# GIS Handbook
## for municipalities

UN Joint Programme on Local Governance
and Decentralised Service Delivery

UN-HABITAT
FOR A BETTER URBAN FUTURE

**GIS Handbook for municipalities**



United Nations Human Settlements Programme (UN-Habitat)
P.O. Box 300030 00100 Nairobi GPO KENYA
Tel: +254-020-7623120 (Central Office)
www.unhabitat.org

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Main author: Asia Adam
Contributors: Gilbert Sosi and Pinar Caglin

Cover photo: Shutterstock
Design and Layout: Freddie Maitaria

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# CONTENTS

# 1 PREFACE

## 1.1 What is the purpose of this handbook?

This handbook serves as an introductory guide to geographic information system (GIS) technology for local government and other interested stakeholders. It suggests some common opportunities for GIS application, the benefits a GIS provides to users, and what is required to set up a GIS and sustain it. This is not a technical GIS manual, but a handbook that provides basic knowledge on GIS.

## 1.2 Who should use this handbook?

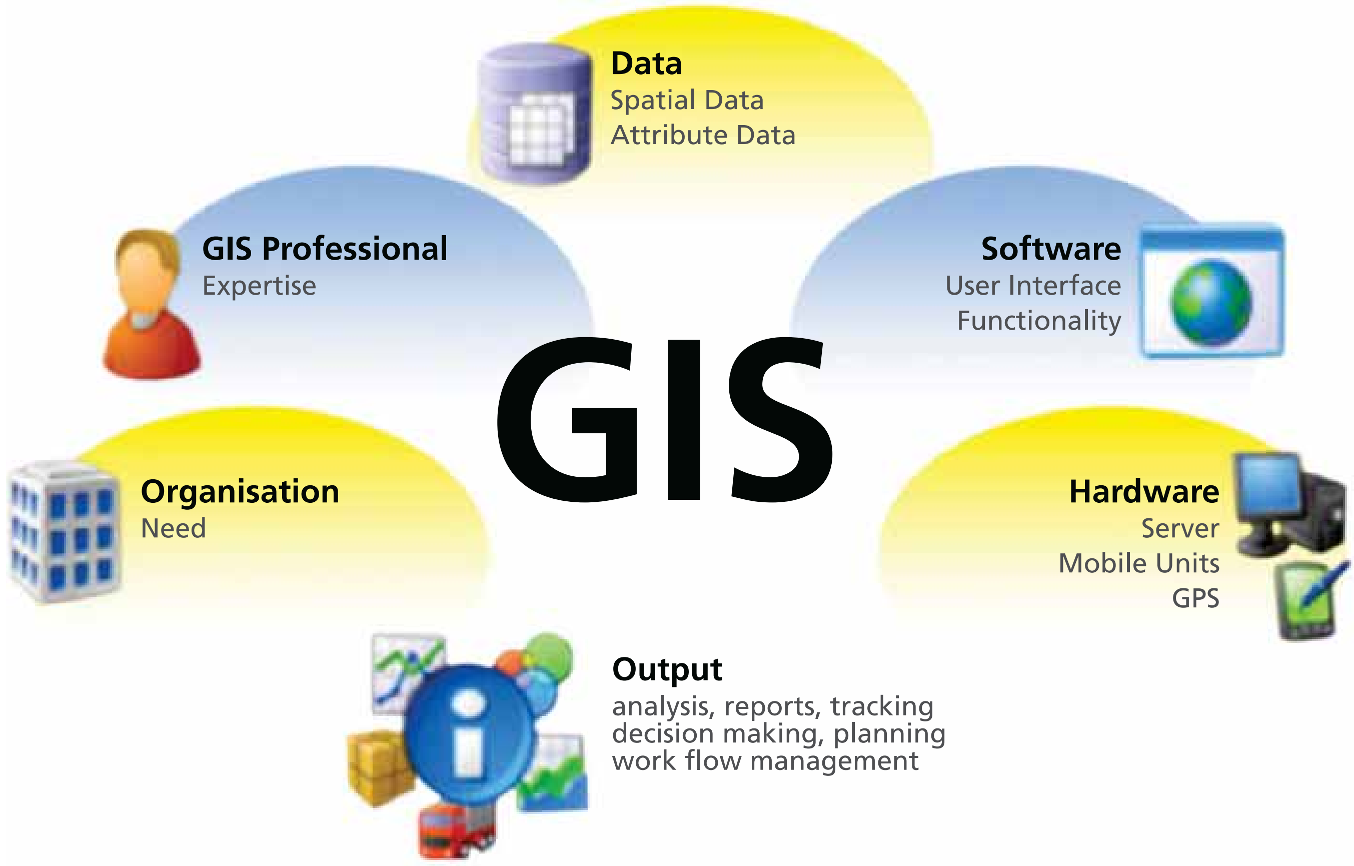
The GIS handbook is intended for local government decision makers (mayors, executive secretaries, heads of departments) and staff, as well as other stakeholders (e.g. NGOs and international agencies), particularly those engaged in development activities that deal with infrastructure, agriculture, hydrology, land administration, urban planning, crime mapping, solid waste management, or natural resource management.

# 2 WHAT IS A GEOGRAPHIC INFORMATION SYSTEM?

GIS technology has emerged as a powerful set of tools for managing and analysing spatial data (data tied to a specific point or area on the ground). The various types of spatial data are at the core of many development efforts, and GIS is seen as a solution to a number of problems local governments face in their area of jurisdiction.

In simple terms, a GIS can be described as an integrated system that combines hardware, software, and spatial data for the purpose of capturing, managing, analysing, and displaying all forms of geographically referenced information. Geographic information systems are a special class of information systems that keep track not only of events (e.g. environmental disasters), activities (e.g. construction), and things (e.g. facilities, institutions, or natural resources), but also of where they happen or exist.

The figure below describes the components of a GIS.



# 3 WHAT DOES A GEOGRAPHIC INFORMATION SYSTEM DO?

A GIS allows the user to view, understand, question, interpret, and visualize data in ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. The GIS answers questions and solves problems by presenting data in a way that can be quickly understood and easily shared. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A GIS can answer the following questions:

- What is at a given location? For example, what facilities (e.g. clinic, school, market) are available in the municipality?
- Where and why does an incident occur? For example, in which areas does flooding occur? Why are these areas prone to flooding?
- What is nearby? For example, what sorts of facilities, services, or dangers are close to a particular school?
- What trends are occurring? For example, what changes occurred to properties in the municipality since 2006?
- What happens "if"? For example, what happens if we expand this road? How many properties will be affected?
- What interactions occur? For example, what is the relationship between access to water and pastoralism?

# 4 HOW DOES A GEOGRAPHIC INFORMATION SYSTEM WORK?

The power of a GIS comes from the ability to relate different types of information in a spatial context and reach a conclusion about their relationship. A GIS expands the two-dimensional nature of a map to include information from a database. For example, a map can tell you where a road is located, but a GIS can show you where it is located and, with the appropriate data layers, tell you its average width, its condition, how many people use it, and how close it is to a service centre.

A GIS works based on data that has been attributed to a location; as mentioned above, this data is referred to as spatial data, with a geo-reference. The first step is to create a spatial database, which then can be used by the GIS to do a variety of analyses and present the information on maps in a clear and concise way.

Data can be presented in the form of lines, points, polygons, and annotations:

- Lines represent linear features such as streams, roads, power lines, railways, pipelines, etc.
- Points represent specific locations such as settlements, wells, electric stations, water tanks, etc.
- Polygons represent areas such as districts or regions, plots, land use zones, etc.
- Annotations represent the text that can be printed on maps.

All the types of maps consist of points, lines, and polygons that can be attributed to tabulated datasheets/spreadsheets. A GIS can actually connect Excel data to the space through those forms of representation.

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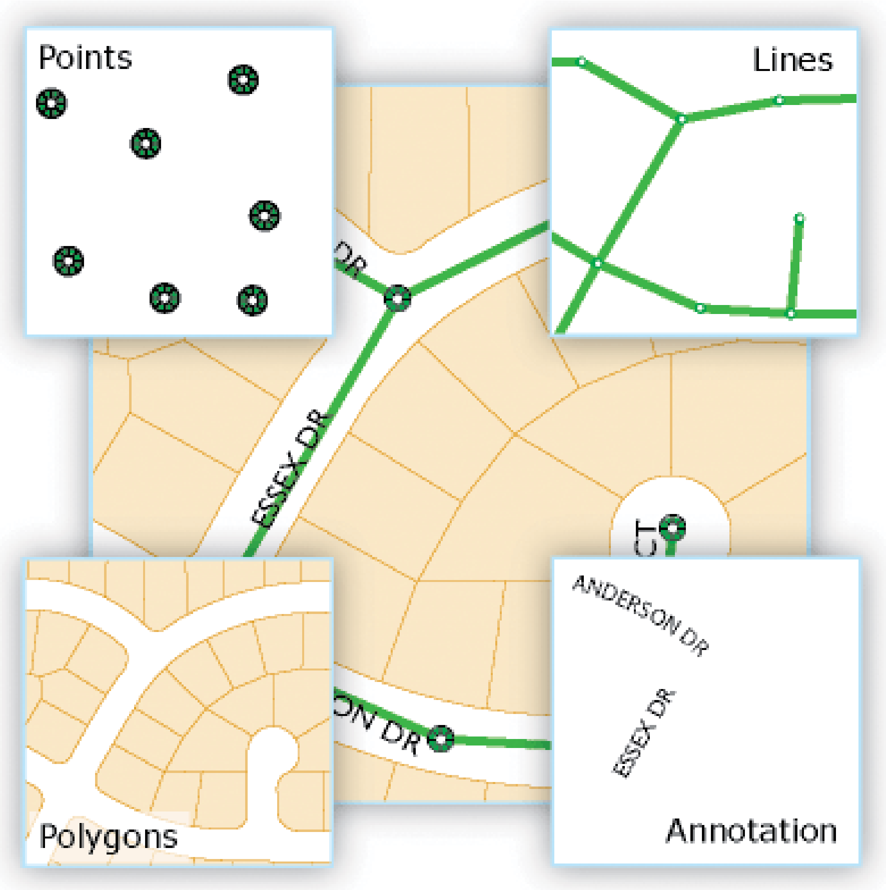
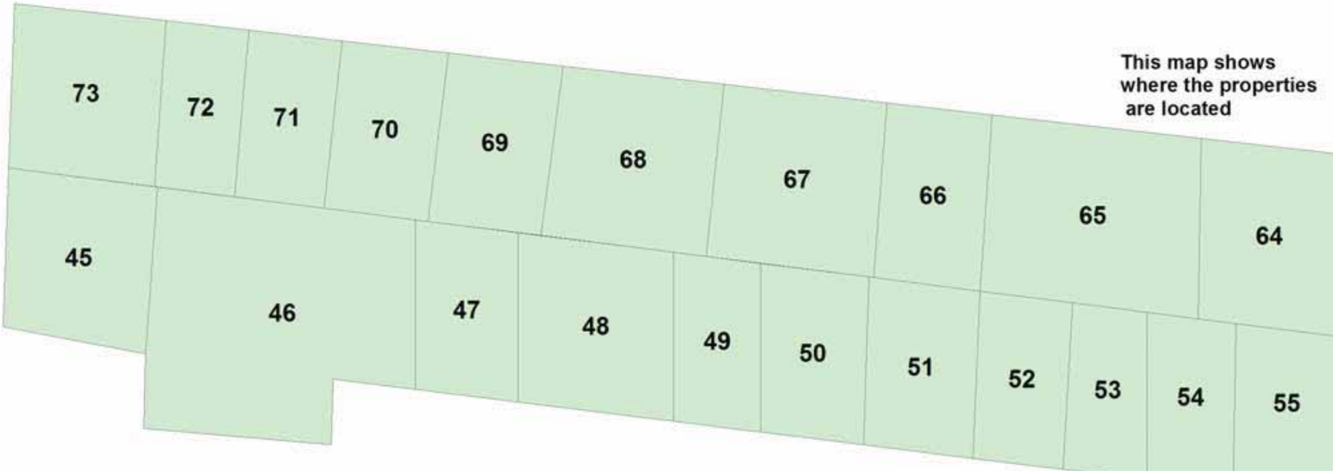



**Source:** http://webhelp.esri.com/arcgisserver/9.3/java/index.htm#geodatabases/feature_class_basics.htm

The image below shows how a GIS presents the location of specific plots and combines it with a variety of information.

| Plot_N0 | PROPERTY_TYPE | ROOF_MATERIAL | WALL_MATERIAL | NUMBER OF FLOORS | OCCUPIER | BUILDING_WIDTH | BUILDING_LENGTH | NUMBER_OF_PERSONS |
|---|---|---|---|---|---|---|---|---|
| 45 | Residential | Iron | Stone | 1 | ALI ABDI | 10 | 10 | 2 |
| 46 | Commercial | Iron | Stone | 1 | GEEDI SHOP | 12 | 10 | 5 |
| 47 | Residential | Iron | Clay Brick | 1 | MUNA ABDIRAHMAN | 10 | 10 | 6 |
| 48 | Residential | Iron | Stone | 1 | ADAN MAXAMUD | 7 | 7 | 12 |
| 49 | Residential | Iron | Stone | 1 | AXMED FARAAH | 6 | 7 | 8 |
| 50 | Residential | Iron | Stone | 1 | MAXAMED AXMED | 7 | 7 | 5 |
| 51 | Residential | Iron | Stone | 1 | QAALI AXMED | 7 | 7 | 9 |
| 52 | Residential | Iron | Stone | 1 | AMIINA DHULE | 7 | 7 | 11 |
| 65 | Residential | Iron | Stone | 1 | MAXAMUD AXMED | 12 | 10 | 8 |
| 66 | Residential | Iron | Stone | 1 | ABDILAHI ALI | 12 | 10 | 7 |
| 67 | Residential | Iron | Clay Brick | 1 | ALI BARE | 6 | 8 | 12 |
| 68 | Residential | Iron | Clay Brick | 1 | AMIINA ALI BARE | 6 | 8 | 10 |
| 69 | Residential | Iron | Stone | 1 | ALI OSMAN | 12 | 10 | 1 |
| 70 | Residential | Iron | Stone | 1 | ASHA HAJI | 10 | 8 | 5 |
| 71 | Education | Iron | Stone | 1 | STAR COMPUTERS | 8 | 8 | 2 |
| 72 | Education | Iron | Stone | 1 | WAABARI SCHOOL | 8 | 8 | 2 |
| 73 | Commercial | Iron | Stone | 1 | ABDI ABDILAHI AND SHOP | 8 | 8 | 2 |

**This list shows information on properties**



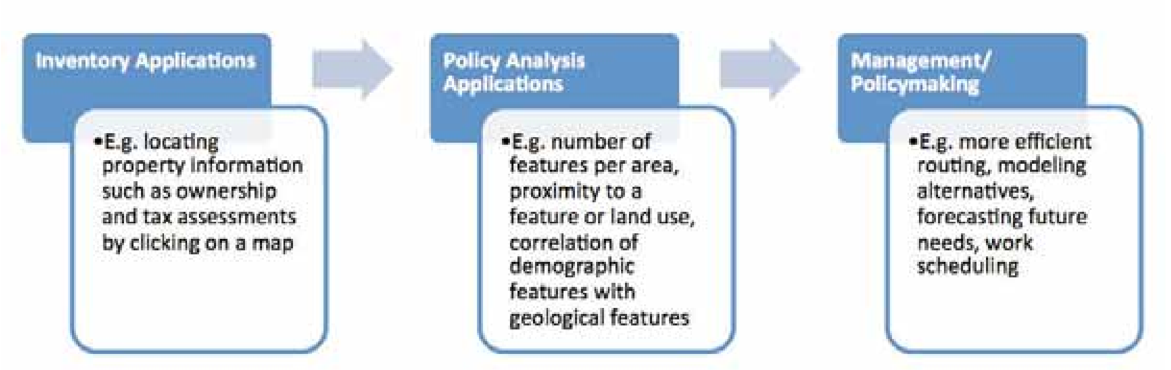

**This map shows where the properties are located**

# 5 HOW CAN A GEOGRAPHIC INFORMATION SYSTEM BE USED?

Geographic information systems are used in government for decision making at all levels, from the national to the neighbourhood level. Local government authorities are aware of the need to improve the quality of their products, processes, and services by using resources more efficiently. A GIS can be used to inventory resources and infrastructure, plan transportation routing, improve public service delivery, manage land development and administration, and generate revenue by increasing economic activity.

Local governments also use GIS technology in unique ways. Governments are responsible for the long-term health, safety, and welfare of citizens. Hence, wider issues need to be considered, including incorporating public values into decision making, delivering services in a fair and equitable manner, and representing the views of citizens by working with elected officials. Typical GIS applications thus include monitoring public health risk, managing public housing stock, allocating welfare assistance funds, and tracking crime. Similar to analysis using geo-demographics, geographic information systems are also used for operational, tactical, and strategic decision making in law enforcement, health care planning, and management of education systems.

Local government GIS applications can be grouped based on their contribution to asset inventory, policy analysis, and management/policymaking. Table 1 summarizes GIS applications in this way.



## **Table 1:** GIS applications in local government

| | | | |
|---|---|---|---|
| **GIS Application Area** | Inventory Applications<br>(Locating property information such as ownership and tax assessments by clicking on a map) | Policy Analysis Applications<br>(E.g. number of features per area, proximity to a feature or land use, correlation of demographic features with geological features) | Management/ Policymaking<br>(E.g. more efficient routing, modelling alternatives, forecasting future needs, work scheduling) |
| **Economic Development** | Location of major businesses and their primary resource demands | Analysis of resource demand by potential local supplier | Informing businesses of availability of local suppliers |
| **Transportation Planning and Service Routing** | Identification of sanitation truck routes, capacities, and staffing by area; identification of landfill and recycling sites | Analysis of potential capacity strain, given development in certain areas; analysis of accident patterns by type of site | Identification of ideal high-density development areas, based on criteria such as established transportation capacity |
| **Housing** | Inventory of housing stock age, condition, status (public, private, rental, etc.), durability, and demographics | Analysis of public support for housing by geographic area, travel time from low-income areas to needed service facilities, etc. | Analysis of funding for housing rehabilitation, location of related public facilities; planning for capital investment in housing based on population growth projections |
| **Infrastructure** | Inventory of roads, sidewalks, bridges, utilities (locations, names, condition, foundations, and most recent maintenance) | Analysis of infrastructure conditions by demographic variables such as income and population change | Analysis to schedule maintenance and expansion |
| **Health** | Locations of persons with particular health problems, locations of health facilities | Spatial, time-series analysis of the spread of disease; effects of environmental conditions on disease | Analysis to pinpoint possible sources of disease |

| | | | |
|---|---|---|---|
| **Property Taxation** | Identification of ownership data by land plot | Analysis of tax revenues by land use within various distances from the city centre | Projecting tax revenue changes due to land-use changes |
| **Land Administration** | Identification of ownership data by land parcels | Analysis of land tenure and land development | Analysis to map out effective land control mechanisms |
| **Human Services** | Inventory of neighbourhoods with multiple social risk indicators; location of existing facilities and services designated to address these risks | Analysis of match between service facilities and human services needs and capacities of nearby residents | Facility siting, public transportation routing, programme planning, and place-based social intervention |
| **Law Enforcement** | Inventory of location of police stations, crimes, arrests, convicted perpetrators, and victims; plotting police beats and patrol car routing; alarm and security system locations | Analysis of police visibility and presence; officers in relation to density of criminal activity; victim profiles in relation to residential populations; police experience and beat duties | Reallocation of police resources and facilities to areas where they are likely to be most efficient and effective; creation of random routing maps to decrease predictability of police beats |
| **Land Use Planning/District Profiling** | Parcel inventory of zoning areas, flood plains, industrial parks, land uses, trees, green space, etc. | Analysis of percentage of land used in each category, density levels by neighbourhoods, threats to residential amenities, proximity to locally unwanted land uses | Evaluation of land use plan based on demographic characteristics of nearby population (e.g. will a smokestack industry be sited upwind of a respiratory disease hospital?) |
| **Parks and Recreation** | Inventory of park holdings/ play areas, trails by type, etc. | Analysis of neighbourhood access to parks and recreation opportunities, age-related proximity to relevant play areas | Modelling population growth projections and potential future recreational needs/play area uses |

| | | | |
|---|---|---|---|
| **Environmental Monitoring** | Inventory of environmental hazards in relation to vital resources such as groundwater; layering of nonpoint pollution sources | Analysis of spread rates and cumulative pollution levels; analysis of potential years of life lost in a particular area due to environmental hazards | Modelling potential environmental harm to specific local areas; analysis of place-specific multilayered pollution abatement plans |
| **Natural Resource Management** | Inventory of natural resources such as land, water, soils, plants | Analysis of how people interact with natural landscapes | Evaluation of how human activities affect the natural environment (e.g. is deforestation for agriculture use sustainable?) |
| **Municipal Services** | Identification of administrative boundaries and identification of citizen needs | Analysis of basic services to be provided to the citizens | Evaluation of how the basic services are available to all citizens within their areas of jurisdiction |
| **Emergency Management** | Location of key emergency exit routes and their traffic flow capacity and critical danger points (e.g. bridges likely to be destroyed by an earthquake) | Analysis of potential effects of emergencies of various magnitudes on exit routes, traffic flow, etc. | Modelling effect of placing emergency facilities and response capacities in particular locations |
| **Citizen Information/ Geodemographics** | Location of persons with specific demographic characteristics such as voting patterns, service usage and preferences, commuting routes, occupations | Analysis of voting characteristics of particular areas | Modelling effect of placing information kiosks at particular locations |

**Source:** Longley, P. A.; Goodchild, M. F.; Maguire, D. J.; Rhind D.W., Geographical Information Systems and Science, 2005, p. 43, with adaptations

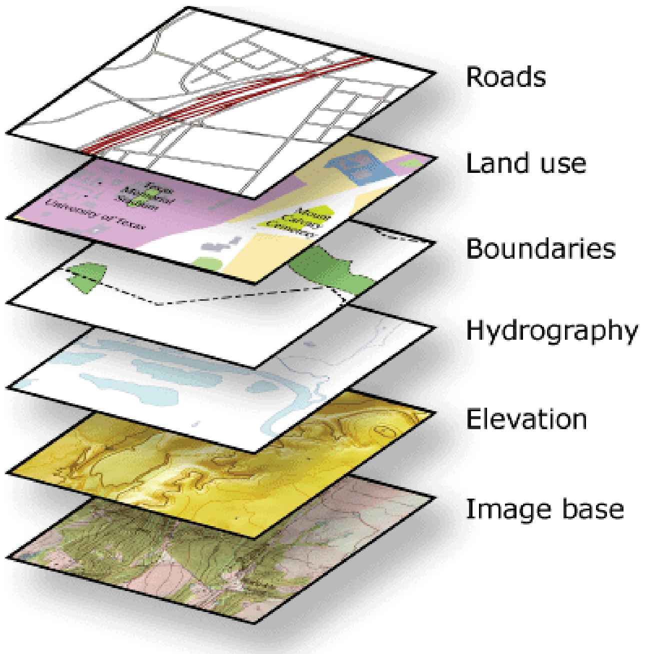
Geographic information systems have been used in Somalia in some of these areas of application in order to improve municipal service delivery, revenue generation, planning, and development. The following sections describe examples of GIS applications in Somalia.

## 5.1 Land Use Planning/District Profiling

GIS technology is a useful and important tool in land use planning, as it allows for the overlaying of various types of data in the form of maps to show how the land is utilized, where residential and commercial areas, open spaces, water sources, landfills, and agricultural and industrial facilities are located, and if there are any conflicting issues among land uses (e.g. if industrial areas are expanding into residential areas or if agricultural land is being invaded by informal settlements).

GIS technology allows for the spatial analysis of socio-economic and environmental data to understand which type of area or location is appropriate for different land uses.

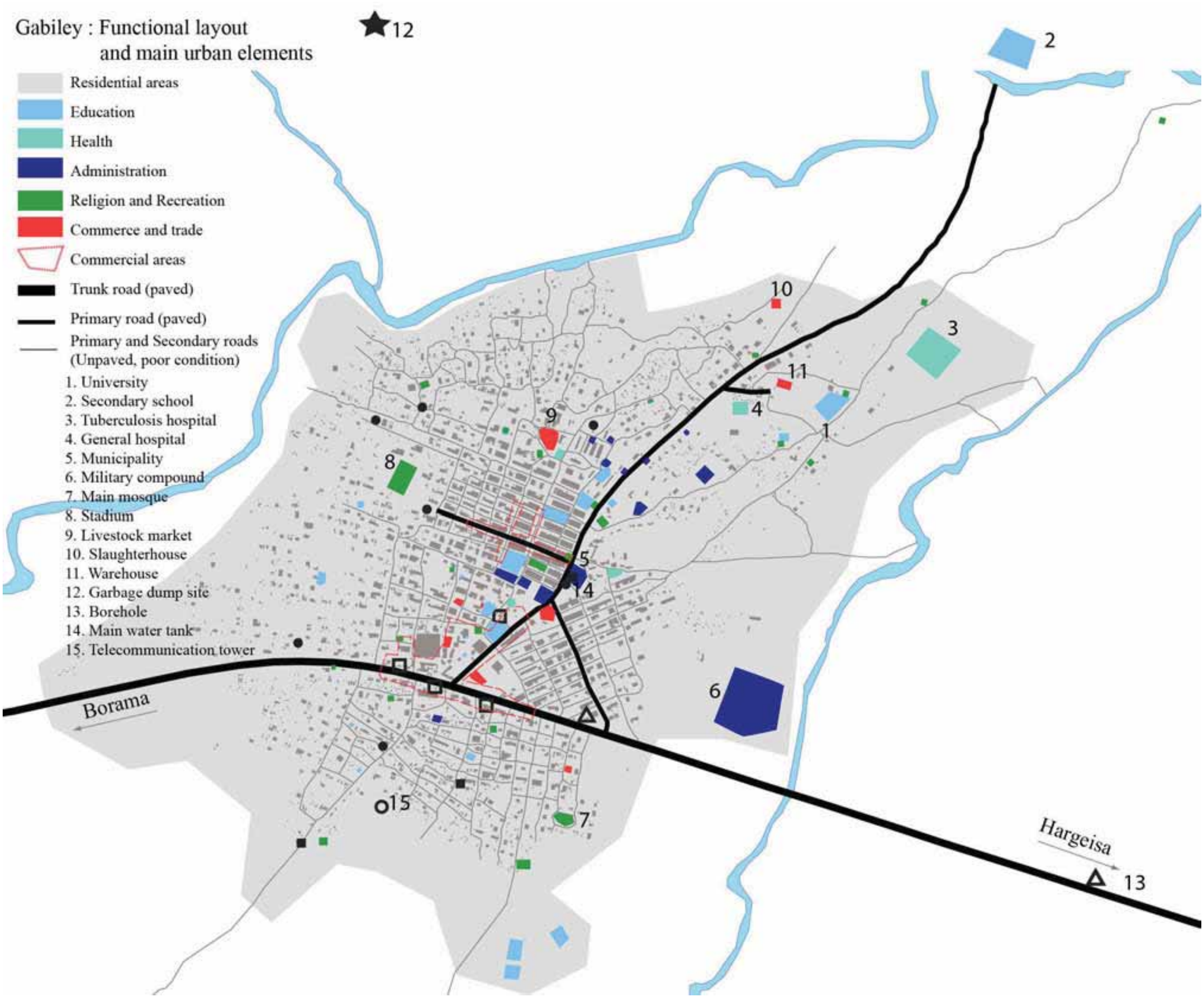
Different types of information can be layered and overlaid as seen on below.




**Source:** http://webhelp.esri.com/arcgisdesktop/9.2/printBooks_topics.cfm?pid=22

Geographic information systems are also useful in district planning processes, which have been exercised under the United Nations Joint Programme on Local Governance and Decentralized Service Delivery (UN-JPLG). The GIS technology is used to map and present the current social and economic conditions of a district. This is then compiled in the district profile, which is composed of social, economic, environmental, transportation, and technical infrastructure profiles, and includes the ongoing projects and development potential and constraints in the district. The main objective of the profile is to help district authorities develop an understanding of the current situation in their district and anticipate future scenarios. The GIS is then used to combine the statistical data of a district with locations presented on maps, and this helps to better understand critical intervention areas in the district.

The district profile is the first step in the district planning process. The map below was prepared for the town of Gabiley in Gabiley District.

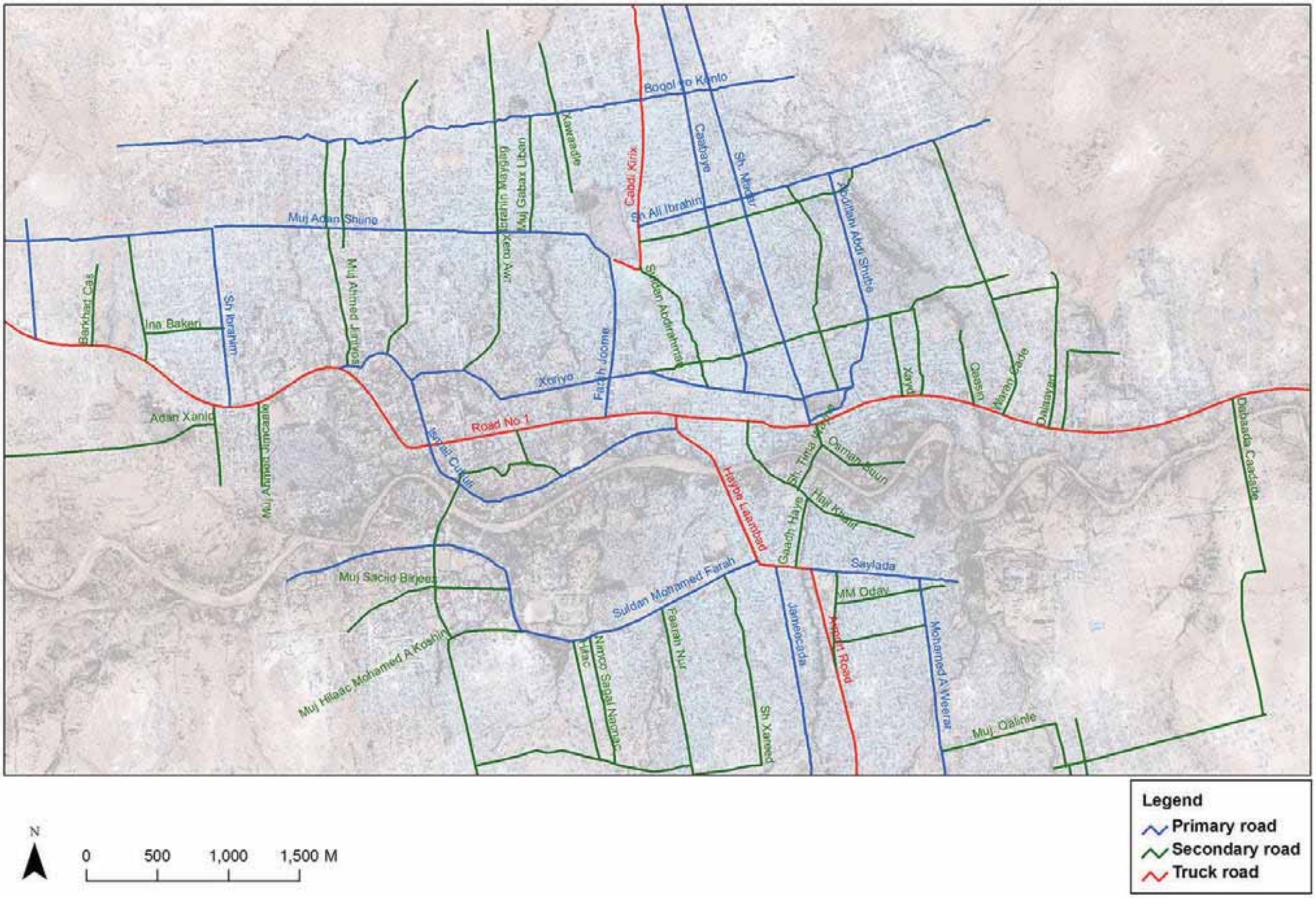



**Source:** Gabiley District Profile

## 5.2 Transportation Planning and Service Routing

Geographic information systems are also used to plan and classify urban roads. The map below shows the road network in a municipality. Using GIS technology, the roads were classified as trunk, primary, secondary, and access roads. A road condition survey was conducted to collect information on each segment of the urban roads for a spatial database. This included road (and street) names, road dimensions (width and length of the road), pavement type, major landmarks on the road, and economic activities along the road. The database was used for planning urban roads, classifying them in a hierarchy, naming the roads, and installing road name signage. The GIS was useful for mapping road conditions, activities along the road, and accessibility and then planning accordingly for road upgrading and prioritizing investments in road making.

## Road Network

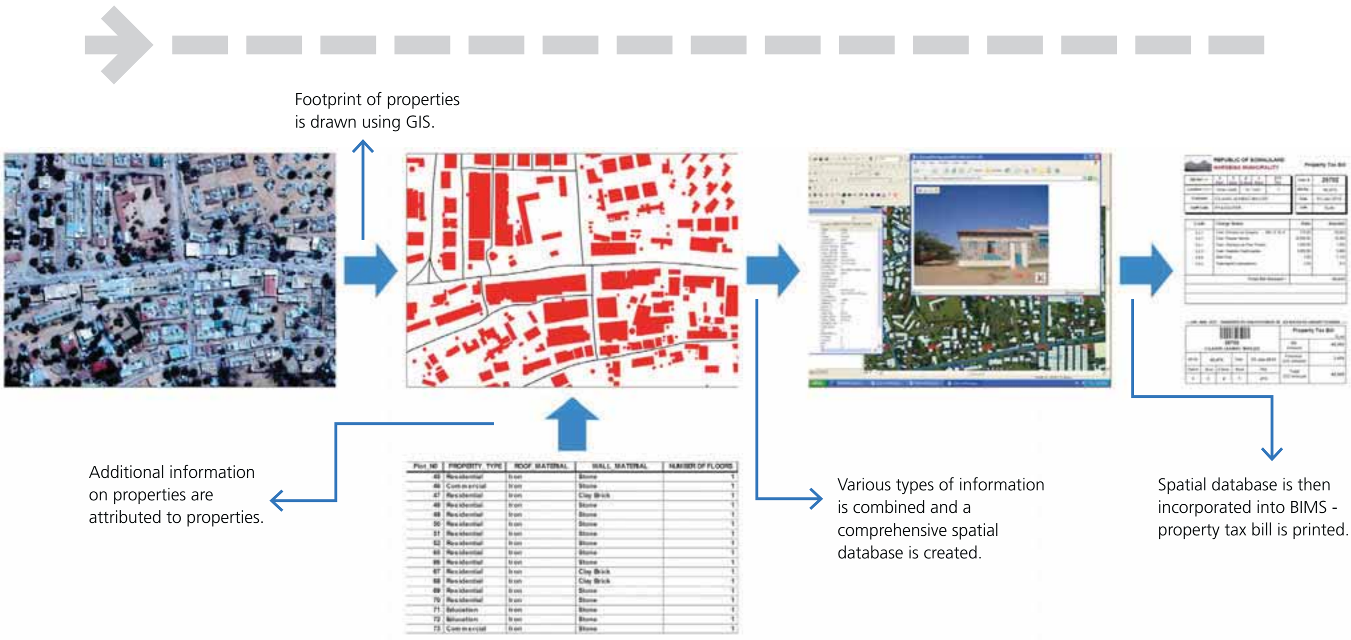


## 5.3 Land Administration and Property Taxation

Land administration is the way in which the rules of land tenure are applied and made operational. The processes of land administration include the transfer of land rights from one party to another through sale, lease, loan, gift, and inheritance; the regulating of land and property development; the use and conservation of the land; the gathering of revenues from the land through sales, leasing, and taxation; and the resolving of conflicts concerning the ownership and the use of land. GIS technology improves the cadastral workflows of land administration stakeholders and helps them better manage their land information assets.

A GIS can be used to capture the relevant data accurately, and the output database can form the basis of a taxation system. To be able to collect property taxes, information is required on property characteristics and property ownership or occupancy. This information is used in taxation laws to define tax rates. A database that is complete and accurate can lead to an increase in revenue. It can also be used to assess land data, update tax maps, prepare and send out property tax bills, and then collect taxes and prepare new tax base projections for budget purposes.

Under the UN Joint Programme on Local Governance and Decentralized Service Delivery (UN-JPLG), UN-Habitat, in conjunction with local municipalities in Somaliland, has developed a property database for Hargeisa, Borama, and Berbera. In Puntland, property databases have been developed in Garowe and Gardho municipalities. Using GIS, a high-resolution satellite image was digitized on-screen to provide a sketch of the footprints of all the buildings. Additional data – including key property characteristics such as building quality, building size, infrastructure characteristics, and number of occupants, as well as a photo of each property – were collected and combined with the digitized footprint of the property, and a spatial database was developed. The database is then incorporated into a Billing Information Management System (BIMS), which facilitates the printing of bills.



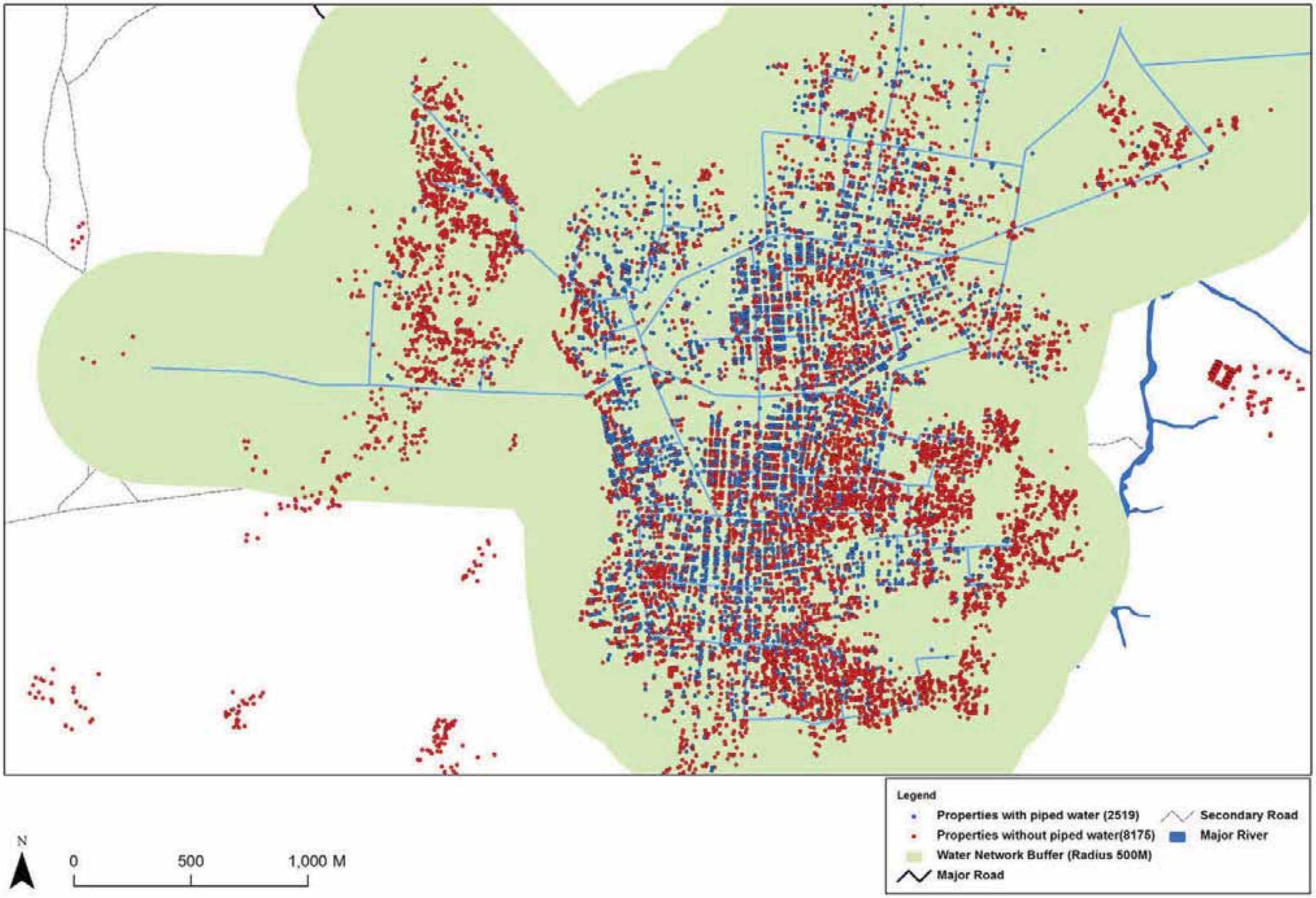

In 2004, one municipality's database had only 15,850 taxable properties; in 2011, the taxable properties increased to 60,000 as a result of the GIS survey, consequently increasing the property tax revenue. The use of a GIS has not only expanded the taxation net, but has also identified a hierarchy of spatial units and a corresponding cadastral coding system (districts, subdistricts, neighbourhoods, subneighbourhoods, and properties), which is reflected in the tax bills.

## 5.4 Infrastructure

Geographic information systems are useful for planning infrastructure development (water, electricity, sanitation, sewerage, etc.) in terms of the delivery of services (distribution, location, etc.) in specific geographical areas. A GIS can map service coverage, which provides an easy understanding of which areas are served with piped water, what the water distribution network looks like, how large the sewerage network is, whether drainage networks have been laid, which areas in the town do not have electricity, etc. This enables planning and the equitable distribution of resources and service delivery to all residents.

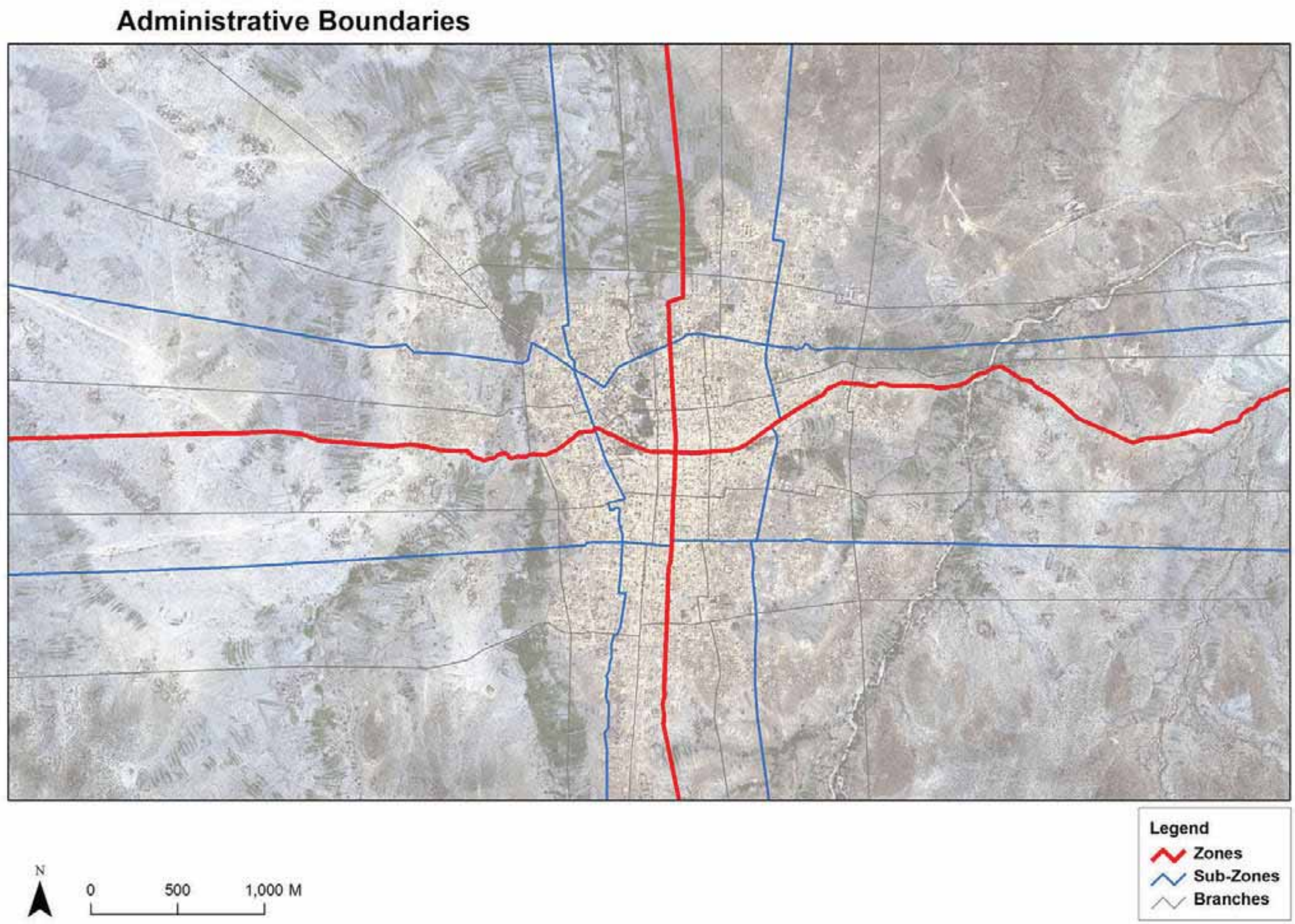
The analysis below shows how much area is not covered by one municipality's existing water network. It shows, for example, that there are houses within 500 metres of the existing water network that are still without piped water connections. This is a good starting point for the municipality to take action.

## Access To Piped Water

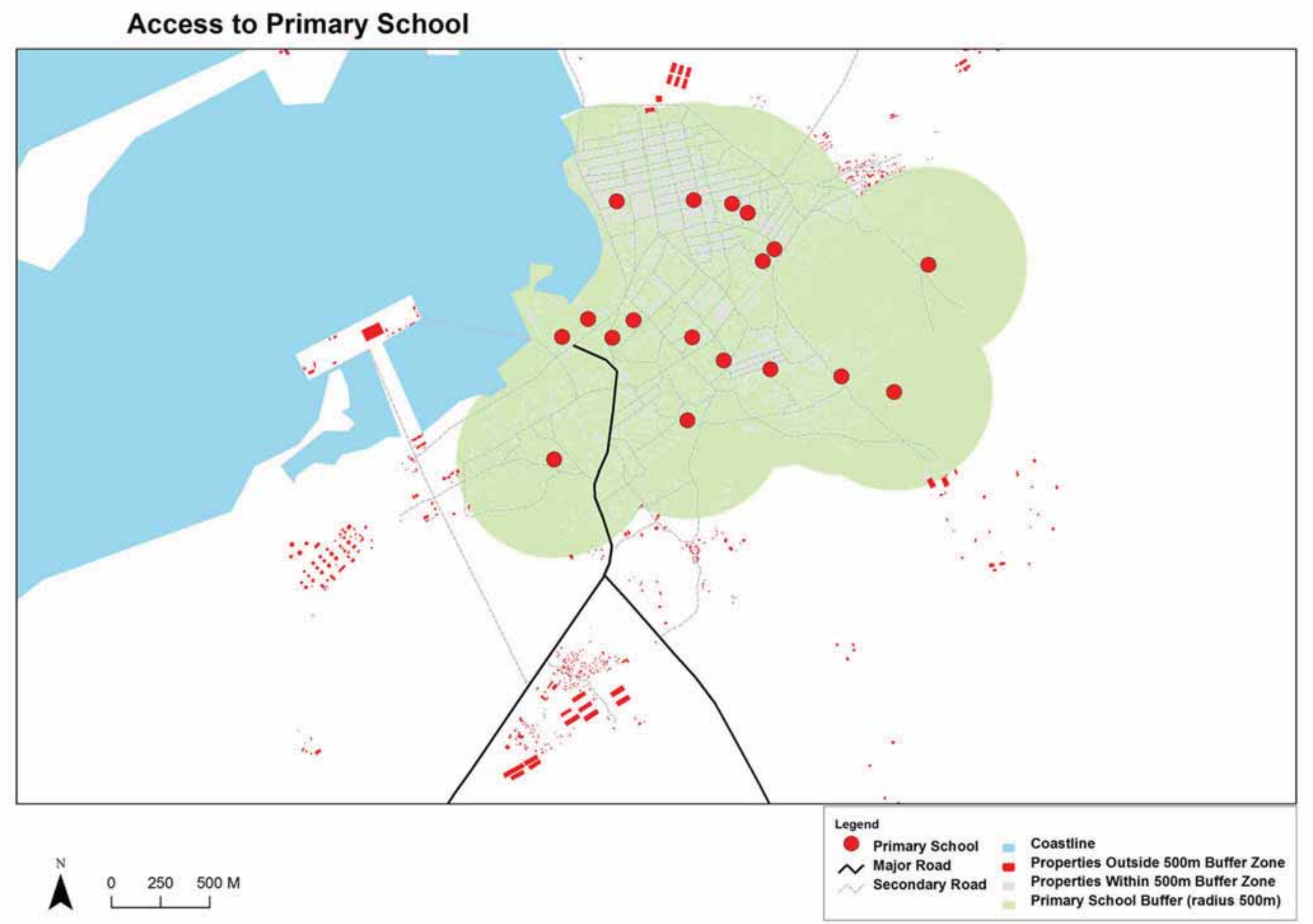


## 5.5 Municipal Services

GIS technology can be used to clearly delineate areas of responsibility in a municipality by mapping administrative boundaries. For example, the district administrative boundaries of some municipalities were defined and mapped using a GIS.



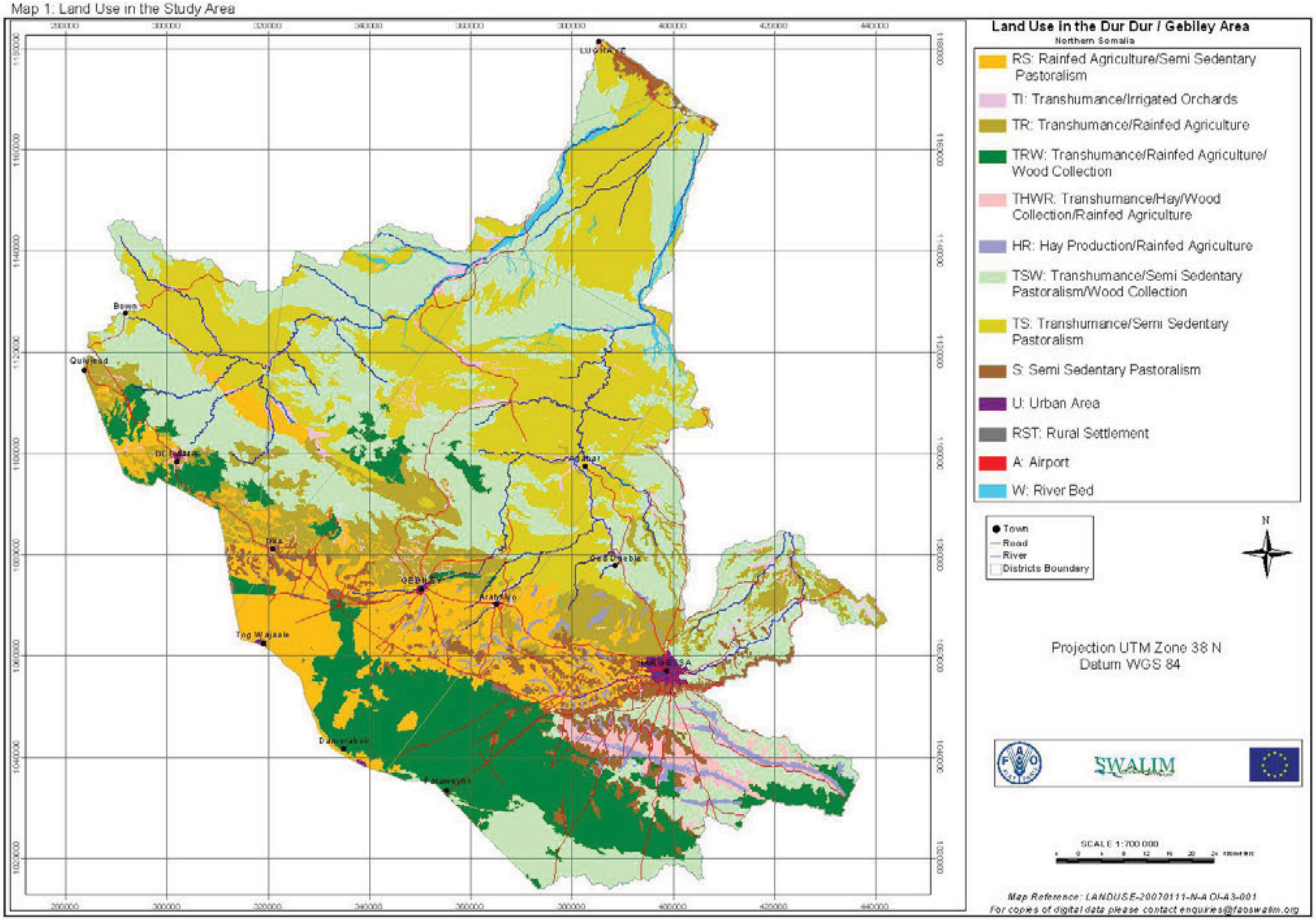
In addition, a municipality can see the condition of services delivered within their jurisdiction. For example, the map below shows the location of primary schools in one municipality, as well as areas where schoolchildren have to walk more than 500 metres to reach the closest school. According to universally accepted standards, a primary school is to be accessible within 500 metres.



## 5.6 Natural Resource Management

GIS data can be used in natural resource management by showing where pastoral people can graze their livestock, where water sources can be found, and where mineral sources exist. It can also show where existing facilities are located, as seen in the map below. Natural resource managers (farmers, hydrologists, pastoralists, planners) rely on the analytical advantages of GIS technology in making critical decisions as they manage the earth's resources. We must manage, preserve, and restore our natural resources, and decision makers who must take action need a complete picture of the issues. Maps provide this complete picture, as the available resources are identified.

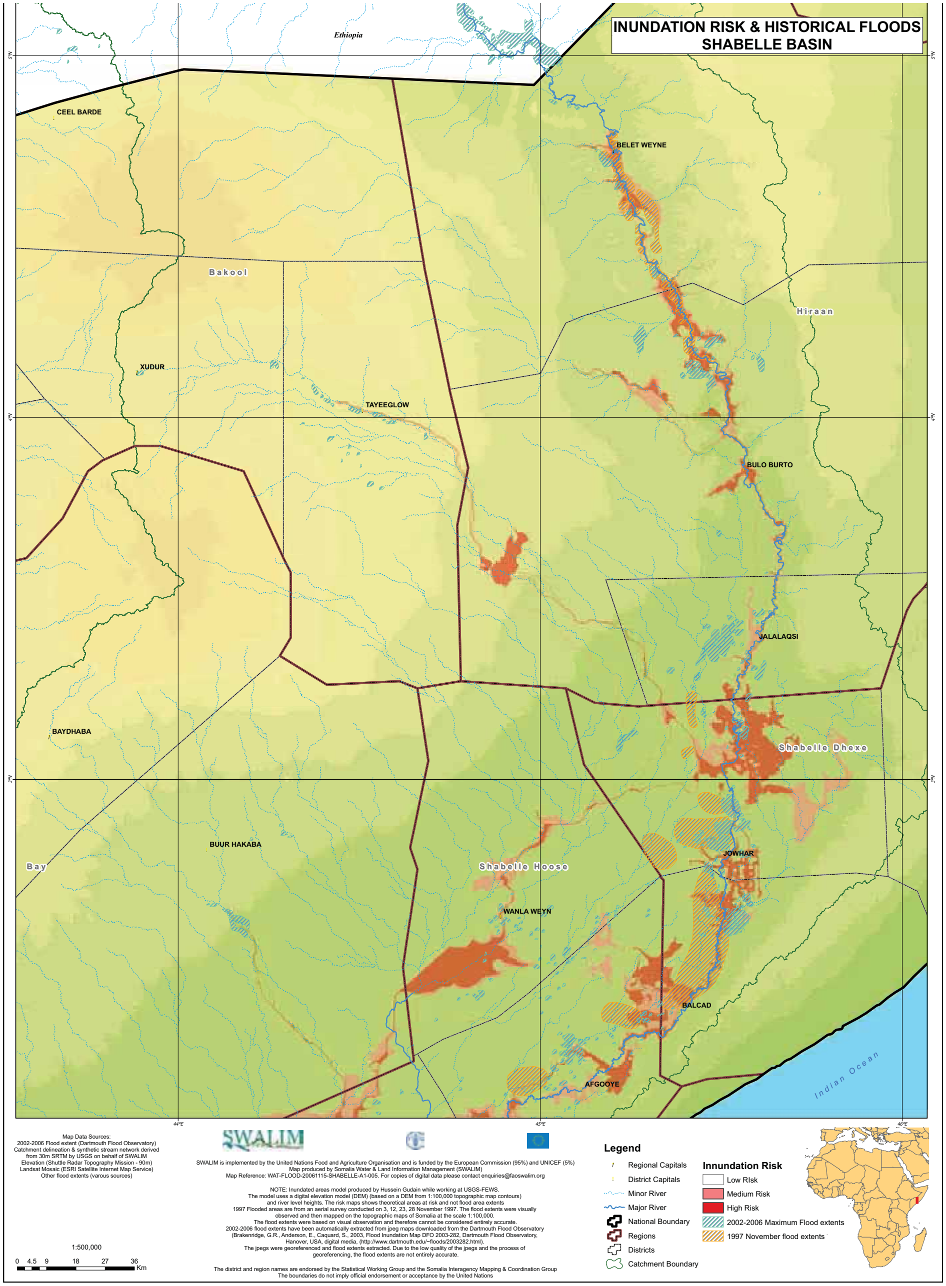
Map 1: Land Use in the Study Area




**Source:** FAO, SWALIM (Somalia Water and Land Information Management Project)

## 5.7 Emergency Management

Humanitarian agencies, inter-governmental organizations, UN agencies and affiliates, and non-governmental organizations need to effectively manage the provision of humanitarian assistance before, during, and after a disaster. GIS technology can aid in mapping where the vulnerable groups (internally displaced persons, returnees) are and which areas are affected by drought or flooding.




**Source:** FAO, SWALIM (Somalia Water and Land Information Management Project)

# 6 WHAT ARE THE BENEFITS AND IMPLEMENTATION COSTS OF GEOGRAPHIC INFORMATION SYSTEMS?

Geographic information systems benefit organizations of all sizes in almost every industry. Table 2 shows the benefits of GIS technology and the implementation costs (hardware, software, data, and people).

## **Table 2:** Benefits and implementation costs of GIS

| Benefits | Implementation Costs |
|---|---|
| **Cost Savings**<br>A GIS allows management to look at the role that geography plays in improving the delivery and use of a service. | **Technical Resources**<br>Resources such as computers, software, and supporting peripherals are required to establish and maintain a GIS. |
| **Improved Accuracy**<br>GIS technology combines information sources that provide accurate, up-to-date facts. Accurate information results in better products, decisions, analysis, reports, and development solutions. | **Skilled Staff**<br>Both technical and clerical staff are needed for operating and maintaining a GIS. |
| **Effective Communication and Collaboration**<br>A GIS can assemble and share a range of information and present it in an understandable way that is useful for staff working in various municipal departments, external stakeholders, business partners, and the public. | **Training**<br>Staff training will be a comparatively high proportional cost because of the initial acquisition of the considerable skills required to successfully manage the system. |
| **Improve Transparency and Accountability**<br>Maps can be a very valuable part of transparency in government as they helps citizens quickly visualize and understand what the government is doing in the areas that are important to them. | **Data Purchase or Collection**<br>Assembling a comprehensive, high-quality database is a challenge, especially in a developing country. Moreover, not all data is created equal; information type, scale, accuracy, compatibility, and timeliness are concerns wherever data is analysed. |
| **Support Decision Making**<br>A GIS runs multiple scenarios efficiently and rapidly and offers multiple alternatives for review. | **Institutional Issues**<br>A GIS department should be functioning as an interdepartmental unit to help other departments in the municipality. Lack of coordination between the GIS unit and other departments can be a threat and may result in effort and cost being wasted. |
| **Build an Information Base**<br>Organizing data in a GIS creates data sets that are reusable and geographically referenced. | |

**Source** (with adaptations): http://www.esri.com/what-is-gis/overview#overview_panel

# 7 WHAT IS REQUIRED TO SET UP A GEOGRAPHIC INFORMATION SYSTEM?

Since GIS technology is relatively new, decision makers must have a good understanding of the technology and its benefits.

A system that is appropriate and fit for the local context of the municipality must be identified. The GIS design process must be viewed as a vehicle to improve the capability of an organization to meet its objectives, as well as to satisfy the institutional development objectives of the stakeholders who embrace it. Before setting up a system, the following actions should be considered:

- Develop a system that is technically functional to meet the information needs of the organization.
- Develop a system that is intuitively accessible and exploitable by the decision makers.
- Develop a system that addresses organizational goals.
- Install a system that technicians and decision makers are motivated to use because it meets their individual needs and goals.
- Recruit qualified staff to set up and operate the GIS. GIS application will require at least

one staff member dedicated to system operation and maintenance, with no other responsibilities.

- Procure the hardware and software. A computer, printer, and Global Positioning System (GPS) are the key hardware. The most commonly used software is ArcGIS. Other software includes Atlas GIS, MapInfo Professional, IDRISI, Map Maker Pro, and Intergraph.
- Train staff. All staff working in the GIS unit should have thorough training on the GIS concept, how to use the selected GIS software package, and the data collection methodology adopted.
- Collect data. Data collection is important, as it is the heart of the GIS. GIS data can be collected as either primary data (through field surveys) or secondary data (from aerial photos or satellite images). Such data forms the basis of database development and spatial analysis.

# 8 WHAT IS NEEDED TO MAKE A GEOGRAPHIC INFORMATION SYSTEM SUSTAINABLE?

GIS sustainability depends on the following factors.

a) Lobbying or awareness raising is necessary, as decision makers are not always aware of the possibilities of GIS technology. Coordination is required, not only between municipal departments but also with the potential users of the data. Municipal council resolutions or legislation may be required to formalize coordination mechanisms and define responsibilities. Therefore, senior management seminars should be organized in which positive and measurable results are demonstrated in order to gain support for the use of a GIS and inter-institutional cooperation. An awareness campaign on GIS technology is also important.

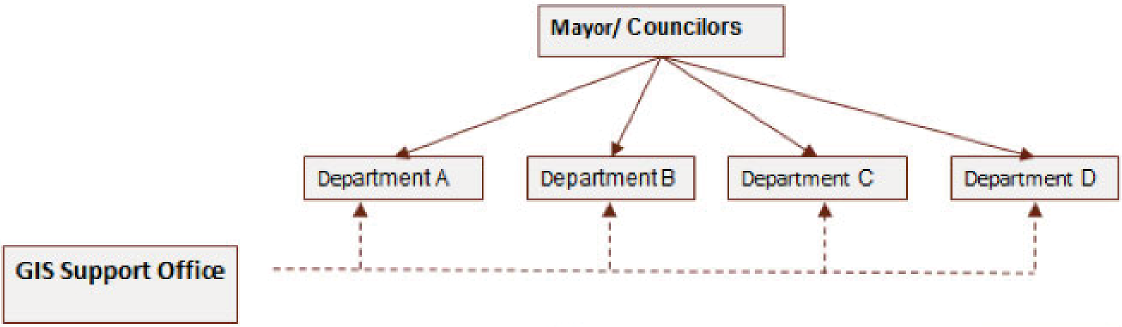
b) Continuous on-the-job training is crucial, as skills and experiences are necessary to maintain a GIS; this ensures the sustainability of the system and adoption of changing technological trends.

c) To enhance usage, a procedural manual for maintaining and updating the spatial database has to be adopted. This will cost-effectively keep the GIS up to date, complete, and accurate, which is vital, as the functional reliability of the spatial system depends completely on its database.

d) Upgrading the system through the adoption of effective tools and methods. GIS technology is developing rapidly, and there is a need to constantly upgrade the system in line with technological changes.

e) Financial resources are required to maintain a GIS, and therefore an adequate budget has to be allocated.

f) The GIS office location within the local government is important, as this is not a new department but rather a support office directly under the mayor. It must have a cross-cutting function in order to serve and support all departments. The GIS unit and staff will be working across all departments in the municipality, as shown in the diagram below.



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United Nations Human Settlements Programme
P.O.Box 30030, Nairobi 00100, Kenya;
Tel: +254-20-7623120;
Fax: +254-20-76234266/7 (central office)
Infohabitat@unhabitat.org

Emrah Engindeniz, UN-Habitat JPLG programme manager
emrah.engindeniz@unhabitat.org

Asia Adam, GIS expert
asia.adam@unhabitat.org

UN-HABITAT

www.unhabitat.org