing Cadastral Plan

The research was to redesign the cadastral survey method. The redesigning of this cadastral survey method should produce a standardized cadastral plan from an application developed and designed to produce such a plan from GPS processed field data.

3.2.4 Case Study Area

A Case Study methodology was adopted as the basis for the development of an appropriate cadastral model. The Camp Ramrod/72nd Military Barrack area was chosen as the case study area. The study area was chosen because it had an existing cadastral plan that could be used for the study. It could also be used to introduce the proposed method and equipment in order to identify the problem and recommend appropriate solutions.

The Case Study methodology involves an analysis of the existing cadastral survey methods, the advantages and disadvantages of DGPS method to that of using compasses and total stations, a description of the system in the context of accepted cadastral principles; and the design of the cadastral plan which can be adopted and modified. Field observational procedures were carried on using a Geodetic GPS, and the results were downloaded, processed and used in the design of a cadastral plan for comparison. A system was also developed as a template for cadastral plan preparation.

The methodology also requires a comprehensive literature review, Data collection from various sources, contacts and media (hard and soft copy), an analysis of the information collected.

It was difficult to have the existing property map of the study area because; these weren't available at the Department of Lands, Surveys and Cartography (DLSC). However, a recent survey has been concluded for the Camp Ramrod/72nd Military Barrack of the Paynesville City of Montserrado County, and it was thought okay to apply the proposed methods to the same survey for the analysis of the results. The survey incorporated the Samuel K. Doe Boulevard and Somalia Drive roads and their intersections with the community roads. This property map shown below was scanned and geo-referenced in ArcGIS10. The comparison of results from the overlay of Google Earth image 2013 of GPS ground coordinates of the study area has shown a great disparity between the two cadastral survey methods (compass and DGPS methods) of the same land. The orientation of the study area map was observed to have been improperly positioned as opposed to the Google Earth image 2013 Map. This overlap of the ground coordinates of the GPS surveyed of the research area as shown in figure 5. The position of the road of Somalia Drive and the Samuel K. Doe Boulevard somewhat not properly positioned on this map shown in figure 5; which has turned the North to the South and south to the north.

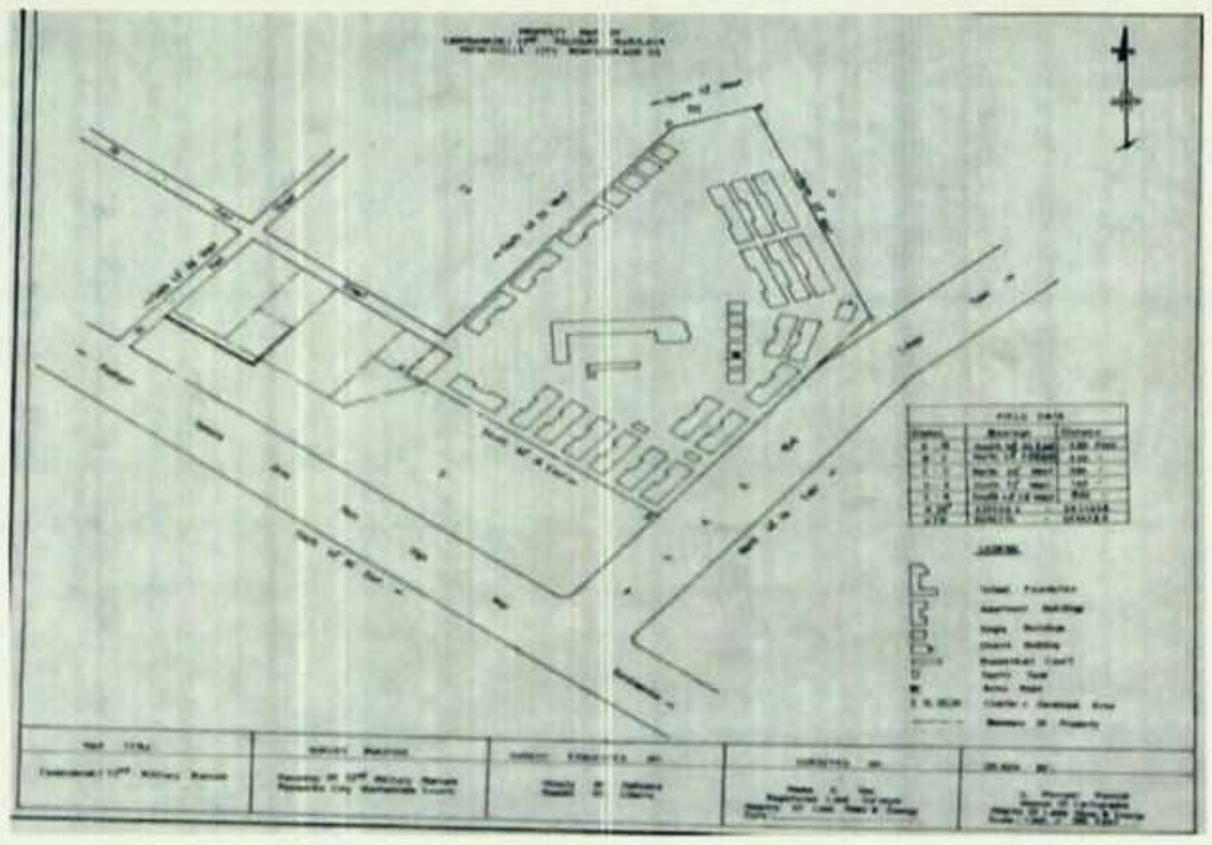


Figure 5: A Scanned Map of Research Area Conducted by Compass Survey

Figure 6: Google Earth image Map 2013

Figure 7: GPS coordinates overlay on Research Area

3.3.1. Methodology Flowchart

The method applied is described in the methodology flowchart as shown below:

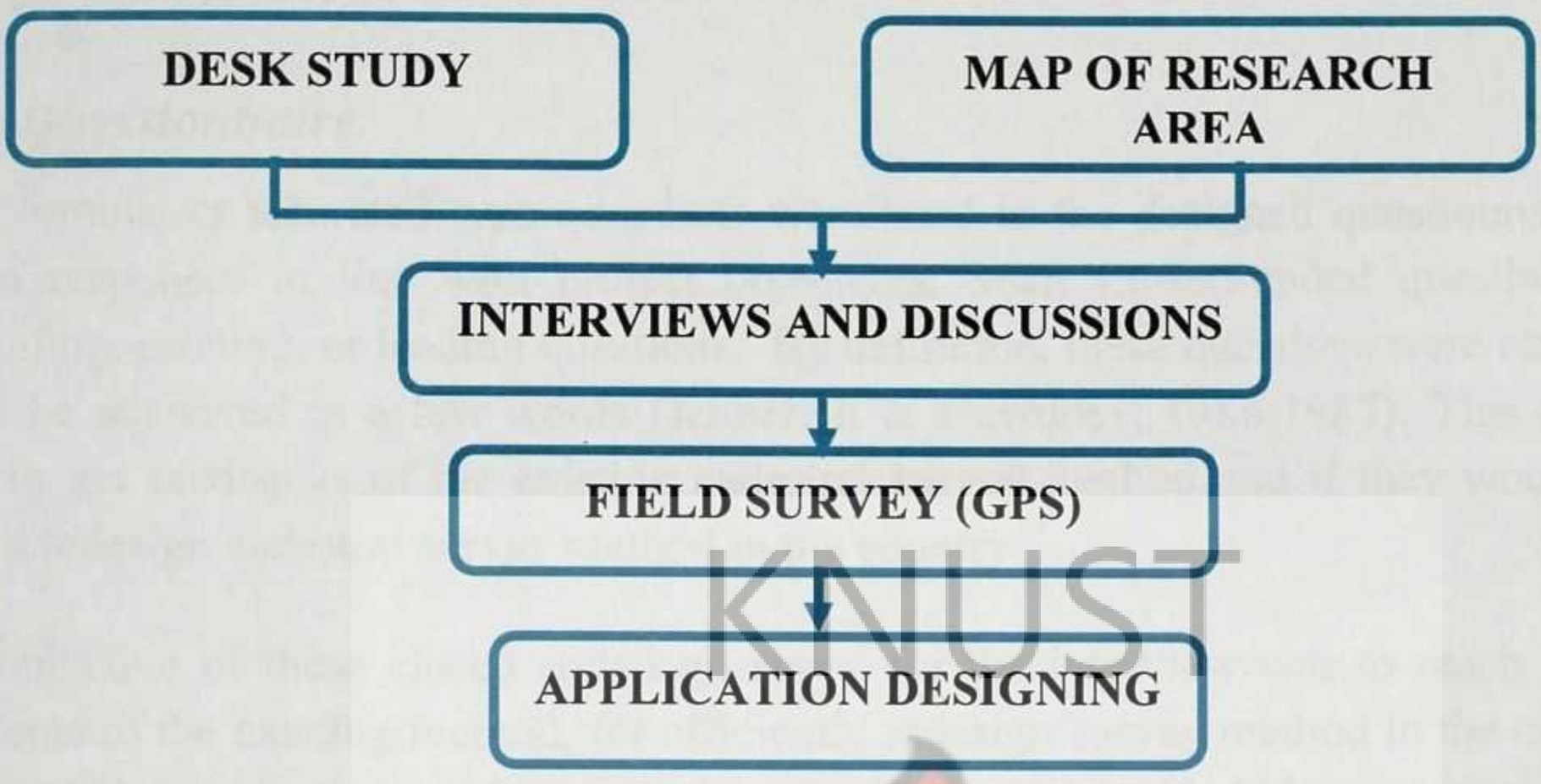


Figure 8: Methodology Flowchart

3.3.2 Information Collection

Documentation on existing cadastral survey methods weren't available because of the devastating civil conflict; hence the main means of information gathering were through interviews and consultations with the Director of Lands and Survey and other senior staffers at the Bureau of Lands Surveys. Consultations were made from some recent publications such as a draft Land Rights Policy and USAID Country profile on property rights and resource governance in Liberia.

The DLSC has a mandate to provide a standard of professional conduct and accountability for all land surveyors and control and regulate surveys and to protect survey monuments, markers, beacons and other legitimate survey reference appurtenances in the country. PRC decree No. 23 of 1980 states that "*The authentication of survey plans shall proceed as follows:*

a) *The Bureau of Lands and Surveys (BLS) Director shall have the power to inspect and verify the correctness of all survey plans affecting the conveyance of lands prior to probation and registration of the deeds, leases or any other documents to title ~~in the~~ probate courts.*

b) *Where a survey plan or plans have been presented to the Bureau of Lands and Surveys (BLS) for the Director's approval and were found to be incorrect, the probate courts shall reject same and shall not permit the registration of the deeds; leases or any documents of title to the land, unless the correct plan or any other authorized personnel of the ministry of Lands and Mines".*

The Bureau of Lands and Surveys (BLS) has the responsibility to conduct cadastral surveys of public land, providing litigation advice, putting forth recommendations for policy, and for supporting legislation in the areas of land purchasing, land administration, land management and land use.

3.3.3 Questionnaire

Dichotomous or saturated type questions were used in the designed questionnaire so as to obtain responses in line with project objectives. Such Closed-ended questions included presuming, probing, or leading questions. By definition, these questions were restrictive and could be answered in a few words (Jennerich & Dewdney, 1986;1987). This method was used to get feedbacks of the existing cadastral survey method and if they would desire to have a redesign cadastral survey method in the country.

The objective of these closed ended questions for the interview was to reach for the core problems of the existing method, for efficiently redesign survey method in the country using the research area as a case. Moreover, the responses also provided ideas on participatory best procedures. These prepared interview questions were in an order the following:

- ***EXISTING CADASTRAL SURVEY METHOD.*** Specific questions were drawn targeting information concerning the existing cadastral method. These questions should be on the conduct of existing cadastral surveys, its perceived advantages, and problems of the method. Finally, the reason why there is a need for modernized methods to be introduced (Appendix 1, 2014).
- ***GPS/DGPS METHOD***. Questions on GPS and other satellite methods were to find out the level of their use and acceptance in Liberia and how integral the results are in any existing methods concurrently in use (Miller, Beyan, & Massaquoi, 2013).

3.3.4 Outcomes and Conclusion

The outcomes from the interviews came directly from questionnaires given to the senior staffers of the DLSC. The responses reveal that:

1 The existing cadastral survey method was introduced by the deed system in 1850s where the property boundaries were fixed using chain and compasses. Its advantages were that they were able to show directions to boundaries corners and measurements to boundaries lines from references relatively irrespective of accuracies. The method is still predominantly used in the country.

2 The senior staffs interviewed were comfortable with the existing method as a means of at least recording security of land tenure. And if it possible for the informal customary lands to be integrated into the formal deed system.

3 They agreed that, there were some problems such as the method lacking the ability to tie the surveys directly to a coordinate reference frame which can assist the tracing and retracing easily in the future.

4 The cadastral surveys are isolated and could not be integrated to other surveys done with more accurate measuring devices.

5 Again they agreed to several overlaps of different surveys leading to litigations especially as attempts were made to retrace previous surveys.

6 The issue of adopting new instruments for surveying, though welcome, they thought was going to be hindered by cost since in their estimation most surveyors would not be able to purchase.

7 The senior staff spoke highly about the DGPS as an accurate survey method with computer software that could be used to process cadastral survey works and agreed that as costs continue coming down, it would become the main surveying equipment which must be integrated into cadastral mapping in Liberia.

8 On the geodetic framework, they agree that the absence of a densified network of controls is affecting the proper surveys in the country either with total stations or the perceived GPS methods.

9 They could, however, not readily ascertain the magnitude of error introduced as a result of compass surveys as against those done by total stations and for that matter the GPS.

10 However, the DLSC is desirous of redesigning its cadastral survey on the basic improved positioning of boundaries and are presently using a Garmin handheld GPS.

Following the outcome, the investigator carried out a field survey of the case study area using a DGPS method.

3.4 GPS Field Surveys

According (Michael, 2002), there are variety of GPS field data acquisition methods may be used for Cadastral Measurements and Cadastral Project Control. These include:

Static Positioning, which typically uses, a network or multiple baseline approach for positioning. This may consist of multiple receivers, multiple baselines, multiple observational redundancies and multiple sessions. A least squares adjustment of the observations is usually required to provide very high accuracy once observation times are long. Static positioning is primarily used for ties to the National Spatial Reference System (NSRS) when observing Cadastral Project Control.

Fast-Static Positioning, which requires shorter, occupation times than static positioning and may use a radial baseline technique or a technique, or a combination of the two. Fast static also requires the least squares adjustment or the use of processing software capable of producing a weighted mean average of the observations.

Post-Processed Kinematic (PPK) positioning can be used in areas with minimal obstructions of the satellites. PPK uses significantly reduced observation times compared to static or fast-

static observations. This method requires the least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations.

Real-time Kinematic (RTK) Positioning which is similar to a PPK or a total station radial survey. RTK does not require post-processing of the data to obtain a position solution. This allows for real-time surveying in the field. This method allows the surveyor to make corner moves (stake out) similar to total station/data collector methods (Michael, 2002).

3.4.1 Field Procedures

Post-Processed Kinematic (PPK) positioning method was used to collect field data. The Base Station was setup to have a good sky view to allow tracking of at least six satellites in common with the rover at all times of the survey. While the base was turn on, it was observed by one of the member of the survey team who noticed that it was collecting data at all times when the rover was running in order to be able to process the rover data..

The GPS antenna mounts were properly leveled as the mount was centered over the mark Reference station-Camp Ramrod Astro. The Antenna to mount was attached properly and aligned, and its height was measured and recorded (figure 9).

Figure 9: A DGPS Base Station Receiver

An external battery was used for power for base station and rover receivers. it was done carefully because the pins could be broken if twisted while connecting it.

The rover receivers were turned on remotely connect to the survey controller with the survey job selected along with survey style, which in this, work was the PPK (continuous mode).

The controller displayed on screen "start survey messages" and the appropriate settings were selected to ensure, for example that the PDOP shows recover was tracking at least 6 to 8 satellites in common with the base receiver.

During the boundary survey, at least 15 minutes were spent at each point that defines a boundary corner of the Camp Ramrod Military Barrack (case study). The starting point was named A, with the others B, C, D, and E; while points of the cluster community were GP006/C1 and GP007/C2 with Somalia Drive points having SKD and SKD and finally Samuel K. Doe Boulevard Road points were labeled as SKD and SKD (Figure 9).

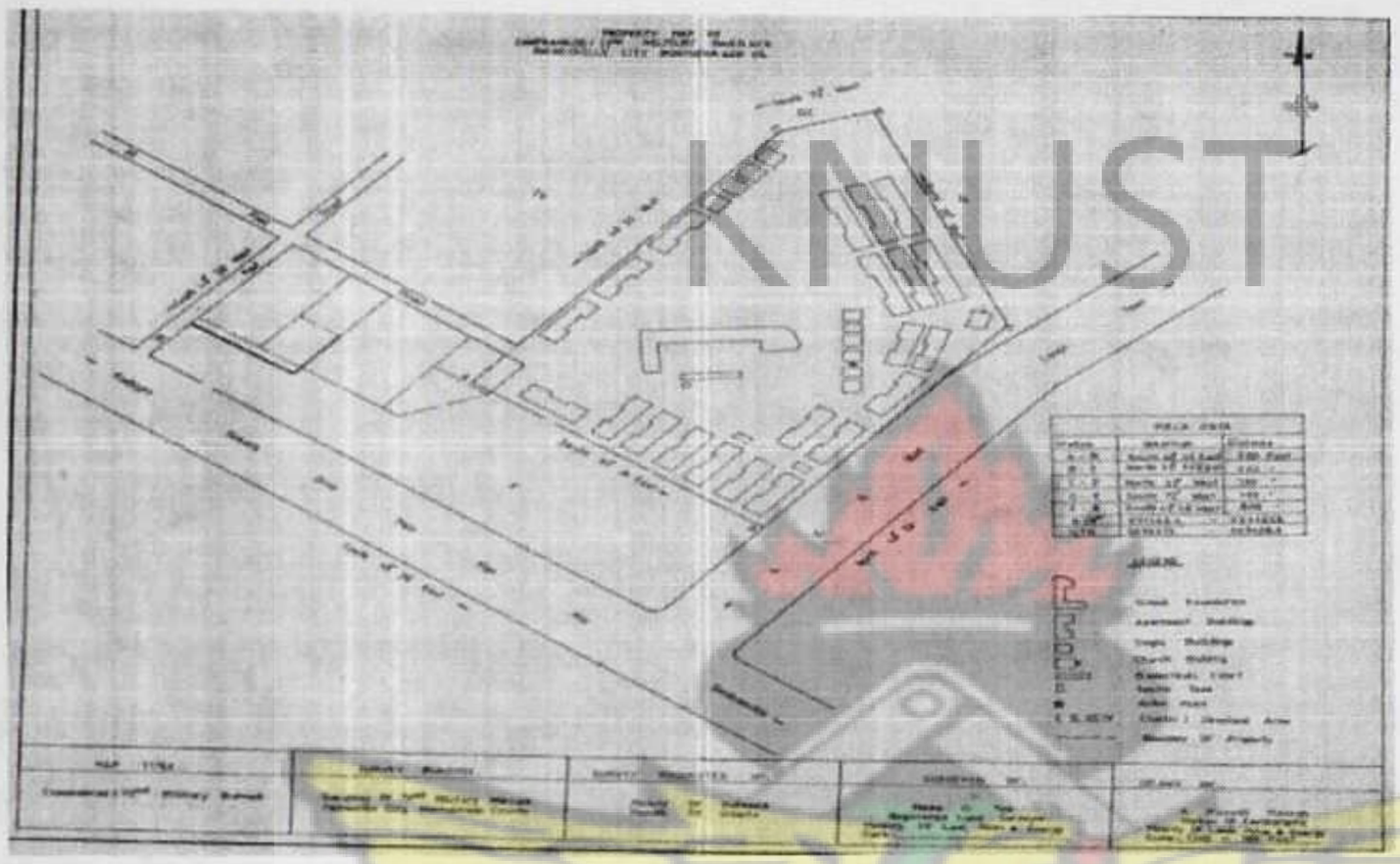


Figure 10: Study Area

The base receiver was only shut down after all the rover station survey has been completed. The antenna height was re-measured and checked if the antenna was still in a level properly oriented.

3.4.2 Downloading and Post processing of Data.

The Data from both the base and rover receivers were downloaded on the PC by saving each of the data from the memory cards one after another. The Leica Geo Office Data Transfer Utility was used to add all the data to a new project for post processing.

The Leica Geo Office processing software had program menus such as view, process data, adjustment of data, and data output of survey into different output formats such as a spreadsheet format. The following steps were employed in post-processing the field data collected.

1. A New "Project" was selected and given a name.
2. The New Project Properties was changed to WGS84/UTM coordinate system zone 29N.

3. The Import was selected, and the base station data, Camp Ramrod Astro, was first selected.
4. The rest of the data (rover receiver) was imported.
5. The base station data was checked to make sure that the occupation information was correct, especially point names, antenna types, antenna heights, and antenna height measurement methods. The 'Roving Segment' was represented by the data collected between the specified data collection which was the rover data continuously. The 'Continuous Segment' was represented by the desired data was also selected.
6. The points were visible on the map. Baselines between static points were shown in gray. However, Baselines to continuous survey points were not shown until the data were been processed.
7. Points on the lower menu of the Project page were clicked on, and the bars were selected and then "Process GPS Baselines."
8. The window showing processed baselines appeared and was listing statistics. The baselines were all checked to make sure they were selected before clicking "Save."
9. The baselines were shown in red color. Red indicated sound statistically baseline. To view the project without baselines shown, go to View-->Plan.
10. To view the distance between two points, select Survey-->Inverse-->select points from the map by clicking on each one.
11. The Results of all the points (coordinates X, Y, and coordinate class) were all shown on the lower right side of the Project window in UTM coordinates.
12. These results were exported from job to output ASC II files. .

3.5 Designing and Printing Cadastral Plan

The cadastral plan output of any cadastral survey is always the building block for any cadastral information system. The result of the survey was used in producing a modified and improved cadastral plan application.

An application has been designed to use the processed field data to generate the necessary plan data, including bearings and distances along each boundary points, the property area size, etc. The design also includes a template to allow for locality information and can be modified to include other information considered relevant.

Chapter 4
FINDINGS AND DISCUSSIONS

4.1. Current Cadastral System Components in Liberia.

Though Liberia has in its laws provision for both a system of Deed Registration and Land Title Registration System, none of these is currently operating due to several logistical reasons. The existing Deeds Registration System is in disarray. Records under that system have been scattered, damaged and in many cases destroyed.

There is a general lack of secure tenure in Liberia because the legal distinction between public land and tribal lands lack clarity, resulting in tensions between government, and tribal communities. The customary law of Liberian ethnic groups is remarkably poorly documented, and studies to establish a fundamental typology and parameters are required as there are large deviations between officially recognized custom administrations from indigenous models on the ground.

Fleeing citizens due to war who left their property return to find these occupied by squatters who claim rights to the property through the law of adverse possession since no documentation is available on the properties left'. The old deed registration system, which existed before, the war did not adequately record land transactions, making it very difficult to track lands due to missing deeds, deed records and databases.

Land administration is fragmented among several state agencies, without an effective coordinating institution and also key land administration agencies have lost human and technical capital that needed rebuilding for any effective land administration.

Currently, there is no cadastre and no effective and reliable land information system in Liberia. The activities of the Liberian Cartographic Service (LCS) which used to include National topographic base mapping, National geodetic control establishment, and National geographic research have all ceased since the conflict, and there are now no clearly defined cadastral surveying methods and guidelines that qualified surveyors can follow to provide accurate and integral cadastral information for developing the National cadastre.

Cadastral information is currently collected in a largely unregulated manner using a variety of surveying equipment such as compasses of different accuracies. There are several situations of "isolated surveys", which are not integral to any consistent spatial framework (or geodetic survey). Surveys are absolutely not based on any existing monumented framework as these were all destroyed during the conflict years. Most surveys are executed by compass traverses using magnetic compasses and low quality cloth tapes.

There are, however, also some surveyors who have acquired total stations and GPS machines for use. Survey accuracies are, therefore, not only often low but variable since minimum accuracy standards and methods for the survey are not specified.

There is currently no available National geodetic control framework as most including records on them are unavailable for use in guiding cadastral surveys. As the country lays in the Northern Hemisphere zone 29N some few surveyors who have access to GPS produce their maps projected in UTM. Others who knew the country used to produce maps on Clarke 1880 produce such maps by relying on old topographic maps. This means grid systems on the maps themselves may also vary.

4.2 Development of an Appropriate Cadastral Model

According to (Webb, 2004). Cadastral mapping has traditionally relied upon well-established cadastral survey techniques of traversing and radiation. The equipment used to accomplish these surveys has evolved from compasses together with chains, through optical theodolites and steel bands, to total stations and data recorder technology. With recent advances in satellite technologies, space-based positioning systems such as the Global Positioning Systems (GPS) are now becoming capable of replacing conventional survey methods for many applications, especially when striving for consistent sub-centimeter three-dimensional positioning.

Cadastral Surveying has always depended on the availability of:

1. A national framework or control system for geographic referencing and data integration.
2. Procedures and Rules regulating both the equipment and methods for use so as to regulate accuracy of works.
3. Laws that seek to remove the restrictions that hinder equitable access to lands to natives and Government commitment to the removal of uncertainty in Native Titles

Cadastral surveys are expected to be completed under the direct supervision, and responsible charge of a land surveyor licensed to practice. The surveyor's work is intended to be checked by the Chief Survey Officer.

The primary purposes of cadastral surveys are to retrace and monument the recorded location of the existing properties and to locate or establish the required property controlling corners. These surveys are an integral part of the land acquisition, disposal, use, and maintenance. The surveys were designed so that a patent Deed, which included reference to the survey on the ground, could describe land and would form the basis of all subsequent property surveys and conveyances of property. Monuments set during the original land survey control subsequent surveys and locations of described properties.

4.2.1 Consistent Spatial Framework

The linkage between cadastral systems and geodetic networks is very well acknowledged as spatially related information in its various forms can only be integrated by a common reference framework (Brinker & Minnick, 1987). A consistent and comprehensive geodetic network, that is, a system of widely spaced marks with known positions makes it possible to establish spatial linkages between all relevant land information so that any features can be related spatially.

Early datum definitions for National Geodetic control networks were largely achieved by initial astronomical measurements techniques together with the choice of a best fitting ellipsoid. There is currently, however, some conflicting findings both in literature and interviews conducted as to the correct geodetic datum used by Liberia. According to (Mugnier, 2011), there was a Firestone Datum, which perhaps was another name for Jidetaabo Astronomic Station φ_o = 04° 34' 40.33" N ±3.7", Λ_o = –07° 38' 55.74" W ±2.16", and a reference azimuth to an unlisted point as A_o = 359° 42' 41.5", with the reference ellipsoid likely the Clarke 1866 where a = 6,378,206.4 m, and b = 6,356,583.6 m.

The literature also mentioned a "Liberia 1964 datum at Robertsfield Astro, φo = 6° 13' 53.02" ± 0.07" N, Λo = 10° 21' 35.44" ± 0.08" W, Ao = 195° 10' 10.57" ± 0.14" to Robertsfield Astro Azimuth Mark, based on Clarke 1880. Again, for the same Clark 1880 ellipsoid, there is a specified False origin at φ= 6° 35' N, Longitude of Origin (λ) = 9° 25' W, Scale Factor at Origin (m) = 0.99992, False Northing = 0, False Easting = 1,500,000 meters (Mugnier, 2011).

Many surveys currently being done in Liberia are tied somehow to features found on an old topographic map. However, few people who use GPS (mostly handheld navigational ones) have the results projected to UTM zone29n. There is currently no determined framework for differential GPS surveys.

In line with recommendations by the International Association of Geodesy, a new datum for Liberia should be based on, and aligned with the International Terrestrial Reference System (ITRS), and the ellipsoid associated with this datum will be the Geodetic Reference System 1980 (GRS80) ellipsoid (NZGD, 2000). In 1990, the International Federation of Surveyors recommended that its members promote and support the adoption of a global geocentric reference system proposed by the International Association of Geodesy (Steed, 1997). In 1991, the 56 member maritime nations of the International Hydrographic Organization (IHO), recommended the production of future navigational charts on a geocentric datum. In May 1994 at the UN Regional Cartographic Conference for Asia and the Pacific, all member countries resolved to adopt a geocentric datum as soon as possible. The International Civil Aviation Authority (ICAO) has decreed that WGS84 will be used for its activities,

commencing 1 January 1998 (Steed, 1997).

The International Earth Rotation Service (IERS) has been established since 1988 - jointly by the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG). The IERS mission is to provide to the worldwide scientific and technical community reference values for Earth orientation parameters and reference realizations of internationally accepted celestial and terrestrial reference systems (Seeber, 1994).

GPS measurement techniques are currently available for the establishment of geodetic frameworks for both classical and GPS differential surveys. GPS measurement approaches can virtually be utilized 24 hours a day dependent on satellite numbers, geometric quality and a favorable topocentric sky-looking perspective. This framework would provide a consistent base reference at national scales through which all mapping, field surveys, and other attribute collection activities are spatially integrated. The advent and rapid development of information technology that has the ability to capture, process, store, query and display large sets of spatial and textual data has given map makers powerful tools for land management.

Global Positioning System (GPS) technology can be used to capture spatial information and other attribute information. GPS is also a powerful tool for completing and densifying geodetic networks. The possible development of a nationwide infrastructure of CORS Base stations would provide access to real time position to the sub-decimeter level and further bring down the costs of re-establishment of boundaries.

4.2.2 Procedures and Rules regulating cadastral surveys

Surveyors are the principal professionals responsible for describing positions related to property and asset within a recognized framework. In undertaking this process of description, surveyors can benefit from improved measuring techniques and equipment, but these surveys must be done in accordance with guidelines and procedures so as to produce accurate results. Cadastral systems must be simple and effective, help in documentations that provide security of tenure and trading of land rights and be part of a national spatial infrastructure.

There appear to be as at now any clear rules and guidelines as regards to surveying equipment and methodology to use for cadastral surveys in Liberia currently. A reliable cadastre arguably relies on the strengths inherent in the surveying infrastructure and any decline or weakness of the surveying infrastructure potentially creates greater opportunity for errors and inconsistencies to occur. Land surveyors must be able to depend on the accuracy and integrity of the infrastructure in order for their surveys to support the integrity of any state cadastre. The determination of cadastral boundaries involves a range of evidence assessed in

accordance with well-documented principles of reinstatement. The description of a parcel includes the metes and bounds as described on the survey plan and reference on the Deed of Grant and/or Certificate of Title. This information is only accurate if the methods used as well as equipment are carefully implemented according to specifications. A true coordinated cadastre would be a cadastre where strong links exist not only between the parcels or properties but also to a common reference framework that covered the entire range of the cadastre. The coordinated cadastre should represent the positions of corner points in the cadastre to a highly acceptable level of accuracy. It is, therefore, very important to develop guidelines for spatial data collection methods and accuracies to assist cadastral surveying in Liberia.

4.2.3 Cadastral Laws in Liberia

Although cadastral surveys or legal surveys are regulated by land laws, in the Liberian scenario, Land Laws that will be developed should include specific reference to cadastral survey methods. The land laws should be to assist licensed and registered Surveyors not only to provide standard for their professional conduct and accountability but to also provide procedures and accuracies level for the modern survey methods they are to use in the production of title registration plans that are made available during adjudication processes of the properties whenever there are litigation issues. Land Laws that are carved should also consider the survey methods and it is obvious that the current land laws, which are under, reform in Liberia is going to have this part in the draft before legislation passage.

Fundamental legislative reform is necessary for the "management of land to meet the current and future economic, social and cultural needs of the people. Providing effective legal security of tenure and access to property for all men and women, including indigenous peoples and other disadvantaged groups is essential. So also must the rights and limitations of lessees and other users of lands be defined, so all users can make confident decisions of their rights and limitations. Statutory survey requirements need to be flexible and relate to the character of the information and the use of information for multiple purposes. The coordinates of boundary points should form the fundamental geo-reference; however, this needs to be balanced against the current Laws. Land administration reforms are essential for sustainable development and facilitating full and equal access for men and women to land-related economic opportunities, such as credit and natural resources (FIG, 1999).

4.4 Use of Global Positioning System (GPS) Technology for Cadastral Surveys.

The existing cadastral survey method currently used in Liberia includes Magnetic Compass and tapes. Its outcomes are usually expressed in metes and bounds (bearing and distances) though there is no evidence of applications of convergence of meridians to correct for

bearings. For long lines, such surveys are prone to large errors aside the fact that the method is laborious for large areas.

A Report-Baseline Assessment for the Department of Lands, Survey and Cartography (DLSC) of the Ministry of Lands, Mines, & Energy (MLME) and the Deed Registry of the Center for National Documents and Records/Archives (CNDRA) indicated that it will take sixteen (16) days to do a cadastral survey of hundred acres with the existing compass survey method in Liberia. (Pichel, 2011). On other hand, the usages of Differential GPS in cadastral surveying could be executed in three days and produced will precise coordinates through post processing of data along with the cadastral plan in two (2) days. GPS survey methods can bring efficient productivity to the cadastral sector and would improve the integrity of spatially related boundaries.

Improved GPS survey techniques offer better ways of knowing where something is located with increased precisions and smaller uncertainties. GPS survey provides four-dimensional reliable data, with abundant redundant data without the traditional traversing requirements of intervisibility between stations and designing of the network to give equilateral triangles.

The GPS, unlike conventional survey equipment and techniques, does not measure angles and lengths between ground marks and hence does not need clear "lines of sight" like conventional traversing, but rather a clear view to the sky. Field surveys using even a Differential GPS method can be carried out by just one person, so survey costs are low. The Cost of GPS equipment is becoming cheaper. GPS systems incorporate a Least-Squares network adjustment programs that assign vector precision within a network solution so errors associated with each point are indicated. Differences of coordinates are transformed to local plane system to provide the same bearing and distance descriptions that can be derived from computations after classical surveys.

Using classical surveying methods, Coordinates produced as a by-product from bearings and distances from electronic total stations become secondary in derivation to the metric measurement information. But in GPS measurements, GPS derived coordinates are a product of carrier-phase trilateration distance measurements made to orbiting satellites directly.

Conversely, consideration of a cadastral system that is deemed "out of control" in the Liberian context, the use of differential GPS would avoid the confusion of a large number of boundary related disputes due to inaccurate surveys. DGPS method will have no necessity for additional instrumentation (such as communications equipment) and can also be used in an all-weather condition in acquiring data that can be post-processed. There is quality assurance measures apply using DGPS method in executing cadastral survey and other

surveys. It provides 3D survey results, and the availability of the satellites is ready with a 24 hours service and has no limitation of the cloud coverage (Leick, 1995).

The Differential GPS is a method used to improve the accuracy of the position on the ground. It reduces the effects of ionospheric variations and can improve position accuracy typically to 1-5 meters. The DGPS receiver transmitter is placed at a known location where, for example, the exact position of a site that has been previously determined. The receiver is equipped to calculate corrections for each satellite received. The correction is the difference between the distances to the satellite from the receiver site as the GPS receiver measure the actual distance to the satellite based on the known location of the receiver site. These corrections are communicated to the DGPS through the base station receiver. The DGPS then uses the corrections to remove errors from its own measurements (Leick, 1995).

In the DGPS mode, the base station receiver and the rovers all receive signals from the same satellites. The established coordinates of the base reference allows corrections to be computed from the satellite signal derived coordinates and hence used to correct for the rover stations during post processing. The results of these positions reading will, therefore, be highly accurate. And the more satellites received by these DGPS receivers, the more accurate the position becomes for better positioning (Leick, 1995).

DGPS instrumentation has its own disadvantages like other survey technologies. Because the instrument is Post-processing method, the software is likely to be instrument specific. Its operations require coordination of data capture at both rover and base receivers working together. This means that the same satellites signals that the base station receiver will be receiving should the same satellites the rover receiver must receive (Leick, 1995).

4.4.1 GPS (PPK) Survey Results of Camp Ramrod Military Barracks

The DGPS, Post-Processed Kinematic (PPK) Survey Method using GPS receivers through the process of stopping and going and continuously leaping frog, while observation are made on the corner points of Camp Ramrod Military Barracks was done. The processed results for the survey are shown in table 4.1.

Table 4.1: Plan Data

FROM	BRGS	DIST.	TO	N(X)	E(Y)
A	296°23'05"	166.69	B	696355.2800	311826.4164
B	207°29'36"	197.39	C	696429.3580	311677.0890
C	148°55'30"	165.35	D	696254.2620	311585.9650
D	071°18'03"	42.11	E	696112.6395	311671.3123
E	026°41'37"	256.47	A	696126.1410	311711.2030

4.5 The Cadastral Parcel for Defining Parcel Boundaries

As the basic building block of any cadastre, the plan must be both accurate as well as have the necessary descriptive information on it so as to serve as legal parcel in the case of litigation or for adjudication purposes. The current parcel plan definition, which accompanies deed and Title documentation in Liberia, lacks scientific accuracy since surveys are not regulated, and also are not standardized. Hence it does not capture all necessary information for proper definition and retracing surveys. A modified cadastral plan is, therefore, proposed as a prototype which would contain the fundamental attributes in line with modern cadastral or survey plans used in Land Title Registration.

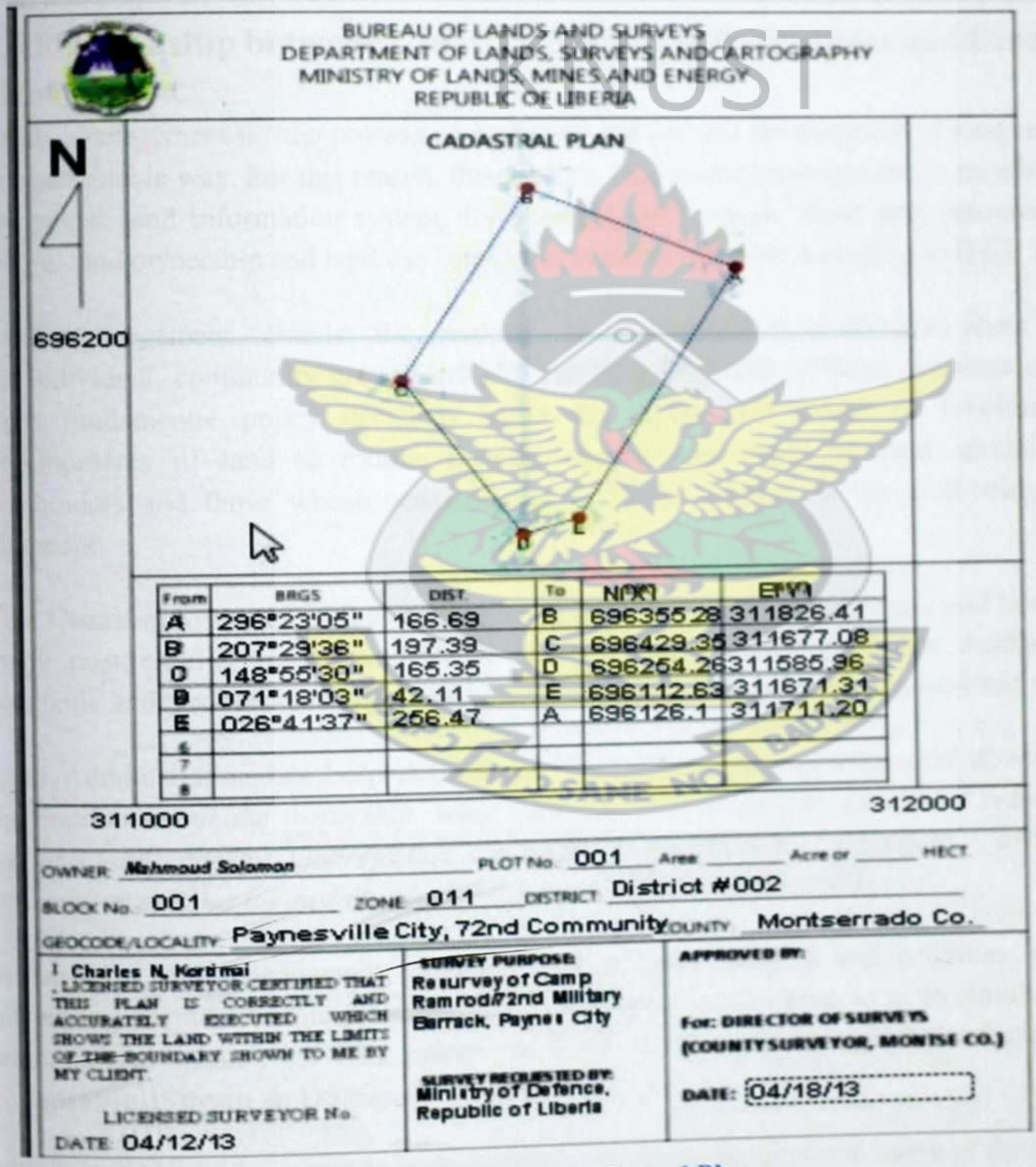


Figure 11: Prototype Cadastral Plan

It must be noted that a good cadastre must exhibit the mirror principle, where the register is supposed to reflect the correct legal situation; the curtain principle, which means that no further (historical) investigation beyond the register is necessary except overriding interests; and the insurance or state guarantee principle where the state guarantees that what is registered is true for third parties in good faith and that a bona fide rightful claimant who is contradicted by the register is reimbursed from an insurance fund maintained by the state (Mugnier, 2011). Due to the guarantee principle, the state must be active in analyzing transactions and documents to minimize fraud, damages and compensation.

4.6 Relationship between Cadastral Surveying Procedures and Land Management.

Land management is "the process of managing the use and development of land resources in a sustainable way. For this reason, the effective land management system is possible when the proper land information system, for example, information about land resources, land tenure, land ownership and land use" are put in better perspective according to (FIG, 1995).

Land management entails the making an implementation of decisions about land by the individual, community groups and governments. The scale of those decisions can vary from fundamental policy decisions about the nature and extent of investments or developments of land to routine operational decisions made by land administrators, landholders and those whose activities have a direct impact on the well-being of the landscape.

Poor Cadastral Systems in Liberia has contributed to poor land management and land loss to many post conflict returnees. Reform of the cadastre would therefore enable social, economic and environmental practices to be re- aligned to societal expectations and needs.

Land Administration has been defined as *"The process of recording and disseminating information about the ownership, value and use of land and its associated resources. It includes land cadastre, landregisters, and land consolidation, valuation and land information systems for sustainable development."* (McLaughlin, 1999).

Sustainable land management combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously maintain and enhance services, reduce the level of risks and be socially and culturally acceptable (Smyth & Dumanski, 1993).

The ability of land managers to make effective decisions to overcome many of the problems

associated with land administration hinges on access to reliable, up-to-date information on land condition. Spatial information collected on a systematic basis provides a cost-effective means of monitoring land status and land use controls. The integrality and use of this spatial information is dependent on the adoption of agreed, uniform standards and the linkage of this data to a consistent spatial reference system or geodetic network.

Land use and resource management is controlled, through instruments such as leases, licenses, covenants, agreements and other restrictions and the cadastre is the means of recording these instruments and therefore play an important role in land management.

A good cadastre would support Land Management and Economic Development by providing better information for land use planning, land administration, and support for socially desired land use and environmental considerations. It would also improve Protection of Land Rights including the reduction and avoidance of land and boundary disputes; the increase in efficiency of property transfers and dealings; increased security of land rights and dealings and fraud prevention; Support the Creation or Development of an Efficient Land Market through the provision of secure title for economic development; increasing revenue for central and local government by accurate identification of land use activity and property values; Simplify processes through standardization and automation of procedures that could lead to removal of duplication between institutions and provide fast, cost effective access to information and improve the integrity of data (FIG, 1996).

4.7 The Need to Change the Current System

The importance of establishing standards and methods for survey measurements has been identified as an essential step in obtaining consistent geographic data capable of protecting land rights and forming part of a National data infrastructure. This requires that the standards and methods of measurement should also be accepted as accurate.

4.7.1 Improving Geodetic Framework for Positioning

Geodetic positioning is about making measurements that link unknown points to high-precision points of known coordinates. These high precision coordinates of known points are established through a National Geodetic Network. A geodetic network in its ideal form can therefore be defined as any geometrical configuration of terrestrial survey points that are connected either by geodetic measurements made among such points as and whose assigned coordinates are accepted and kept by the National Survey Office and used to link other surveys (Leick, 1995)

Such a network system can easily now be established using geodetic GPS positioning methods to provide controls for all survey works and would meet the needs of new co-ordinate collection techniques and emerging technologies in surveying and mapping

applications.

With the development of Global Navigational Satellite System (GNSS) technology, separated horizontal and vertical datums would ultimately be integrated into one geometric or three dimensional (3D) datum if also accurate geoidal models become available. The International GPS Service (IGS) and the International Terrestrial Reference System (ITRS) have provided the impetus for a renovation and redefinition of many National Geodetic datums based and aligned with the ITRS.

The accuracy of such a datum would support modern survey techniques of Satellite methods as well as classical measuring methods using total stations. Such a datum would also be a three dimensional one which would allow height determinations simultaneously and eventually avoid the laborious spirit leveling process. It would also afford uniformity in coordinate definitions across the country.

It is therefore beneficial to adopt the WGS84 Geodetic datum which is associated with GPS measurements and also adopt Geodetic GPS techniques to establish sufficient controls for survey works in Liberia for cadastral applications.

Once such a framework is established, all cadastral surveys nationwide will be initiated from a control of a permanent reference marks from the framework to accurately fix all positions relative to it. The framework should be densified to areas where cadastral surveys are to be initiated and executed in the country. The key points of the framework would be to provide national consistency in all surveys by providing the following:

- A basic spatial data framework which will assist in unifying parcels boundaries.
- Support in quality control, for example, facilitate in detecting mistakes and checks against the accumulation of errors in survey measurements, hence maintaining consistency, improving accuracy and, therefore, giving greater degree of reliability of survey data.
- Aid to speed up fieldwork and decrease survey costs when controls are readily available.
- Provide scale and correct orientation for producing plans and maps.
- Reduce uncertainties in boundary surveys, for example, checks against encroachments or overlapping surveys, thus avoiding confusions of boundaries, which may cause conflicts among parcels owners and;
- Produce ground coordinates which are easily manipulated in cadastral application for developing cadastral plans from surveys conducted in the country.

4.7.2 Adapting Appropriate Cadastral Survey Method.

Adopting the appropriate cadastral survey method (s) that will produce accurate surveying results in Liberia is very important to improving cadastral surveys and for the development of a multipurpose cadastre for Liberia as of now. Therefore, selecting a survey method that has the abilities of capturing spatial data, and other attributes accurately as they relate to the national geodetic network is essential.

The advancement of Differential GPS services have made it possible for positioning accuracies of a few centimeters; which make this method advantageous in cadastral surveying presently. In addition, GPS surveys are completely compatible with modern geodetic frameworks and can produce mathematical transformations. Post-Processing Kinematic Survey Method has been proven as one of the GPS technology methods that is fast less costly in terms of field survey procedures and completely suitable for meeting cadastral accuracies. It has the ability to produce spatial data in horizontal coordinates, and if geoid models are available can also give vertical coordinates to a reasonable degree of accuracy. This method should, therefore, be preferred over other survey methods.

Differential GPS surveys provide ground coordinates for parcels corners boundaries that have the ability to improve the cadastre which is the basic building block up to a centimeter level. The issues of land litigations are becoming numerous and social cadastre are unable to assist the processes of adjudication and ascertainment of boundaries so land recordings based on social cadastre must be abandoned in support of the mathematically based descriptions using not just metes and bounds but properly determined co-ordinates (UN, "Multilingual Thesaurus on Land Tenure", 1996).

4.8. Introduction of the Cadastral Application

The cadastral application is designed software that accepts coordinates obtained from Processed GPS data and uses this to produce a modified cadastral plan together with computed derivatives from such coordinates (bearings and distances between points, Areas etc.).

Application Design

The designed architecture, conceived was to develop an application similar to most desktop GIS application which includes the Main Menu, Toolbar, Legend Window, main Map Display and Coordinate page. The Main Menu and Toolbar contain functions to manage projects and manipulate and query the map. The main Software used was Microsoft Visual Studio 2008, and selected programming language was Visual Basic (VB. NET), see Figure 8: showing the application main user interface (see fig 10).

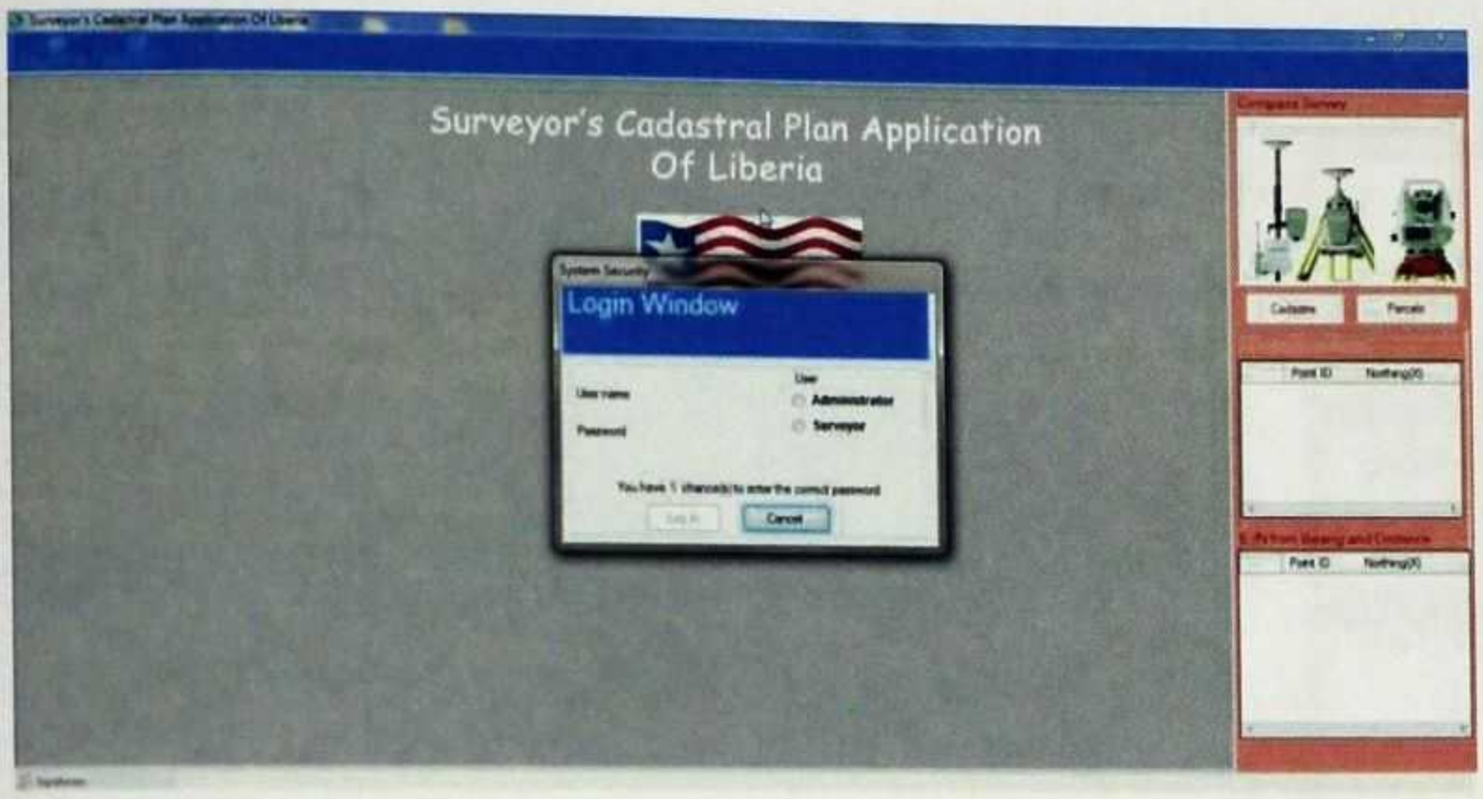


Figure 12: Login Graphic User Interface

The Map Plotter interface view is used by loading Plane Coordinates from a popup menu that appear when left clicked Add (N, E) UTM in the upper right corner on Map Plotter window. The Map Plotter window accepts and converts coordinates in UTM Northings (N) and Easting (E) figure13 which may be loaded from a comma delimited format (CSV file) in Microsoft-excel into the Map Plotter view as Points by clicking Point File and clicked on the Plot Point. This process is re-executed, but this time around, the coordinates are loaded to form the Polygon Shape by clicks Plot Point for lines to connect the Plane Coordinates Points that were previously plotted in the Map Plotter Window.

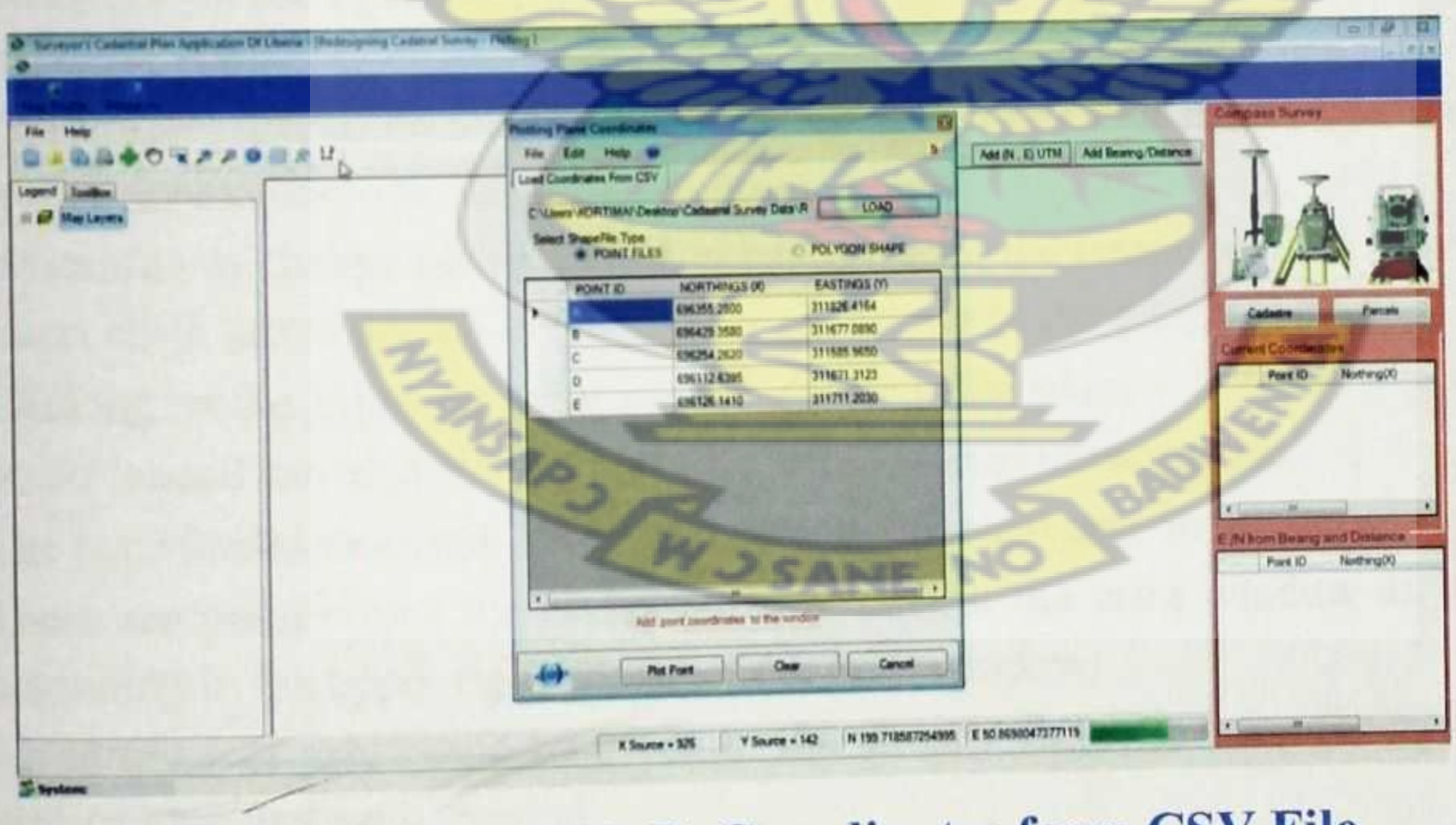


Figure 13: Loading (N, E) Coordinates from CSV File

The Add Bearing / Distance bottom when clicked would add computed bearing and distance to each of the boundary lines appropriately. The bearings and distances can be adjusted properly in terms of placement on the boundary lines. In adding application is designed to accept the bearings and distances to form the figure that will be in the Map Plotter Window, it is always done by imputing them one after another.

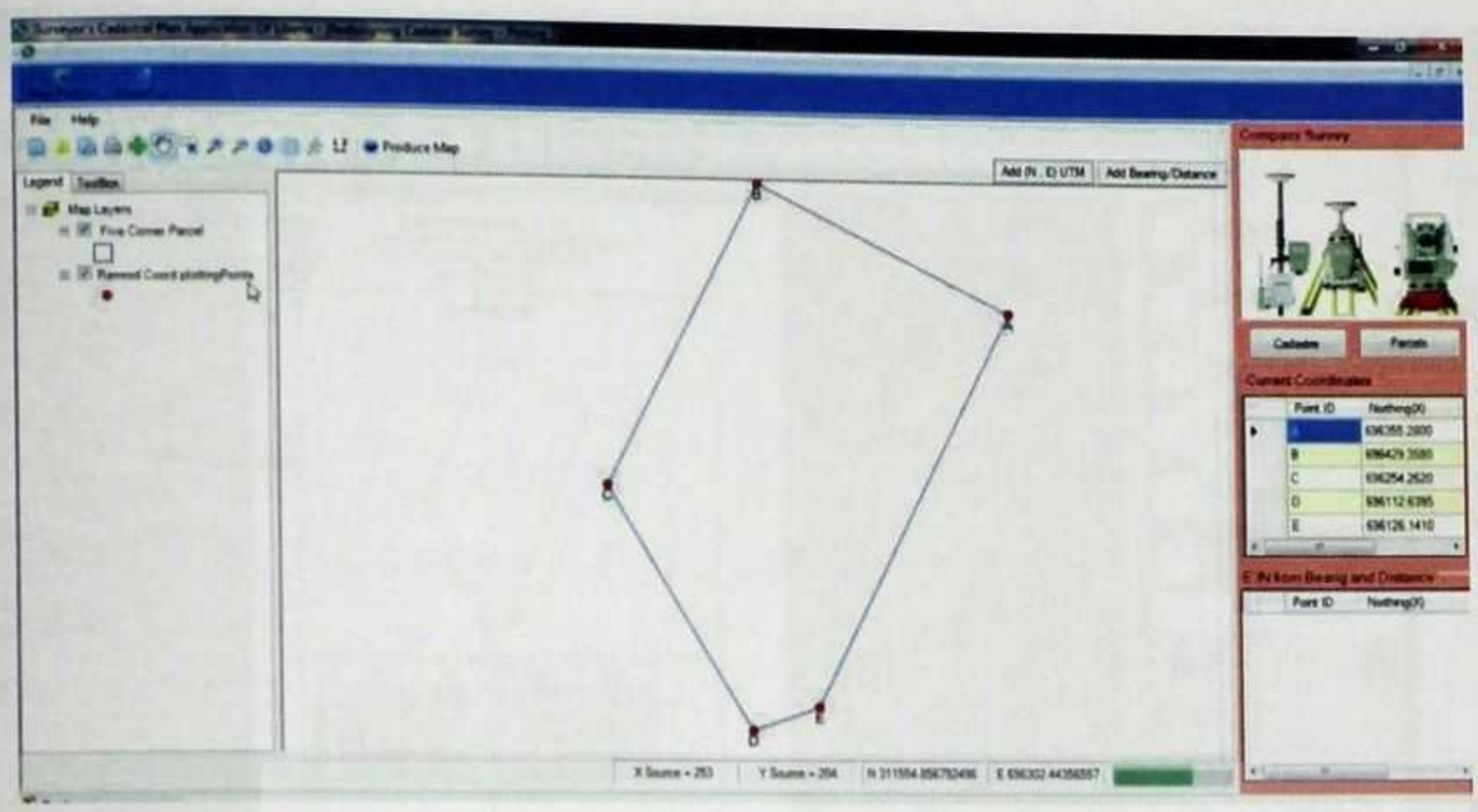


Figure 14: Coordinates Plotted in the Map Window

The Map Publisher is used to draw the cadastral plan of the parcel whose points have been plotted in the Map Plotter Window. In the Print Window, the surveyor is able to draw the cadastral plan of the parcel by left clicking on insert bitmap in which the plan template can be accessed and drawn in the Print Window. Bring the plan template, the surveyor or whosoever that is producing the plan must left click on the Print Window to have the plan template drawn. There are some other functions that one needs to perform before completing the plan. They as follow:

- Left click on the insert map to draw the parcel in the space right below the inscription cadastral plan;
- Click insert text to be able to put in all the literatures that need to be on the plan as spaces are available on the print window;
- If wanting to change the fixed true north arrow on the template, then you can click on insert north arrow seeing in the upper right corner of the print window.
- Clicking on the insert scale bar to give a scale to the plan;
- Insert legend can also clicked on to include a legend if necessary;
- The coordinates chart can be filled by using the insert text in the upper right corner;
- There are possibilities for zooming (in or out) in the print window as shown at the beginning in the upper right corner of the print window.
- An interval of grid could be given to the already fixed lines on the template of the plan (with a thousand interval)

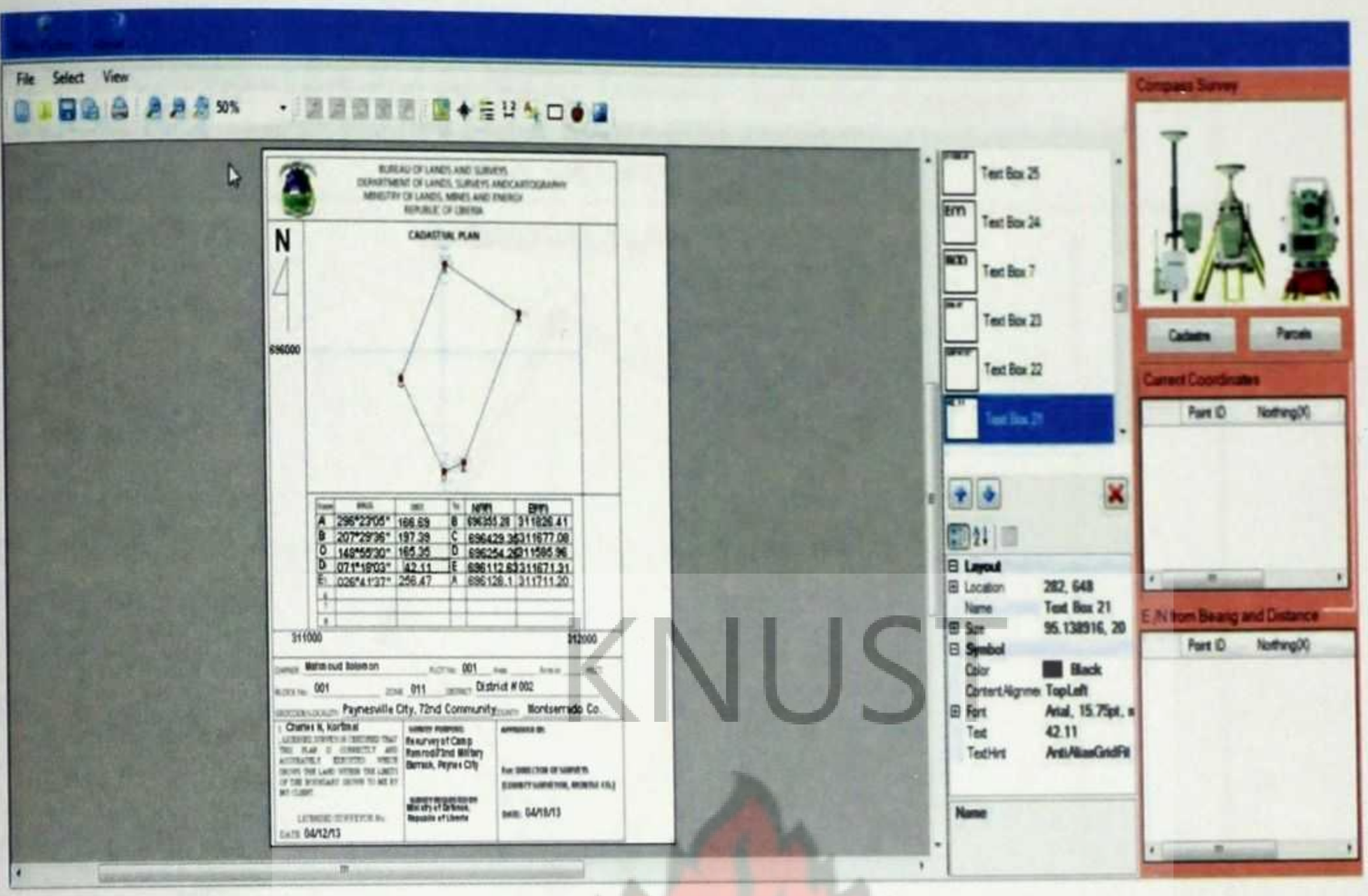


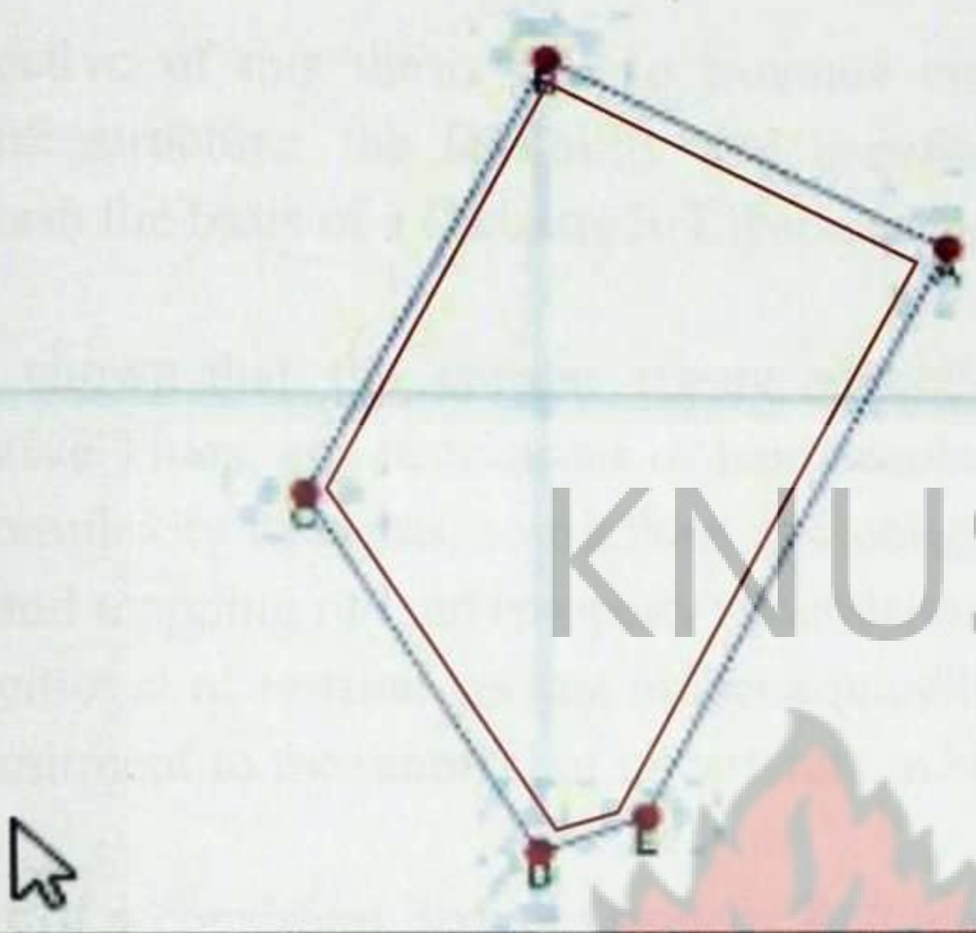
Figure 15: Developing Cadastral Plan in the Map Print Window

BUREAU OF LANDS AND SURVEYS
DEPARTMENT OF LANDS, SURVEYS ANDCARTOGRAPHY
MINISTRY OF LANDS, MINES AND ENERGY
REPUBLIC OF LIBERIA

CADASTRAL PLAN

N

696200



From	BRGS	DIST.	To	N(m)	E(m)
A	296°23'05"	166.69	B	696355.28	311826.41
B	207°29'36"	197.39	C	696429.35	311677.08
C	148°55'30"	165.35	D	696254.26	311585.96
D	071°18'03"	42.11	E	696112.63	311671.31
E	026°41'37"	256.47	A	696126.1	311711.20
6					
7					
8					

311000 312000

OWNER: Mahmoud Solaman PLOT No. 001 Area _____ Acre or _____ HECT

BLOCK No. 001 ZONE 011 DISTRICT District #002

GEOCODE/LOCALITY Paynesville City, 72nd Community COUNTY Montserrado Co.

I Charles N. Kortimai, LICENSED SURVEYOR CERTIFIED THAT THIS PLAN IS CORRECTLY AND ACCURATELY EXECUTED WHICH SHOWS THE LAND WITHIN THE LIMITS OF THE BOUNDARY SHOWN TO ME BY MY CLIENT.

LICENSED SURVEYOR No.

DATE 04/12/13

SURVEY PURPOSE:
Resurvey of Camp Ramrod/72nd Military Barrack, Paynes City

SURVEY REQUESTED BY:
Ministry of Defence, Republic of Liberia

APPROVED BY:

For: DIRECTOR OF SURVEYS
(COUNTY SURVEYOR, MONTSE CO.)

DATE: 04/18/13

Figure 16: A Printed Prototype Cadastral Plan

Chapter 5

CONCLUSION, RECOMMENDATIONS AND FUTURE RESEARCH

5.1 Conclusion

The primary objective of this thesis was to examine current cadastral survey methods, equipment and infrastructure, the feasibility and benefits of recommending a cadastral method that can form the basis of a Cadastre in Liberia to facilitate sustainable development.

The study has shown that the current tenure administration is unable to cope with issues such as Native Titles, and restrictions of land acquisitions to indigenes and also the ever increasing complexity of rights, restrictions and obligations which now exist without clear delineation and mapping of land (property) boundaries in a cadastral system. There is the need for the removal of restrictions that hinder equitable access to lands to natives and Government commitment to the removal of uncertainty in Native Titles.

The establishment of a consistent Spatial Geodetic Reference framework was identified as crucial to provide the spatial rigor and universal means for integrating spatial information. The availability of a well-defined geodetic reference network (GRN) is critical for the integration of all cadastral data is required or needed for the development of a Spatial Data Infrastructure (SDI). The geodetic network and associated subsidiary networks of survey control marks would provide the fundamental framework for spatial data integration, mapping control and infrastructure development as well as orientation and datum transformation for GPS and terrestrial surveys.

The unregulated methods of surveying and the use of inaccurate surveying equipment in Liberia have been identified as currently leading to non-integrality of geographic data and causing confusion in the land delivery service. As such training of land surveying professionals is urgent to avert the looming danger caused by leaving the practice of land surveying with unscrupulous untrained practitioners whose actions continue to fill court dockets with unresolved land disputes cases.

The study also identified the need to develop appropriate demarcation and survey rules and procedures including cadastral survey accuracy standards for data integration. Standards and guidelines must be adopted for all cadastral surveys and such guidelines must incorporate the possibility of using both terrestrial and satellite based methods whilst meeting set cadastral accuracy standards.

Improvements in mapping technology such as the development of the Global Positioning

Systems have made it possible to use both terrestrial and satellite based methods for cadastral surveying. The study found the PPK survey method using GPS systems as efficient for cadastral survey in terms of accuracy, savings on field survey time and labor costs.

As a tool that can support land settlement and taxation, the cadastral system must be modified along clearly defined and established legal parcels that can form the basis of a cadaster in Liberia.

There is the need for the recognition that the nation cannot develop without information or maps so there must be a clearly defined mapping policy to provide geographic data for development of land tenure security and land use regulation.

There is the need to work towards the development of a cadastre and an effective and reliable land information system to improve security of tenure. The Department of Land Surveys and Cartography and the Bureau of Lands & Surveys must provide cadastral maps and map derivatives as an important step in the adoption of a Multipurpose Cadastre system capable of managing overlapping Foreign and Native Title interests.

5.2 Recommendation

The study recommends that:

- The GPS should be used to establish geodetic Cadastral Control and/the practice of surveying must be considered the practice for professionally trained Land Surveyors so that all GPS surveying projects must be performed under responsible charge of an authorized Surveyor or a Professional Land Surveyor licensed to practice Land Surveying in the Republic of Liberia.
- There must be adequate densification the Geodetic Reference network to meet the expectation of Differential GPS techniques which it is envisaged would increasingly be used for positioning applications, including cadastral re-establishment, in the future.
- The establishment of sufficient geodetic controls such as Continuously Operating Reference System (CORS) at suitable intervals of 100 kilometer interval and other passive stations at suitable intervals to aid Differential GPS surveys in a compatible geodetic framework nationwide.
- When using GPS measurement techniques for Cadastral Surveys, the method used shall be DGPS so the Cadastral Project must always have a base reference on a Control network monument with coordinates supplied by the cadastral office of the Director of Surveys and Cartography. The points and resulting baseline vectors used in the Cadastral Project Control network shall be processed to derive the baseline solutions and be adjusted by least squares independently of the observed Cadastral

Measurements.

For the purposes of monitoring and control, a surveyor's narrative report shall be prepared and submitted to the Director of Survey and Cartography upon successful completion of the cadastral survey project and such a report should include:

- Make and Model of the GPS receiver, Antenna, and related equipment.
- A processing generated report regarding the baseline processing results and the software and version number used.
- A processing generated report regarding the Network adjustment results including a summary of covariance's, standard deviation or RMS values and the software and version number used.
- A list of the HARN, CORS or reference stations used in the survey.
- A list of coordinates by station including the datum, geoid model, epoch, and measurement units used.

5.3 Future Research

Modern object oriented database designs allow the integration of spatial and textual data, generating a wide range of reports and outputs, according to client demand. Spatially enabling textual datasets such as the Titles Register can provide a powerful tool for decision-making, particularly if accessible via the World Wide Web electronically.

The application of GIS and Internet technologies will allow distributed databases to be connected, accessed and presented in a seamless fashion to the user. In this way, spatial and textual databases physically store in different platforms and different locations, could be quarried and analyzed with in a system that can have its interoperability. These could well form the basis for future research into the development of an automated cadastral System in Liberia.

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APPENDIX I. RESEARCH INSTRUMENT

Dear Sir/Madam:

I am a Graduate student of the Department of Geomatic Engineering of the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi City, Ghana, West Africa. In partial fulfillment of my studies, I am doing a research on the Topic: "***Redesigning Cadastral Survey Methods in Liberia***".

I will appreciate it very much if you would share vital information that would be useful for this research to be successfully conducted in Liberia. Every piece of information gather will be kept confidential and use for the purpose of this research.

I would love to extend my heartfelt appreciations to you for your timely invention in assisting me during this period of information gathering of this research work.

Charles N. Kortimai

QUESTIONAIRE

Direction: These research questions, seek to collect pieces of information for the purpose of The Redesigning Cadastral Survey Methods in Liberia. Please place a check on the best answer of your choice.

Respondent Personal Data

Name: _____

Occupation: _____ Position: _____

Age: _____ Sex: ( ) Male ( ) Female County: _____

Community: _____ Educational Level: _____

Marital Status: ( ) Single ( ) Married

Date of Survey: _____

Existing Cadastral Survey Method

Do you have detail documentation on the existing cadastral survey method?
Yes ☐
No ☐

Are you aware of the conduct of cadastral survey in Liberia?

Yes ☐
No ☐

Are you comfortable with the existing method?
Yes ☐
No ☐

What are some problems you can identify with the existing method in Liberia?

Are you a Licensed/ Official Surveyor?
Yes ☐
No ☐

If yes what equipment do you usually use for cadastral surveys?

What Accuracy (Angular Misclose and Linear Misclose) is allowed for cadastral surveys?

Would Survey standards and guidelines improve of current cadastral practices?

GPS/DGPS Method

Are you familiar with the Global Positioning System (GPS) GPS?
Yes ☐
No ☐

Do you have any previous idea of Differential Global Positioning System (DGPS)?
Yes ☐
No ☐

Are you informed on the benefits the DGPS could offer to cadastral surveys?
Yes ☐
No ☐

Accuracy

Are there set of accuracies By Law for the existing (Compass) cadastral survey method?
Yes ☐
No ☐

Do Licensed Surveyors know any law that backs the existing cadastral survey method in Liberia?

Yes ☐
No ☐

Are Surveyors willing to accept new Laws for any cadastral survey method in Liberia?
Yes ☐
No ☐

Affordability

Do you know the cost of a DGPS cadastral survey in Liberia?
Yes ☐
No ☐