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Digital Terrain Modelling (DTM) and Spatial Analysis Using Geographic Information System (GIS) Techniques: A Case Study of Durbar Grammar School, Oyo, Oyo State, Nigeria

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Abstract:*This study applied Geographic Information System (GIS) Techniques in assessment of the Digital Terrain modelling (DTM) and spatial analysis of Durbar Grammar School in Oyo town, Oyo State, Nigeria. The study area has improper physical planning which poses various environmental challenges on the school community. A good three dimensional representation of the topography will help in making quality decisions toward better restructuring of the school. The geometric and attribute data of the terrain features were collected and processed using AutoCAD, and ArcGIS was used for integrating the dataset into a geodatabase for performing spatial queries and analysis. The analysis of the terrain topography identified the differences in elevation at various points within the study area. This difference in height makes some structures more vulnerable to erosion. Recommendations were made for proper landscaping and construction of good drainage system in the study area to protect the vulnerable buildings, and improve the aesthetics of the study area.*
Key Word*: surveying, topographical survey, digital terrain modelling, vulnerability.*

I. Introduction

Surveying and mapping constitutes the bedrock of all socio-economic development and national security (Fubara, 2011). In order to create a sustainable society we need to develop more sustainable communities. The key to creating a sustainable community is the establishment of well-defined design objectives and guidelines to ensure that the members of the multi-disciplinary design team (including surveyors) are aware of the expected outcomes. (Narelle Underwood, 2010). This implies that developmental projects will becomes unsustainable and detrimental to the environment it was supposed to develop if proper attention is not paid to the importance of surveying to such project.

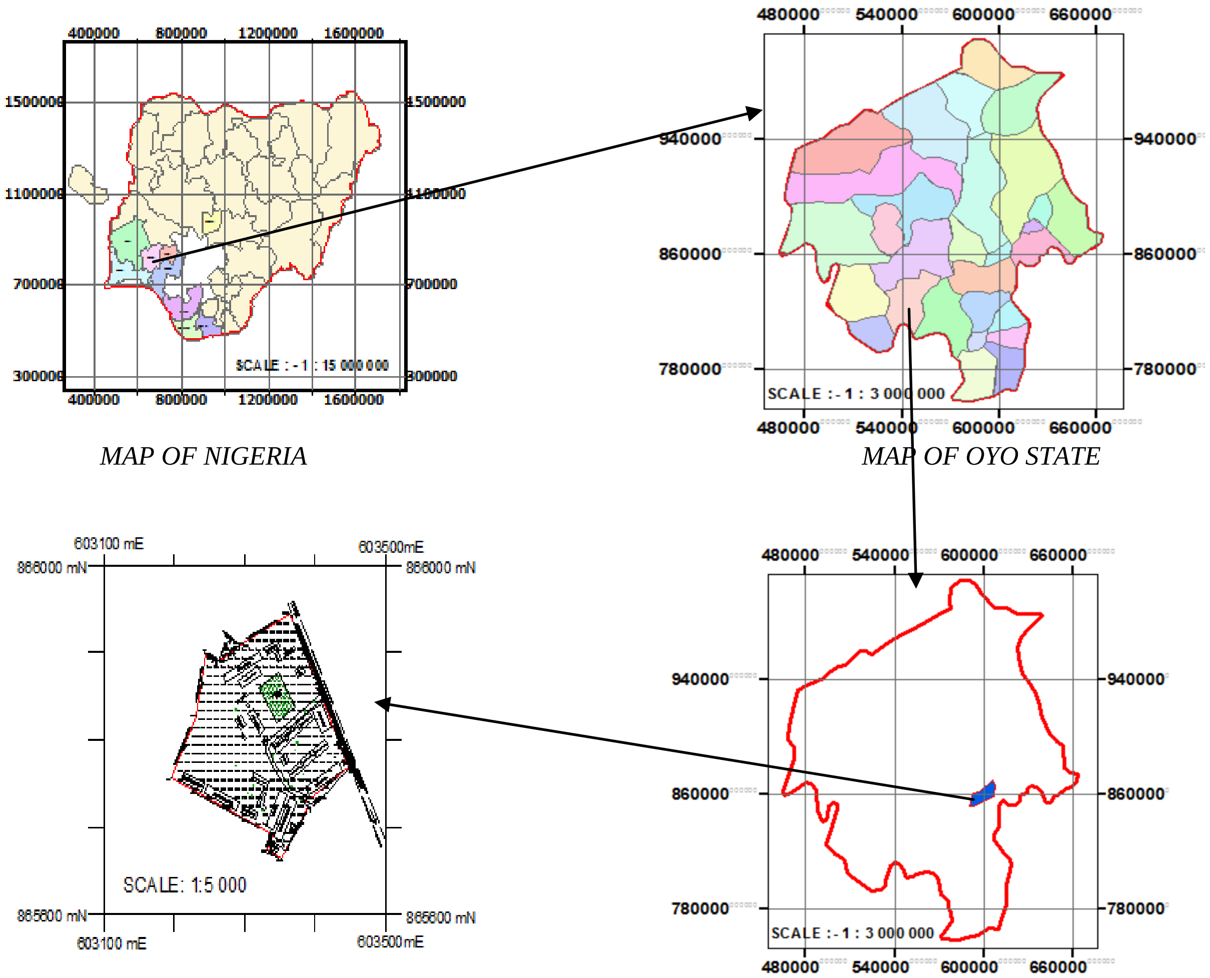
The American Congress on Surveying and Mapping (ACSM), defines surveying as the science and art of making all essential measurements to determine the relative position of points or physical and cultural details above, on, or beneath the surface of the earth, and to depict them in a usable form, or to establish the position of points or details.

Surveying has been an essential element in the development of the human environment for so many centuries. It provides important requirement in the planning and execution of nearly every form of construction projects. Surveying was essential at the dawn of history, and some of the most significant scientific discoveries could never have been implemented were it not for the contribution of surveying. Its principal modern uses are in the fields of transportation, building, apportionment of land, and communications.

Topographical survey data is imperative to developments on land as it enables a detailed understanding of the terrain topography and helps in making quality decisions economically viable and environmentally sustainable. Digital Terrain modelling (DTM) on the other hand is a 3-dimensional representation of a terrain surface consisting of x, y, z coordinates stored in digital form

II. Study Area

The project took place in Durbar Grammar School located in Oyo town, Oyo East local government area Of Oyo state. Geographically it falls between longitude 03^0 38’ 00’’E and 03^0 56’ 49.18’’E and between latitude 07^0 49’ 35.40’’N and 07^0 49’ 50’’N. It was bounded by Durbar – Akinmoorin road by the east, Araromi inlet road by the south and Oyo – Ogbomosho express road by the north. The average elevation of the area is 320m above the mean sea level. Many of the structures in the school are in bad condition and the topography is characterized with some level of erosion which has left the vulnerable structures in deplorable condition.



The Study Area

Map of Oyo State Showing Oyo East Local Govt

Figure 1: Map of the Study Area

III. Methodology

The methodology included data collection through classical ground surveying methods and digital data importation from external sources, database design, database creation and spatial analyses using appropriate hardware and software.

3.1 Reconnaissance

These involve adequate planning prior data collection. It helps in facilitating decisions like the purpose of the work, accuracy requirements, and equipment selection among others. The study area was visited, nearby control beacons were located and checked for suitability, the selected equipment was tested before data collection commenced.

Table 1. Eastings(m), Northings(m) and Height(m)

STN ID	EASTING (m)	NORTHING (m)	HEIGHT (m)
FSS2/GPS/09	603303.430	866119.760	317.399
FSS2/GPS/10	602959.909	865881.513	314.307
FSS2/GPS/11	602540.837	865725.549	307.029

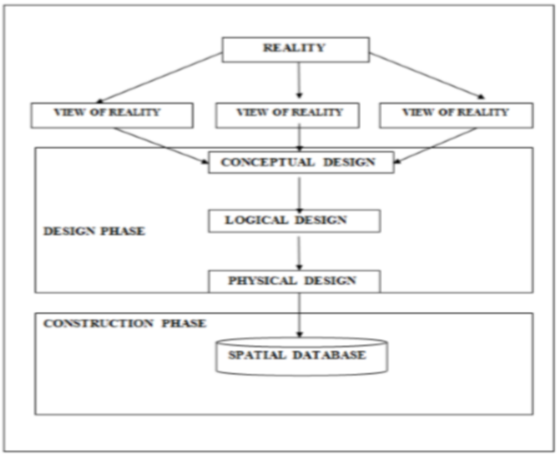
Coordinates of the control beacons

3.2 Data Collection

Both geometric and attribute data were collected for this study. The geometric data was collected using total station while the attributes of the features in the study area were collected from sight. Other forms of data were also imported in digital data from external sources. This include the map of Nigeria and the local government area of the study area with their geographic coordinates.

3.3 Database Design

Spatial database is very important in the application of Geographic Information System (GIS) at solving any given spatial problem. The process of designing a database is referred to as database modelling whereby real world entities and their relationships are analysed and modelled. This process of database implementation involves two phases namely the design phase and the implementation phase. According to Kufoniyi, (1998) database design consists of three stages namely conceptual design, logical design and physical design.



Design and Construction Phase of a spatial Database. (Kufoniyi, 1998)

3.3.1 View Of Reality

Reality is the state of things as they are or appears to be rather than as one might wish them to be. Kufoniyi, (1998) reality is the phenomena, as they actually exist at the time of the investigation, thus includes all aspects, which may or may be perceived by individuals. The view of reality is therefore the simplified view as perceived by the observer

3.3.2 Conceptual Design

This is the representation of human conceptualization of reality and the objective is to determine the basic entities, the spatial relationships among the entities and attributes of each entity (Idhoko, K. E. et al, 2015). It begins with the identification of the needed data and goes on to cover several other activities collectively. The conceptual design of a GIS also includes the identification of the basic GIS architecture (functions of GIS hardware and software), estimate of usage (derived from the needs assessment) and scoping the size of the GIS system. All of this is done with reference to the existing data processing environments (legacy systems) which must interface with the GIS.

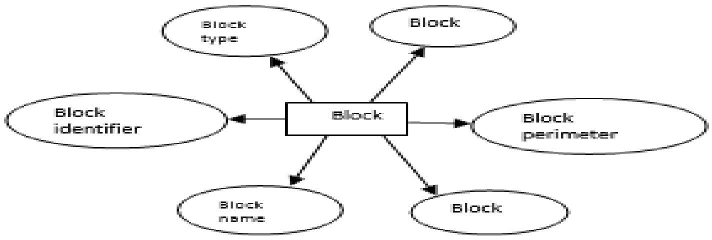
However, the following steps are required during the conceptual design:

1. Construction of the Entity Definition and Entity Relationship (ER) model.
2. Checking the model for redundancy.
3. Validating the model against user transaction to ensure that all the scenarios are supported.
4.

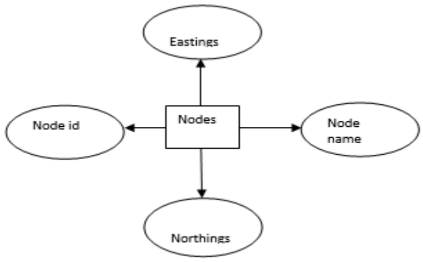
I. Entity Definition

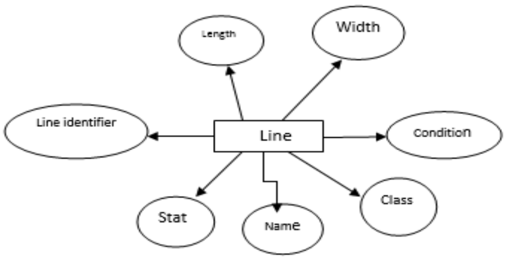
Entities are defined for inclusion in a computer model by a method of representation which is established through geospatial phenomena. All geospatial features are represented in two dimensions by three main entity types i.e. point, line and polygon.

The figures below shows the spatial data model for each of the entity types



Block entity and its attributes.



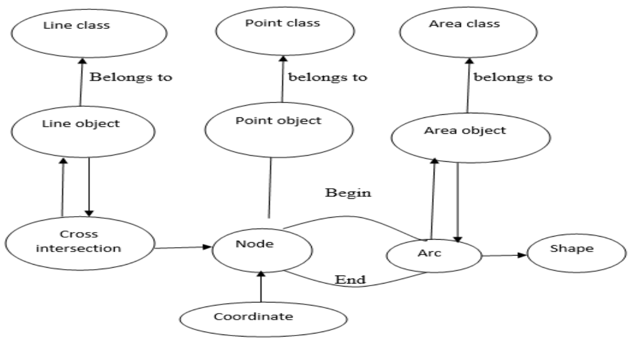


Line entity and its attributes.

Node entity and its attributes.

II. Entity Relationship Modelling

Entities are class of distinct identifiable objects or concepts. Their relationship deals with the relationship among them. Entity Relation (ER) modelling is a pictorial representation (or schematic diagram) of the real world problem in terms of entities (which have attributes). The entity relationship is used in database to distinguish objects that are represented. In addition to the relationship, there are linkages that link those basic entities together. Such relationships are represented by diamonds and connecting lines which turns out to form part of the database as their basic entities as shown below.

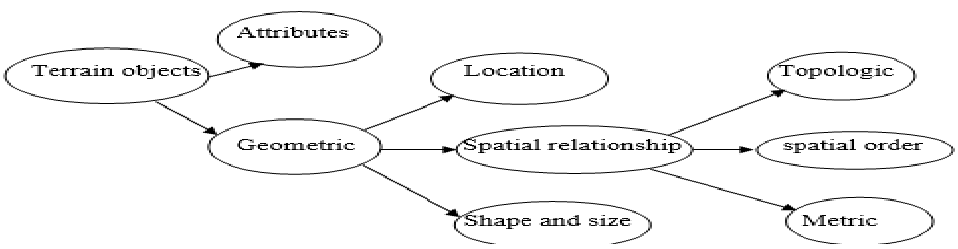


Entity Relationship Diagram

3.3.3 Logical Design

This is the process of constructing a model of information which can then be mapped into a storage object supported by the database management system. It is a representation of data model in a computer / database management system.

This leads us to the basic components of spatial objects as adopted from Kufoniyi, 1998.



Logical Design

The above figure represents the chain of analysis for spatial objects and how it helps in database creation for spatial object from conceptual design.

3.3.4 Physical Design

According to Kufoniyi (1998), physical design is the representation of the data structure in the format of the implementation software and it is usually done at the beginning of the Database Creation. It is usually done at the beginning of the database creation. The steps involve the following:

- Describing the database relations
- File organization
- Index design for efficient data access
- Other associated integrity constraints and security measures.
-

IV. Database Creation

The database was populated using ARCGIS 10.2.2. The attribute tables were further linked with geometric data to allow for reasonable analysis. The table below show an extract of the database.

Table

BUILDING

OBJECTID *	BLD_SHAPE	BLD_PERIMETER	BLD_AREA	BLD_TYPE	BLD_USE	BLD_CONDITI	BLD_USAGE	BLD_MEA	BLD_USE_1
1	Polygon ZM	57.770888	178.969	BUNGALOW	LABORATORY	FAIR	USE	319	<Null>
2	Polygon ZM	84.145653	338.005	BUNGALOW	CLASSROOM	POOR	ABANDONED	319	CLASSROOM
3	Polygon ZM	121.323914	549.414	BUNGALOW	CLASSROOM	GOOD	USE	319	CLASSROOM
4	Polygon ZM	62.729767	193.939	BUNGALOW	CLASSROOM	POOR	ABANDONED	319	CLASSROOM
5	Polygon ZM	111.659929	488.489	BUNGALOW	CLASSROOM	POOR	ABANDONED	320	CLASSROOM
6	Polygon ZM	125.720212	582.572	BUNGALOW	CLASSROOM	POOR	ABANDONED	319	CLASSROOM
7	Polygon ZM	37.940517	86.842	BUNGALOW	CLASSROOM	POOR	ABANDONED	319	CLASSROOM
8	Polygon ZM	19.223186	20.629	BUNGALOW	TOILET	FAIR	USE	321	<Null>
9	Polygon ZM	58.837652	188.254	BUNGALOW	CLASSROOM / LAB	POOR	USE	321	CLASSROOM
10	Polygon ZM	59.295318	191.563	BUNGALOW	CLASSROOM	POOR	ABANDONED	321	CLASSROOM
11	Polygon ZM	38.824532	94.081	BUNGALOW	COMPUTER LAB	GOOD	USE	321	<Null>
12	Polygon ZM	59.003112	191.261	BUNGALOW	CLASSROOM	FAIR	USE	320	CLASSROOM
13	Polygon ZM	58.639359	188.824	BUNGALOW	CLASSROOM	POOR	ABANDONED	320	CLASSROOM
14	Polygon ZM	90.304344	463.909	BUNGALOW	CLASSROOM	GOOD	USE	320	CLASSROOM
15	Polygon ZM	38.205733	37.659	BUNGALOW	TOILET	POOR	USE	319	<Null>
16	Polygon ZM	11.566894	7.484	BUNGALOW	TOILET	POOR	USE	320	<Null>
17	Polygon ZM	76.515018	262.54	BUNGALOW	WORKSHOP	POOR	ABANDONED	320	<Null>
18	Polygon ZM	46.699005	133.838	BUNGALOW	OFFICE	POOR	USE	320	<Null>
19	Polygon ZM	24.980866	31.104	BUNGALOW	MOSQUE	POOR	USE	320	<Null>
20	Polygon ZM	156.896321	1485.436	BUNGALOW	SPORT	FAIR	USE	320	<Null>
21	Polygon ZM	43.121875	86.463	BUNGALOW	RESTURANT	POOR	ABANDONED	319	<Null>
22	Polygon ZM	41.175529	104.765	BUNGALOW	FIRST AID ROOM	POOR	USE	319	<Null>

1 (0 out of 34 Selected)

BUILDING

Table Extraction of the database

4.1 Data Download, Processing And Result Of Spatial Analysis

4.1.1 Data Download

The geometric data acquired was downloaded from the total station by connecting the equipment with the downloading cable. The downloading software was lunched and the necessary settings were made such as the COM port number, the parity and bud rate and the downloading format. After download, the data was exported for further processing.

4.1.2 Linear Accuracy

STN ID	EASTING (m)	NORTHING (m)	
FSS2/GPS/10	602959.909	865881.513	STARTING STN
FSS2/GPS/10	602959.897	865881.493	CLOSING STN
	0.012	0.020	ERROR

The linear accuracy of the traverse carried out was determined using the formula below

$$\text{Linear accuracy} = \frac{1}{\dfrac{\sqrt{\Delta E^2 + \Delta N^2}}{\text{Total distance traversed}}}$$

Total distance traversed = 1775.504m

$$\text{Linear accuracy} = \frac{1}{\dfrac{\sqrt{0.012^2 + 0.020^2}}{1775.504}}$$

$$= \frac{1}{\dfrac{\sqrt{0.000544000}}{1775.504}}$$

$$= \frac{1}{\dfrac{0.0023323808}{1775.504}}$$

$$= \frac{1775.504}{0.0023323808}$$

$$= 76{,}124.10597$$

$$= 1:76{,}000$$

4.1.3 Result of Spatial Analysis

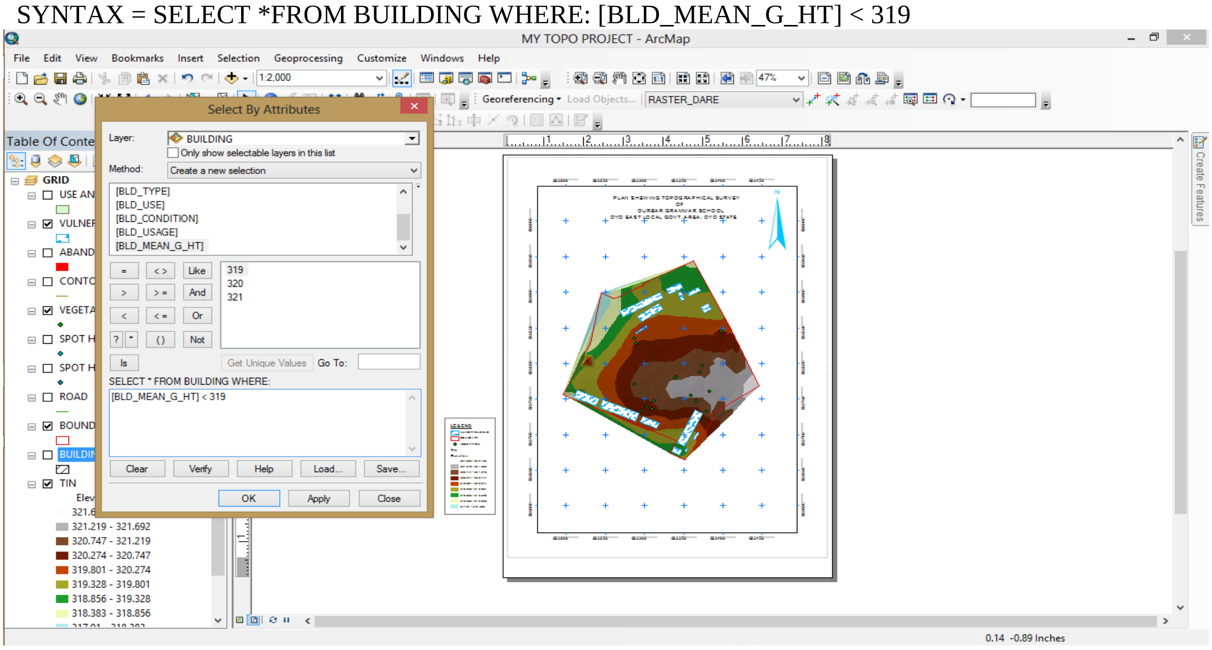
The essence of database creation was actually to be able to question or query it. Spatial queries, otherwise referred to as spatial search, can be described as an operation, which defines attribute within a database to give answers to generic questions. From the queries, intelligent decisions can be made to solve several problems. Both single and multiple criteria queries were performed from the database created.

I. Single Criterion Query

SINGLE CRITERION QUERY

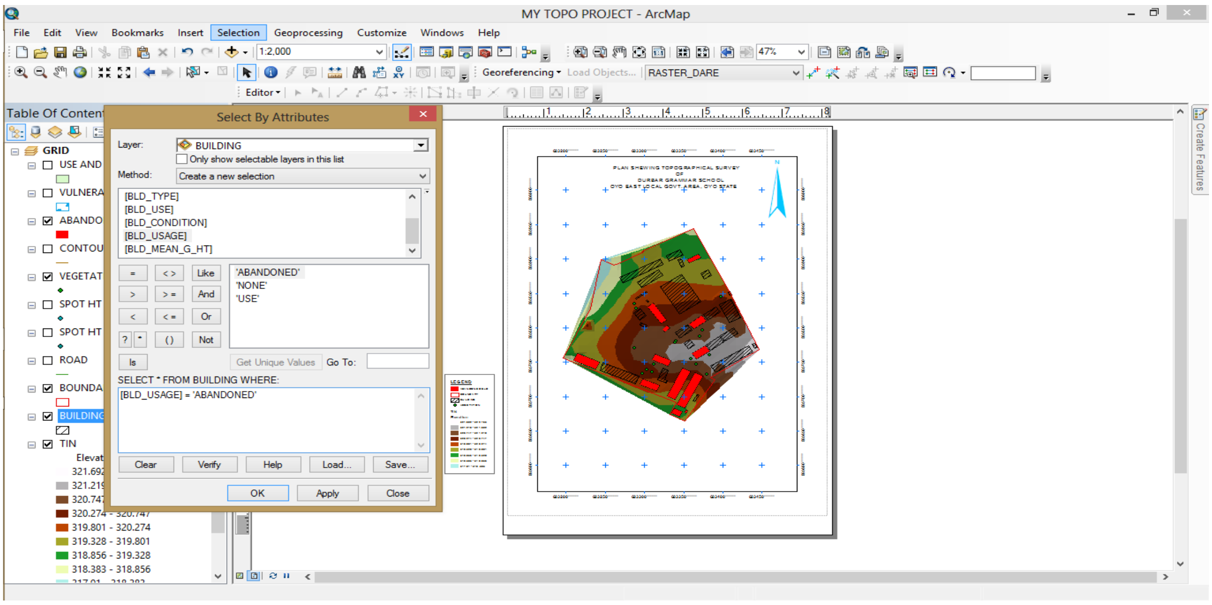
1. Query for all buildings whose mean ground height is less than 320m. These buildings are vulnerable to erosion.

SYNTAX = SELECT *FROM BUILDING WHERE: [BLD_MEAN_G_HT] < 319



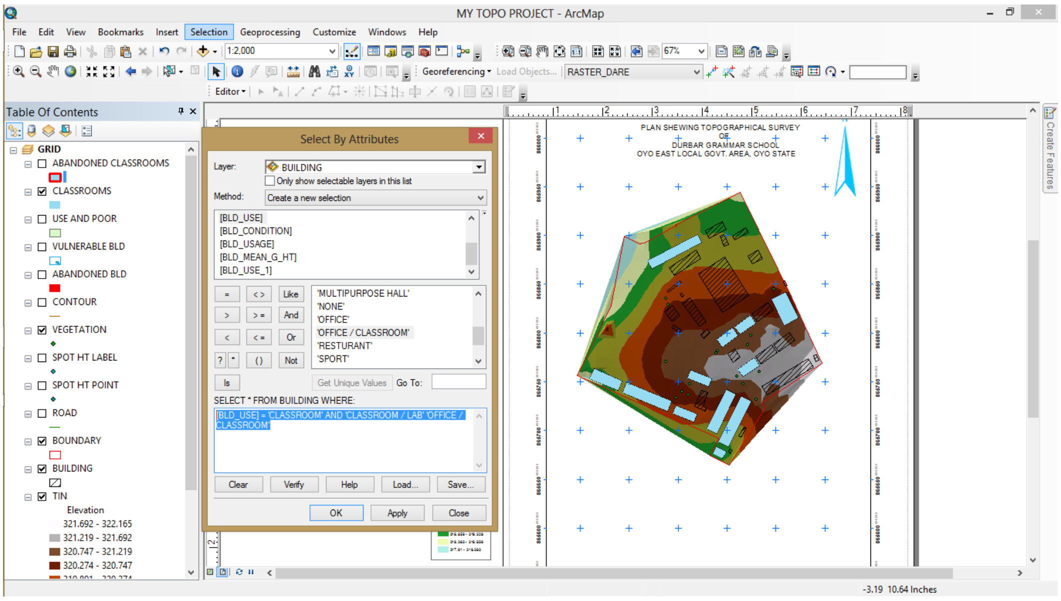
2. Query for all abandoned building.

SYNTAX = SELECT *FROM BUILDING WHERE: [BLD_USAGE] = 'ABANDONED'



3. Query for all classrooms

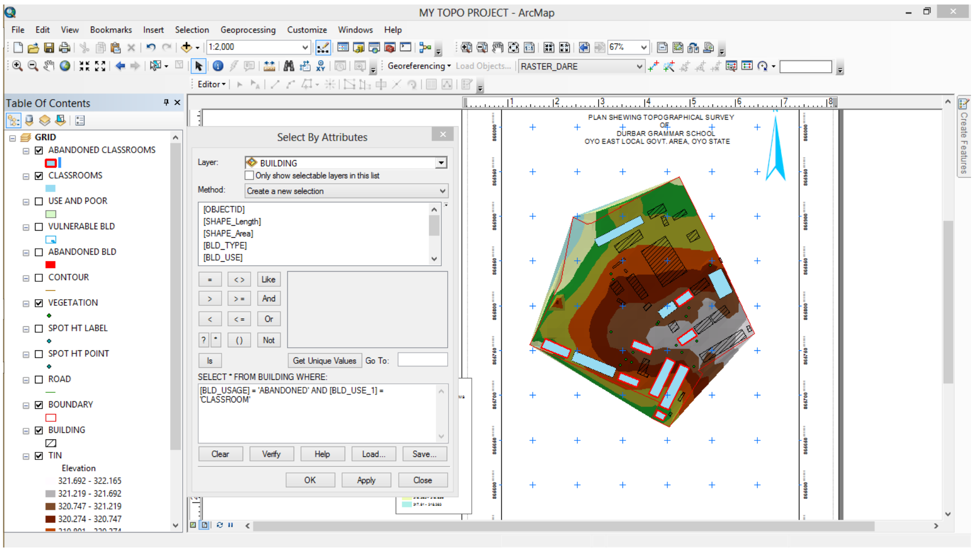
SYNTAX = SELECT *FROM BUILDING WHERE: [BLD_USE] = 'CLASSROOM' AND 'CLASSROOM / LAB' 'OFFICE / CLASSROOM'



II. Multiple Criteria Query

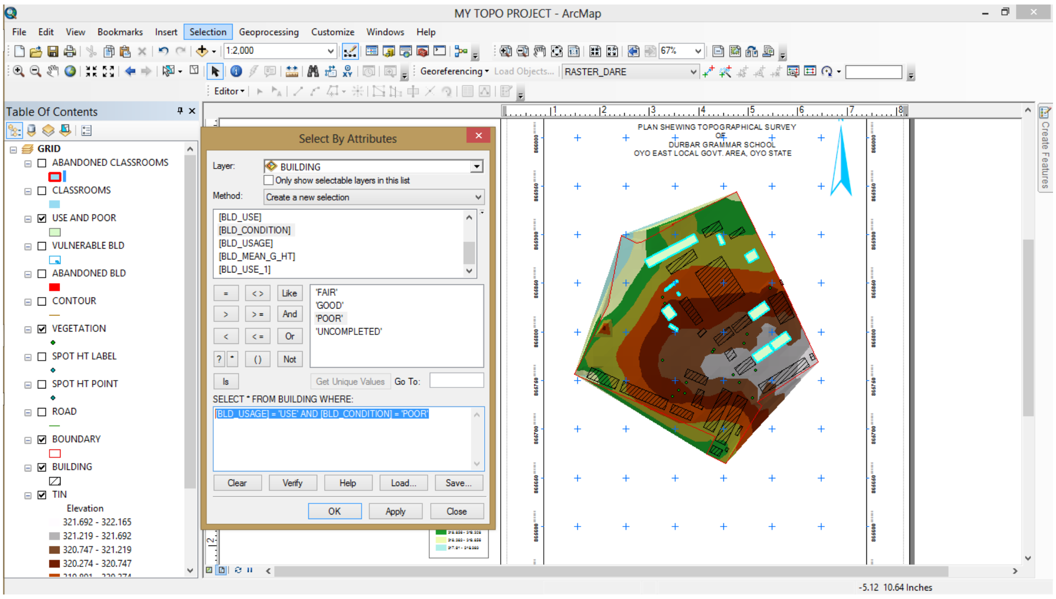
1. Query for all abandoned classrooms

SYNTAX = SELECT *FROM BUILDING WHERE: [BLD_USAGE] = 'ABANDONED' AND [BLD_USE_1] = 'CLASSROOM'



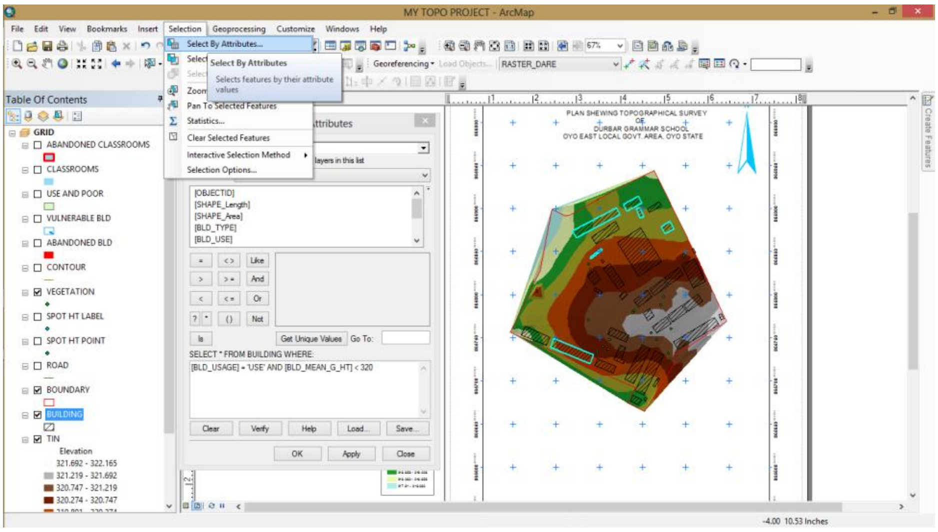
2. Query for all buildings in poor condition and are still in use

SYNTAX = SELECT *FROM BUILDING WHERE: [BLD_USAGE] = 'USE' AND [BLD_CONDITION] = 'POOR'



3. Query for all buildings that are still in use but are vulnerable to erosions

SYNTAX = SELECT *FROM BUILDING WHERE: [BLD_USAGE] = 'USE' AND [BLD_MEAN_G_HT] < 320



V. Conclusion

This paper showcases the proficiency of GIS as an effective tool for integrating both the geometric and physical properties of spatial entities for implementing spatial analysis. GIS helps decision making systems to proffer solutions to real world problems. Summarily, the digital terrain model of Durbar grammar school, Oyo was created and spatial analysis were implemented thereby achieving the aim of the project.

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