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GEOSPATIAL ANALYSIS OF THE DISTRIBUTION OF PRIMARY WATER PIPELINES IN LAGOS STATE (A CASE STUDY OF ALL LOCAL GOVERNMENT AREAS IN LAGOS STATE)

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ABSTRACT

The problem of meeting growing demand for portable water in an ever growing city such as Lagos is complex and goes beyond just putting in place adequate water distribution facilities. Rather other factors remain very crucial in meeting daily water need of Lagosians. It is expected that in planning for an effective and sustainable water distribution system, the need for valuable information such as average daily consumption of water per person is a required planning data. The aim of this project was to use Geographic Information System (GIS) technology to integrate necessary planning information such as: available water resources, alternative water sources, resident population, land use and daily water need to carry out an effective water supply system. To achieve this aim, a number of set objectives were carefully examined from available planning standards. Of paramount importance among these objectives was to delineate the Lagos metropolis into existing local government areas, to determine water requirements (per heads) according to the World Health Organization standards, to document the existing water facility network in the Lagos metropolis/capacities and lastly to identify local government areas with acute water shortage. In search of these noble objectives, quite a number of methodological procedures were applied sequentially and logically. These were done using appropriate combination of hardware and software packages as well as spatial and attribute data sets. Both spatial and attribute data sets were collected in analogue formats and were converted to digital form leading to the creation of seamless GIS database. The GIS database comprises of spatial data (which are stored as digital maps) and attribute data (in form of additional information about details on the map). However, the content of the GIS database focus mainly on relevant information about water facilities in the metropolis as well as other baseline information. The information contained in the GIS database was subjected to rigorous analytical operations such as queries using Structured Query Language (SQL) available in GIS software, spatial geo processing, coordinate transformation, projection, cleaning/topology building and legend editing to produce the desired results. From this study, GIS has been used as a relevant tool to identify the available water distribution network and areas of acute water supply based on available water facilities and the World Health Organization (WHO) water requirements per heads in Lagos.
Keyword: *GIS, Spatial, Attribute, data, Water, Facilities.*

INTRODUCTION

Since the beginning of time, water has been shaping the face of the earth, not only as a geologic agent, cutting valleys, Canyons and sculpting rock formations. Water has been a major factor in the rise and fall of great civilizations, source of conflict and tension between nations. The first great civilizations arose on the banks of great rivers, the Nile in Egypt, the Tigris-Euphrates of Mesopotamia, the Indus in Pakistan, and the Hwang Ho of China. All of these civilizations built large irrigation systems and made the land productive. By the same token, civilizations collapsed when water supplies failed or were improperly managed. The decline of the Sumerian civilization of Mesopotamia, for example, is believed to be due to poor irrigation practices resulting in saline soils (El-Ashry, 2000). Today, water contributes immensely to the increasing worldwide concern about human health, the environment, and the path towards sustainable development. Of all the natural resources needed for economic development, water is one of the most essential, particularly in semi-arid regions. At the dawn of the 21st century, we find ourselves facing formidable challenges: rapid population growth; increasing demands for water to satisfy people's needs, both in agriculture and in expanding urban centers; failing water quality, pollution, and associated health and environment impacts; groundwater depletion; and international conflict over trans-boundary water resources, (Cvjetanovic, 1986, Agricultural Organization of the United Nations, 1989; Cairncross, 1990 and Cotruvo, 2011).

The Significance of Global Water Crisis

Lagos, for example, the commercial centre of Africa's most populous country, is a city with a current population of almost 14 million, about half that of Kenya and larger than most African countries. It is the most populous city in Africa and Europe, the sixth in the world, and could jump to number three in the world in another 20 years. This would require expanding water access and provision of other basic services and infrastructure to several more million inhabitants. As in many other African countries, Lagos is a city on the verge of a water crisis.

In spite of huge fund being expended on water related projects in Lagos in the last few years, very little success has been achieved in eradicating water crisis in the city. Financial & Operating Statistics of Lagos State Water Corporation shows that Investment expenditure on water projects in Lagos state in the year 2000 was put at #24,458,000, about #10,358,000 was expended on water production and treatment, #3,000,000 was spent on water distribution while #11,100,000 was spent on operational support. In spite of this investment the impact of water shortage is still stronger in Lagos metropolis. Thus this implies that a multidisciplinary approach from planning stand point would be required for the problem to abate. In view of this, this paper intends to use Geographic Information Systems (GIS) as a planning tool for evaluating the impact of water crisis in Lagos metropolis with the view to identify area of needed attention.

THE AIM AND OBJECTIVES

The primary aim of the project is to carry out evaluation of water demand and supply in Lagos metropolis using GIS. However, a set of objectives have been identified for actualizing the primary aim. The objectives are as follows

- to collect relevant spatial and attribute information about water reservoirs, pipe network and water demand in Lagos metropolis
- to integrate these data sets collected onto GIS database
- to carry out water demand and supply evaluation with the view to know if the

International recommendation for daily water supply has been met.
These objectives are expected to be implemented following a set of GIS procedure in order to manage all forms of errors that could jeopardized the quality of decision to be taken thereafter.

Water Distribution in Lagos Metropolis
Due to the fact that Lagos is surrounded by water, many people assumed that it would be easy to provide the people with the required water; however the present situation is far from this. The water in the lagoon and ocean surrounding Lagos are not fit for human consumption. The large expanse of water around Lagos is not potable and does not meet World Health Organization standard. Hence, the public authorities in Lagos had to search far and wide to get water for the people of Lagos to drink and for other domestic use. The search began at the beginning of this century in 1901 by the colonialists who searched as far as Iju, a suburb in the outskirts of Lagos then, where water was flowing in from River Ogun. Water was supplied from Iju to Lagos areas like Ikoyi and Obalende. The first water works was built in 1910 and has since evolved through several stages. The first treatment plant; with a capacity of 11,000m³/d (2.42mgd) was installed in 1910 at Iju village, a part of Ogun state, abstracting raw water from spring water trenches within the Iju hills. The scheme was then designed and executed to serve the residential reservation of the colonial administrators living at Ikoyi in Lagos state when the first cast iron trunk main "A" of nominal diameter 28" (700 mm) was laid. Subsequent expansion was made to the plant in 1943 by increasing its capacity to 27,000m³/d (6mgd) accompanied by the laying of another cast iron trunk mains "B" of nominal diameter 24" (600mm). The plant drew its raw water resource from Iju River. Subsequently, the plant capacity was again increased in 1954 to 50,000m³/d (11mgd).

Additional abstraction investments were developed at Akute contiguous to the River Ogun, which is the most bountiful source of surface raw water available to the Lagos metropolis. With the increasing demand of the residents and the growth of the industrial sector, the production and distribution potentials became over stretched. A third steel trunk main "C" of diameter 42" (1050mm) was subsequently laid in 1962. Iju waterworks went through another upgrading in 1965 to 109,000m³/d (24mgd) through a "crash programme". The capacity of the three Primary Trunk Mains "A", "B" and "C" now cater for the transmission of about 159,000m³/d (35mgd) since 1973, (Lagos State Water Corporation facts data, 2002). Since 1910 to date, the main concern of the authorities managing water supply to Lagos has always been how to increase the supply of water due to the ever increasing population of Lagos as a commercial nerve centre of the nation's economy. The population of Lagos is growing rapidly daily with more people settling down than moving out. At present, Lagos has a population of about 15 million. Over the years, therefore, the supply from Iju was no longer enough to meet the demands of Lagosians and a second waterworks had to be constructed at Ishasi, deriving its source from River Owo. It has a capacity of 18,000m³/d (4 mgd). This waterworks was developed primarily to meet the water requirements of the residents of Festival Village during the All Black and African Festival of Arts and Culture, FESTAC '77. In view of the fact that rapid population growth in Lagos has posed a heavy burden on the public water system, there has been a continuous demand and need for expansion of the Lagos water supply and distribution capacities (fig. 2). Although the Iju Waterworks was expanded in 1973 to 35mgd, it had to be upgraded again in order to further reduce the shortfall between the water demand and water supply. This was done between 1982 and 1985 to achieve 45mgd production target. It was at this stage that an overhead 5,000 cubic meter reservoir was also constructed at Ishaga. The supply of water to Lagos, as can be seen from this highlight, from the beginning had been, a federal responsibility under the federal ministry of works, but this great responsibility was transferred to Lagos state in 1967 when the state was created. So, for 66 years, federal authorities took care of the establishment of waterworks and distribution channels for Lagos (fig. 2).

Lagos state took over in 1967 till date to carry the enormous responsibility. The state set up a Water Board to carry out the various duties in this respect and in 1980, created the present Water Corporation backed up with an enabling edict in 1985. There were many positive developments between 1979 and 1983 in Lagos State Water Supply under the then civilian administration in the state which initiated the construction of ten Mini Waterworks in 1980 located throughout the state (fig.2). Mini Waterworks are waterworks that can provide water supply up to 3 million gallons daily, (Agenda 21, 1992; Barth, 1993; Black, 1990; East Bay municipal Utilities district, 1991; Engelmann and LeRoy, 1993; Bulletin 160-93, Sacramento, CA, U.S.A., 1994; Brooks and Peters, 1988). Seven of the mini waterworks in Lagos metropolitan; had a combined design output of 82,000m^3/d (18 mgd) while the remaining three in the semi-urban areas have a combined capacity of 38,000m^3/d (8.4 mgd). The Mini Waterworks were designed to feed directly into the networks laid in their various locations, to give immediate effect in these areas. Along with the installations of the Mini Waterworks, additional tertiary distribution networks have been laid on a continuing basis, to improve access to consumers. In 1979, the Lagos State Government received the report of "The study of the projected water demand of Lagos up to the year 2000". It became imperative that the State Government had to consider Water supply expansion schemes, (Lagos State Water Corporation facts data, 2002).

These included:

i. Expansion of Iju Waterworks from 109,714m^3/d (24.1mgd) to 208,000m^3/d (46 mgd)

ii. Construction of Adiyan Waterworks in three phases to supply 320,075m^3/d (70 mgd) per phase.

iii. Expansion of Ishasi Waterworks from 18,000m^3/d (4 mgd) to160,000m^3/d (35.1 mgd) and

iv. Expansion of primary, secondary and tertiary Distribution network.

It was in recognition of the amount of work involved that the Lagos State Water Management Board was created in August 1980 to operate and maintain the existing water supply systems (fig.3) and eradicate the pail system of sewage disposal, while the water supply department of the Ministry of the Environment and Physical Planning continued to handle the capital projects.

Due to the huge cost expected to be expended on the above expansion project, International Commercial Banks and External Funding Agencies were invited to assist with providing loan facilities. The invitation resulted in two French Commercial Banks accepting to fund the construction of Adiyan Waterworks Phase 1 and the laying of the Primary Trunk-mains, while the World Bank (IBRD) opted to fund the transmission and distribution systems including, rehabilitation works, institutional development, administrative infrastructure and technical support services.

MATERIALS AND METHODOLOGY

The method of implementing the set objectives would follow sequential GIS procedure using computer hardware, software packages and data sets. The use of high speed computer processor has been put in place to run graphic intensive GIS software package – ArcView GIS 3.2 while larger storage device was used to store water distribution information in Lagos metropolis.

DATA COLLECTION

In view of the need to create a GIS database, the type, source and quality of data needed for this purpose has been identified and as a result the data sets were collected from reliable source. Reliability of these data sets plays a central role in view of the need to create a credible database that is devoid of error that can comprise the quality of information to be derived from such a database. Thus, there are two categories of datasets requires – spatial and attribute datasets.

Spatial Data Collection

In view of the above, the relevant spatial data sets needed for this paper include the followings:

- Administrative map of Lagos state showing drainage, settlement e.t.c.
- population density and land use map
- Water facility map showing water reservoirs and pipe network in Lagos metropolis.

The administrative map was collected from survey office Alausa while the water facility map was collected from Lagos State Water Corporation (LSWC) Ijora. The population density and land use map was derived from the report of GWK Consultants who develop Lagos Metropolitan Water Supply in 1985.

Attribute Data Collection

The attribute records needed to compliment the spatial data were as follows –

- Population data
- Water demand

Relevant data sets on population and water demand for Lagos metropolis in year 2000 was projected by GWK Consultants in 1985 and was adopted as the basis for carry out water demand and supply evaluation.

Data Structuring and GIS Database Design

Spatial and attribute data sets collected were structured logically for the purpose of conversion and processing. For this reason, the structure and pattern of GIS database was designed. Database design involves implementation of the above structured spatial and attribute data sets. The technique through both spatial and attribute data sets is converted into a GIS database is defined. In this way, the type and number of theme layers to be created are determined for the spatial data while the features of associated attribute database are determined. The spatial data sets were captured in vector mode as point, polyline and polygon while the attribute records were structured into tabular database. The attribute records stored additional information about the spatial features and both databases ultimately linked through a functional multi relational linkage. Keeping both spatial and attribute databases in a single GIS database is step towards eliminating data redundancy, inconsistency, update anomalies and data maintenance and uncertainty, which could impair data quality to give bias information about the problem under view.

Besides, a well-structured database enhances the speed of data retrieval and conserves storage space among others, (Omogunloye, et al, 2007, 2008 and 2010).

Data Conversion and Processing

The above data sets were collected in analogue format and converted to a digital format. A GIS database was digitized spatial and attributes data set. This process involves using hardware accessories and software packages. The process involves the following steps:

Analogue to Raster Conversion

The first step in conversion of spatial data is scanning of analogue map collected into raster image. In this way, an image file is created using large format scanner.

Scanner is a device that enables the scanning of a picture, line drawing, text or other graphic element into a form useable in CAD (Computer Aided Design)/GIS environment. Scanning a map is a straight forward process that converts details on the analogue map into picture element (pixel). In other words, scanning converts points, lines, areas and text on paper maps into a series of picture elements or pixels. The higher the resolution of the scanned image (more dots per square-inch), the smoother and more accurately defined the data will appear. As the dots per inch (dpi) increases, so does the file size. One of the advantages of scanning is that the user sees a digital image that looks identical to their maps.

However, a large format A0 scanner was used to convert the maps to raster image. With A0 sized scanner, the details on the analogue cadastral map was captured to 1200 dpi spectral resolution at a line art image format and saved as an image file (nigertour.tif). The image file was sized 124MB and was saved into a removable medium - 600MB sized compact disc via HP CD writer. The image file was later transferred to ArcView GIS for subsequent image processing and vectorization, (Omogunloye, et al, 2007, 2008 and 2010).

Raster to Vector Conversion

The ArcView GIS software was used to convert the scanned raster image into vector entities. It is important to highlight some of the features of this software that make ideal software for this purpose. It is true that there are other software packages (AutoCAD/Raster Design, R2V, etc.) capable of raster to vector conversion. The ArcView GIS software is embedded with image processing extension (tiff 6.0) – a module used in viewing and processing image stored in .tif format. The module show to display the nigertour.tif in the ArcView. Another module of the software – stuff extension – was used to geo referenced the image. In other words the image – nigertour.tif was registered to geographic coordinate system and projected to decimal degree.

Attribute Database Creation

All theme layers created have their associated attribute databases which are geo linked to the spatial database. The attribute databases have additional information about water facility in the state such as population, population density and water demand in each district of the metropolis. This information were captured and integrated as part of the spatial dataset.
However, the combination of these spatial and attribute databases make up a typical GIS database.

Data Storage

Besides the spatial and attribute database files created above, there are other supplementary files that were created as topological files meant to keep topological structure of the spatial entities. These files are digital files that are stored into storage devices of the GIS platform. The hardware used for the GIS storage device was 40GB Seagate hard disk. All these files created in ArcView GIS occupy about 437MB of the 40GB capacity hard disk. These files can be saved into a removable disk of 100MB, 250MB and 600MB as back up facility, (Omogunloye, et al, 2007, 2008 and 2010).

Result and Discussion

Data Analysis *Result*

In view of evidences derived from the review of relevant literatures on water need requirements around the world, it is imperatives to give an overview of the status of water demand and available water distribution facilities in Lagos metropolis based on acquired information. It is evident that water requirement for various human activities varied widely and depend largely on land use patterns and population.
To this effect, population, population density and land use data acquired were processed for this purpose. The global estimates of long term population growth and future water demand as well as development of land use was reported in GWK report (Water Demand, 1975). The overall figures were distributed according to existing land use and assumed developments in the so-called "Planning Control System which was introduced as a planning tool for the definition of the Primary Distribution Network Report" (August 1976) for Lagos metropolis. These two reports served as the necessary framework for the main structures of Lagos Water Supply, but were not intended to give exact information on population and water demand on a detailed scale for any specific area.

Population Density, Land use and Domestic Water demand analysis
However, the domestic water demand depends largely on the type of housing and on the income situation (population density and land use characteristics). There is also a strong correlation between housing conditions, socio-economic standards and residential densities. For the design of the secondary network, it is important to establish a distribution pattern of population and water demand according to the different consumer categories. To facilitate this, the metropolitan area of Lagos state has been divided into twenty-one controlling/planning units or districts and a detailed land use map for each district has been prepared (fig.4) where the residential areas are classified according to three main density categories as specified below:

Residential Category R1: Gross density of 50 persons per hectare; upper income of one or two family houses with garden and adequate facilities.

Residential Category R2: Gross density of 200 persons per hectare; middle income, medium class housing with medium facilities.

Residential Category R3: Gross density of 450 persons per hectare; low income houses of poorer building material, inadequate facilities, partly slum like areas, also houses of higher standard deteriorated due to over crowding.

For the three residential categories, the per capita water consumption rates have been adopted as 300, 110 and 70 liters per day. These values have been taken after field investigation and after comparison with cities under similar climatic and social conditions, and have been agreed by L.S.M.W.P. (Lagos State Management Water Project. 2002; WHO, 1971, 1972, 1987 and 2009). The domestic water demand for the different residential categories can therefore be summarized in tabular form as shown below:

Table 1

Category	Gross Density (Persons per hectare)	Water Consumption (Liters per capita per day)
R1 Low Density	50	300
R2 Medium Density	200	110
R3 High Density	450	70

In view of this, chart of the domestic water demand and supply to 21 planning districts in Lagos metropolis is shown in figure 5:

From the Figure 4 and Table 1, it is evident that the largest coverage (604 sq km) of low population density was recorded in Lagos Island and Ikoyi while the lowest coverage (18.40 sq km) of low population coverage was recorded in Oshodi. By implication, water demand in low density area such as these is expected to be as high as 300 liters per person per day

(GWK Consultants). Consequently, largest coverage (1,568 sq km) of high population density was experienced in Idimu while the lowest coverage (111.40 sq km) of high population density was observed in Lagos Island and Ikoyi. In other words, the highest coverage of low population density of 50 persons per hectare was recorded in Lagos Island and Ikoyi. In this area, the per capita income is high and thus family or household could avoid luxurious facilities (such as gardens, swimming pool etc) that demand high water consumption. Conversely, highest coverage of high population density of 450 persons per hectare was observed in Idimu where the general condition of living is generally low. Thus facilities that required the use of voluminous water could not be afforded; as a result water demand in the region is as low as 70 litres per person per day (GWK Consultants). In view of this, daily water requirement for the entire Lagos metropolis was computed (following GWK recommendation) based on the projected population for 2000 and land use patterns, and available water supply in these regions was also derived from existing reservoirs and their daily supply capacity (fig.5).

From Figure 5 above, it is evident that daily water demand and supply in Lagos metropolis varied greatly for obvious reasons. But most important it is expected that the government should provide certain percentage of portable water to its citizen. It was recommended that international organizations, national and local governments and water providers adopt a basic water requirement standard for human needs of 50 liters per person per day (l/p/d) and guarantee access to it independently of an individual’s economic, social or political status. According to US Agency for International Development, the World Bank, and the World Health Organization about 20 to 40 liters per person per day the target set and it was in line with the recommended standards of the United Nations International Drinking Water Supply and Sanitation Decade and Agenda 21 of the Earth Summit. Thus the water supply planning for the region was far above the international recommendation. Although GWK recommended 300 litres for low density, 110 litres for medium density and 70 litres for high density. Based on the GWK recommendation average water demand per day per persons was derived for metropolitan Lagos is shown in (fig.5). However, looking at available water supply in the metropolis, one found a total deviation from this recommendation. It is often evident that daily water supply to the city as being conditioned by the number of available reservoirs for each supply district is far inadequate. The highest water demand in the metropolis was observed in Ipaja with an average daily demand of 122,103.28m^3 for about 782,000 persons. It is shocking to reveals that no single reservoir is available for this area (fig. 7B). Thus the residents seek alternative water source to meet their demands. Consequently, the only place where the demand is met is in Owode (figs.5, & 7A) where about 170,000m^3 is supplied daily to 364,500 persons through three reservoirs (Ishasi Ground level Reservoir_160,000m^3, Ojo Overhead level Tank_5000m^3 and Owode Overhead level Tank_5000m^3). By implication, individual would have daily access to about 0.47m^3 of water. This is the only place where daily water supply is met.

ACKNOWLEDGEMENT AND CONCLUSION

This Study has analyzed the spatial and attributes data accurately, showing that the number of water reservoirs for the distribution of water in the Lagos metropolis has failed in providing sufficient portable water to the people, (fig 5). The consequence of this development may lead to health hazards where community would have to resort to untreated water to meet their needs. Although Lagos is surrounded by water bodies, most of the surrounding water bodies have their salinity level very high and are contaminated by diets and human excretes (Black, 1990; WHO, 1971, 1972, 1987). Based on the study conducted, it is evident that water demand is far higher than water supplied to the metropolis (fig. 5) and (fig. 7A, queries (1 - 5) and fig. 7B) shows the areas with the highest number of reservoir and lowest number of reservoir respectively indicating the status of water supply capacity in Lagos metropolis. It is recommended that the government and stakeholders should get an updated statistics about changing populations, land use and socio economic status of Lagos residents so as to update the statistics in Table 1 and Figure 4. This will help the L.S.W.C to identify the local government areas in short of portable water. The twenty-one planning units under L.S.W.C should be upgraded and extended so as to meet the ever growing demand for water in Lagos state, (fig. 2 and fig. 3). This will enable L.S.W.C. to meet the basic water requirements for human activities. The maintenance of all the facilities provided for portable water and necessary repair should done as at when due.

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Table 1 – Population Density and Land Use Patterns in Lagos Metropolis

		LAND USE CATEGORY (ha)				
ID	**NAME**	**LANDUSE_LOW DENSITY**	**LANDUSE_MEDIUM DENSITY**	**LANDUSE_HIGH DENSITY**	**INDUSTRY**	**SPECIAL**
1	IPAJA	153	2,089.75	792	323.5	1,087.00
2	AYOBO	0	476.46	1,111.23	58.96	364.01
3	IKOTUN	0	1,075.92	1,031.83	601.85	258.94
4	ISOLO	144	842	342	352	239
5	BLACKARTS/AMUWO	30.74	587.39	691.32	492.45	596.95
6	OWODE	70.8	401.21	39.06	202.08	480.14
7	OLUTE/KIRIKIRI	51.25	73.5	1,097.27	59	66.25
8	AJEGUNLE/APAPA	491.9	460.2	196.3	75.9	202.7
9	ITIRE	120	1,058.00	1,082.50	33.1	138.3
10	ISERI OKE	107.25	593.9	420.42	250.35	164.43
11	OGUDU	42.75	345.45	515.68	280.42	143.63
12	OSHODI/GRA	18.4	559.5	1,112.60	147.2	85.1
13	AGEGE	155.4	921.7	560.5	85.2	1,048.10
14	IDIMU	0	179.1	1,568.00	126.8	57.1
15	IKEJA/AIRPORT	0	290	606.7	233.8	514.6
16	SURULERE	0	144	681.6	0	439.7
17	MUSHIN	0	0	810	636.2	1,695.90
18	YABA	0	105.6	539.2	171.5	2,684.90
19	SHOMOLU/BARIGA	265	96.35	1,499.70	220.33	681.35
20	LAGOS ISLAND/IKOYI	604	69.8	111.4	0	851.8
21	VICTORIA ISLAND	464.9	581.4	345.5	5.3	832.8
	TOTAL (ha)	2,719.39	10,951.23	15,154.81	4,355.94	12,632.70
	(m^2)	271,939.00	1,095,123.00	1,515,481.00	4 35,594.00	1,263,270.00
	(km^2)	271.94	1,095.12	1,515.48	435.59	1,263.27

The following queries were performed in this study,(Queries 1 – 5):

Query 1: highlighted the type of and the capacity of Eredo reservoir in yellow colour.

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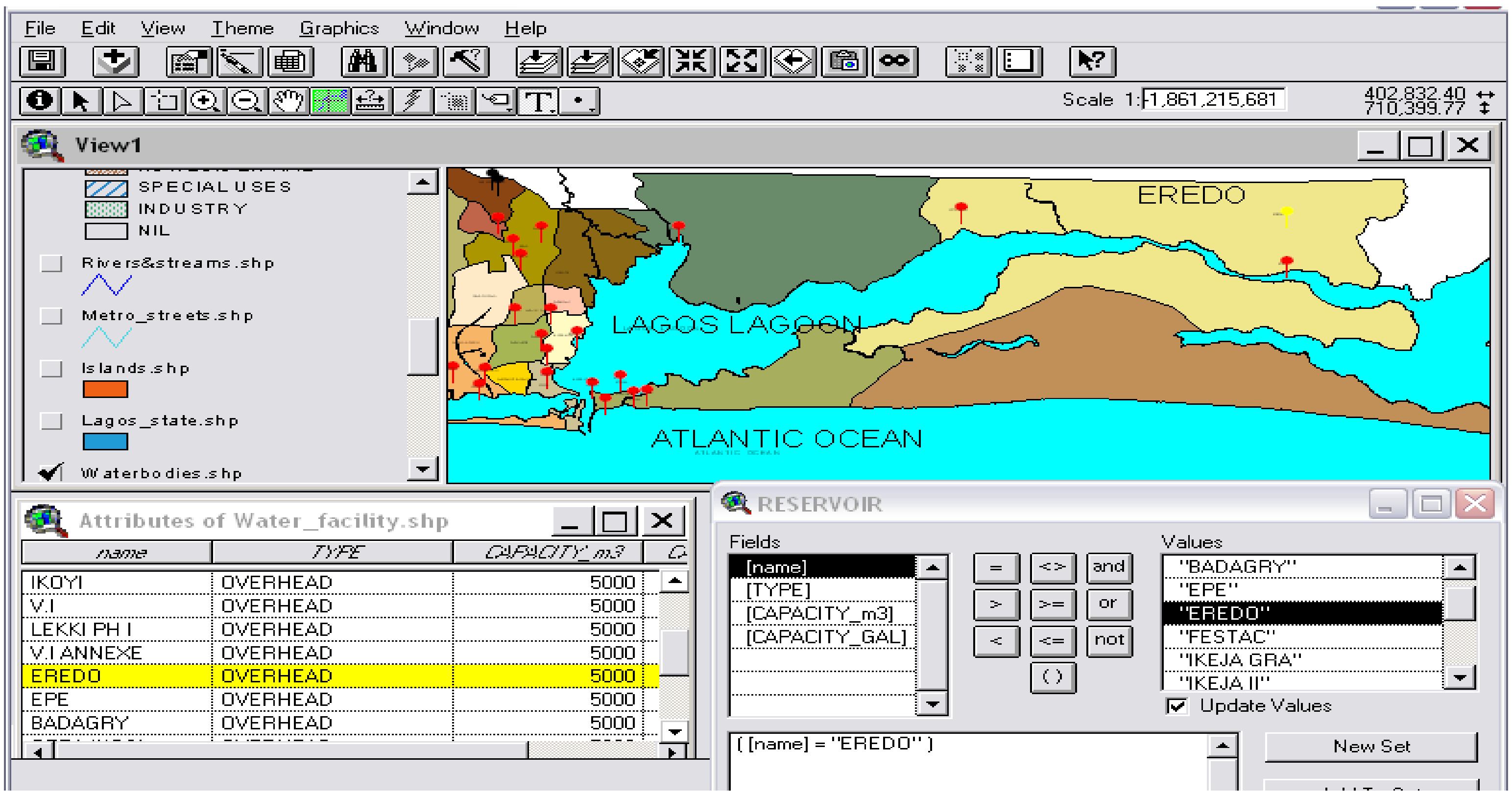
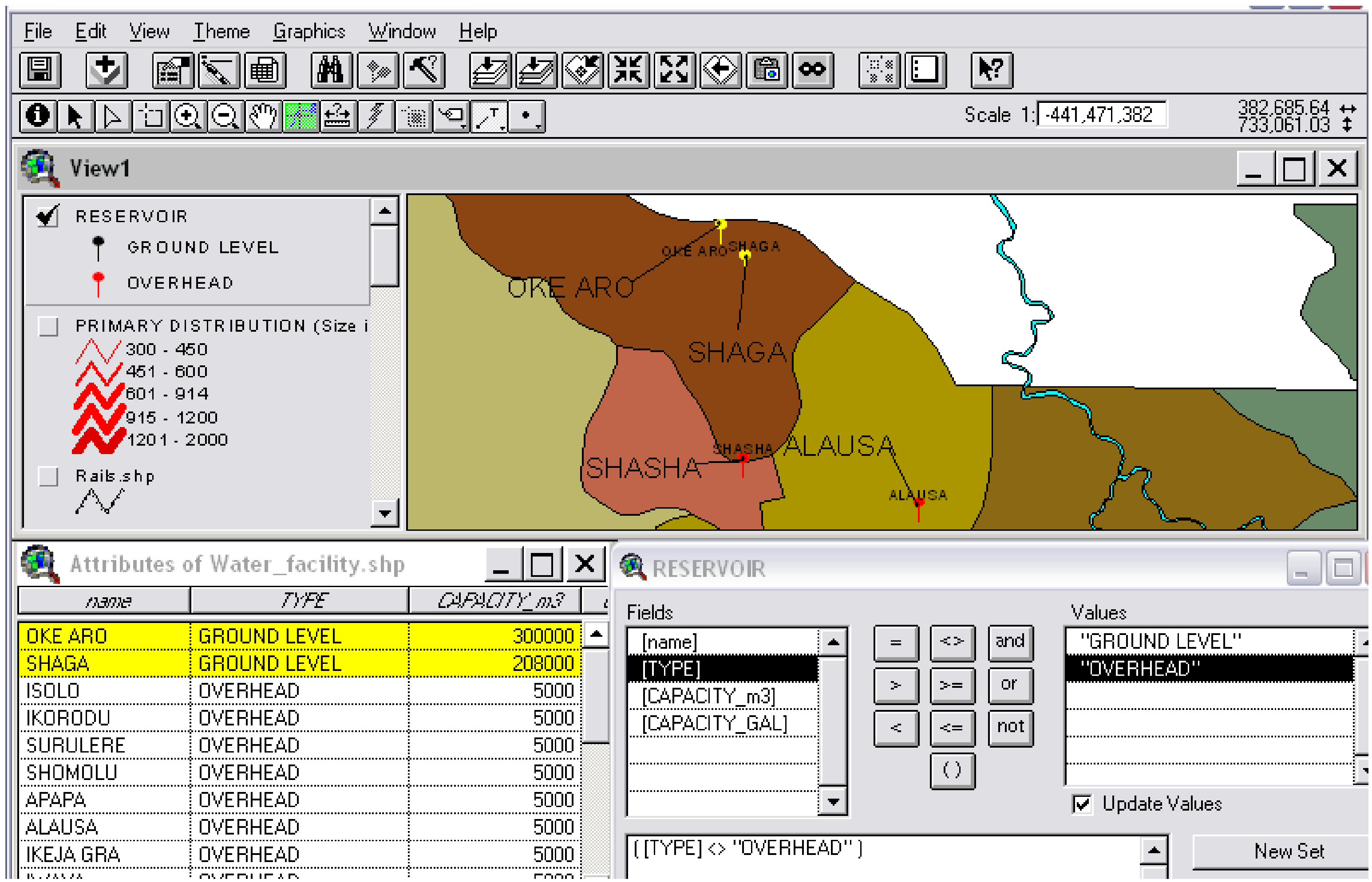
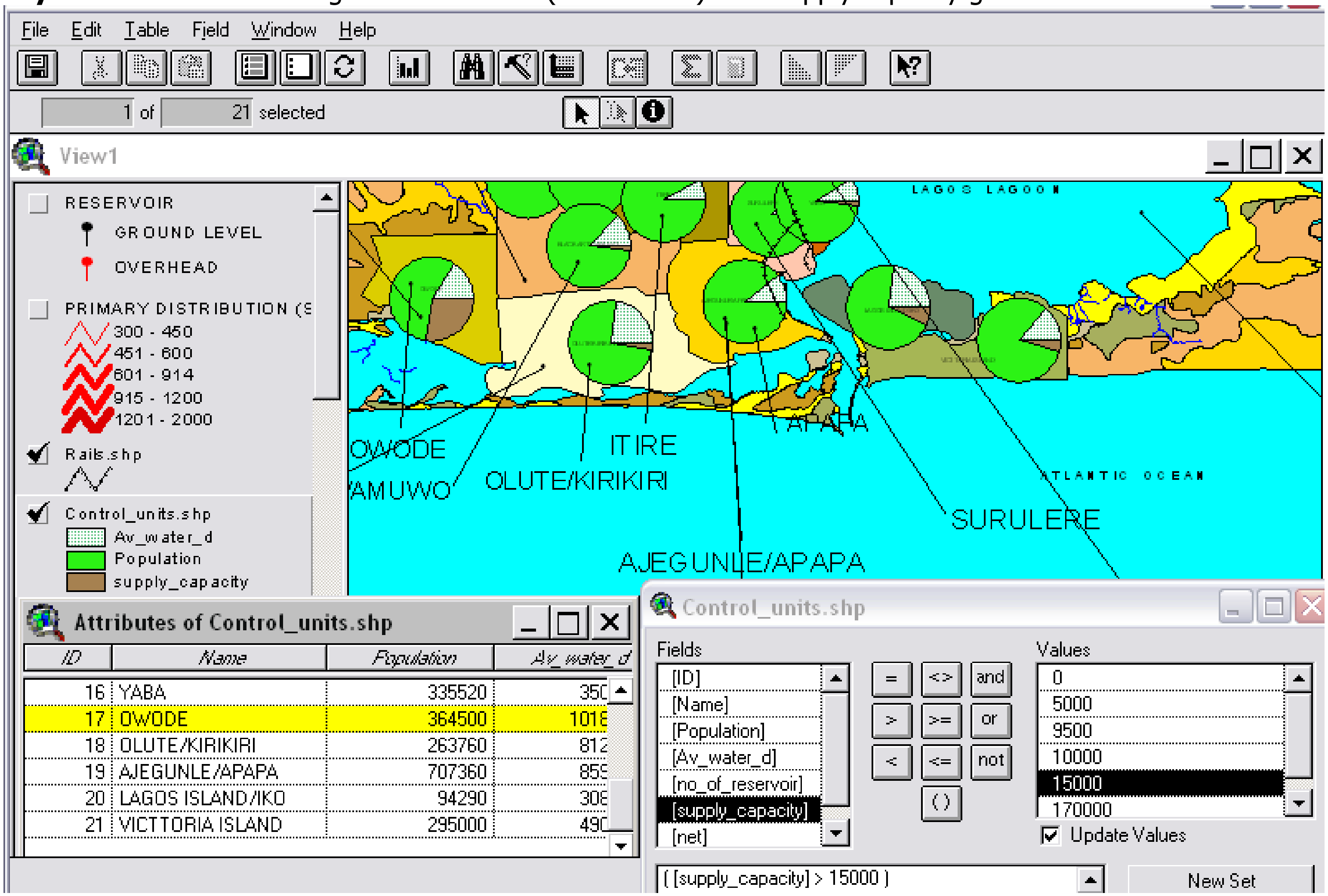


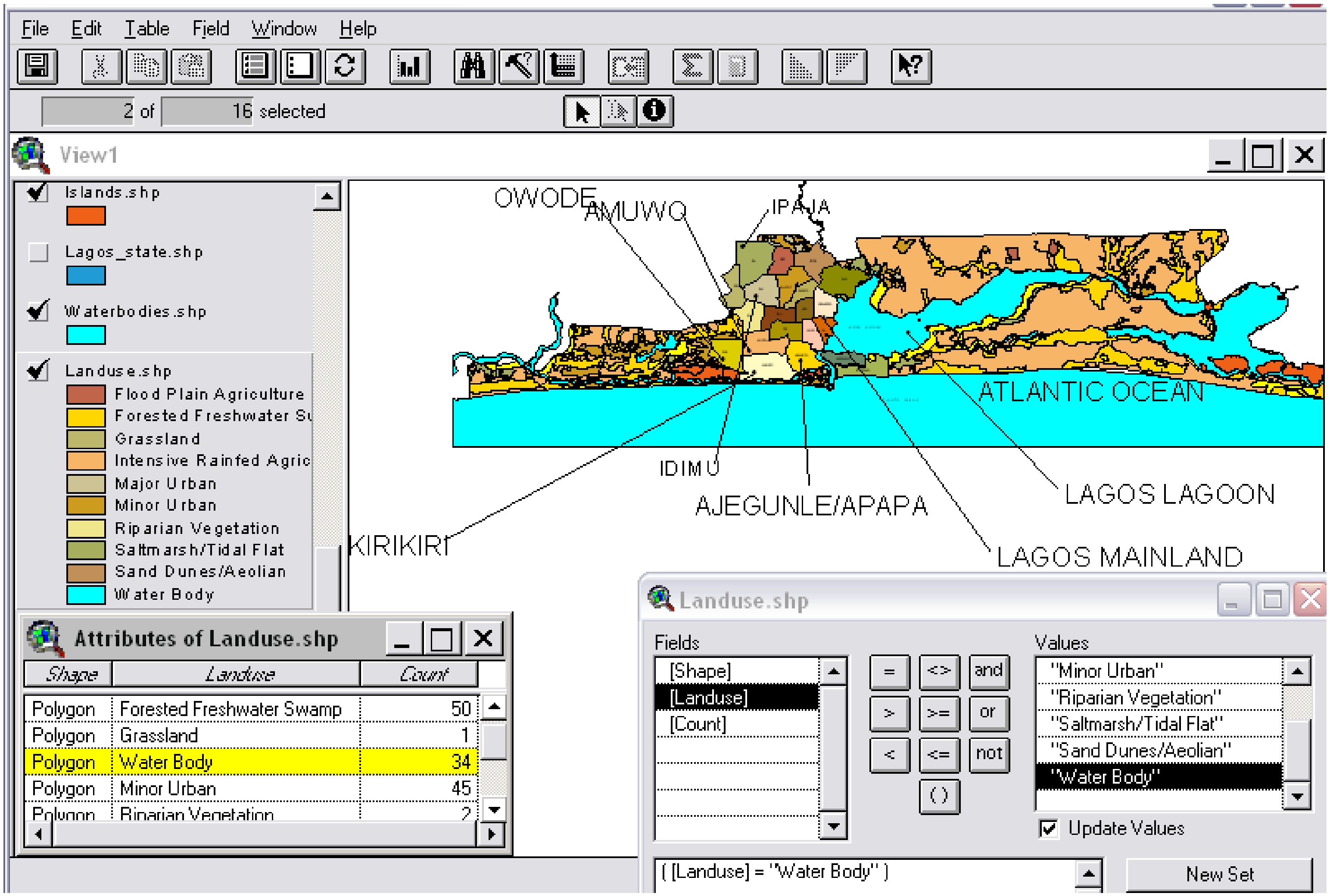
Query 2: highlighted the locations of the Ground Level type of tank and their Capacities (Oke Aro and Shaga reservoirs) in yellow color.



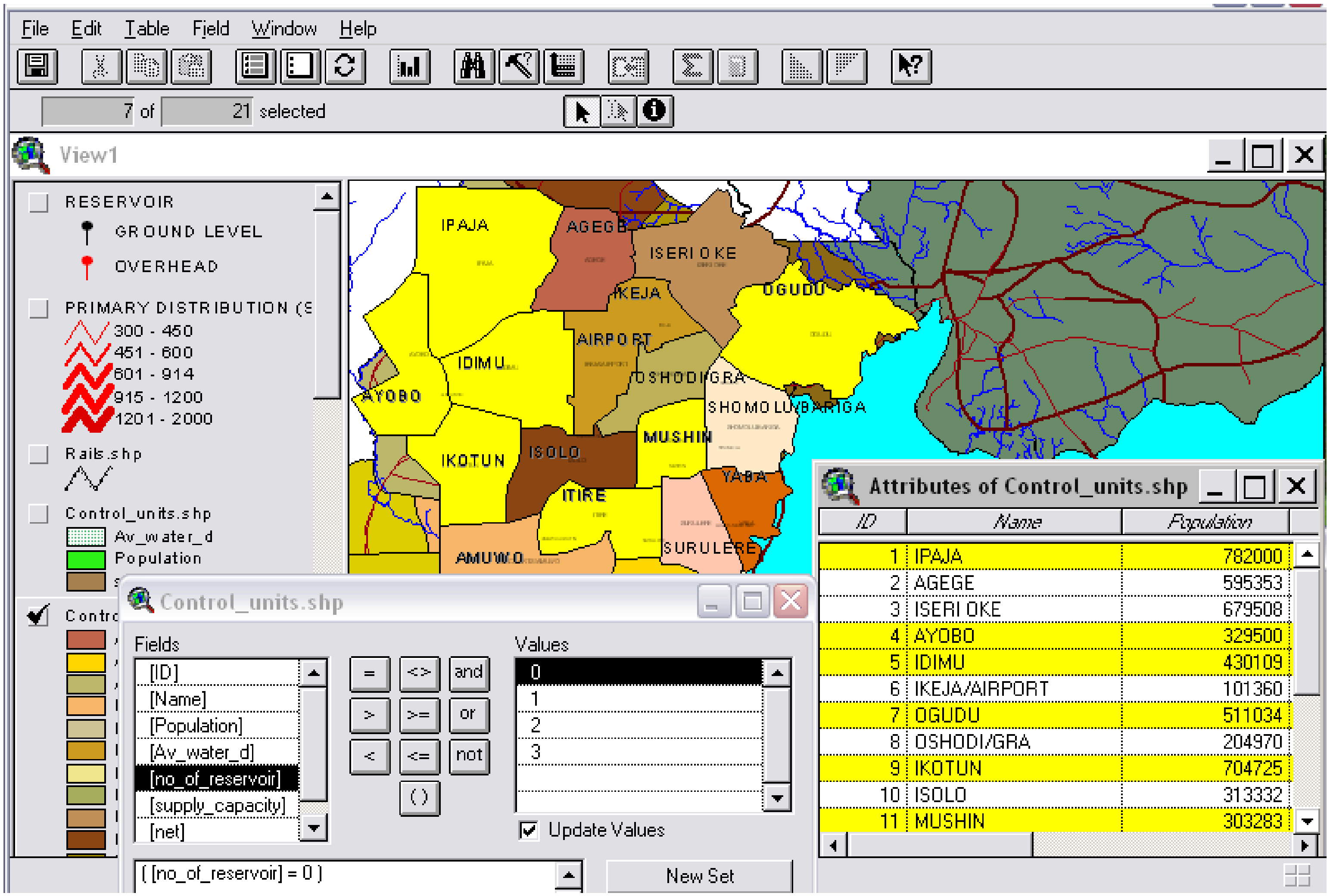
Query 3: This view is showing the control unit (Owode unit) with supply capacity greater than 15000 cubic meters.



Query 4: This view is showing the land use areas made up of water.



Query 5: The highlighted area in yellow color represent areas without any reservoir.



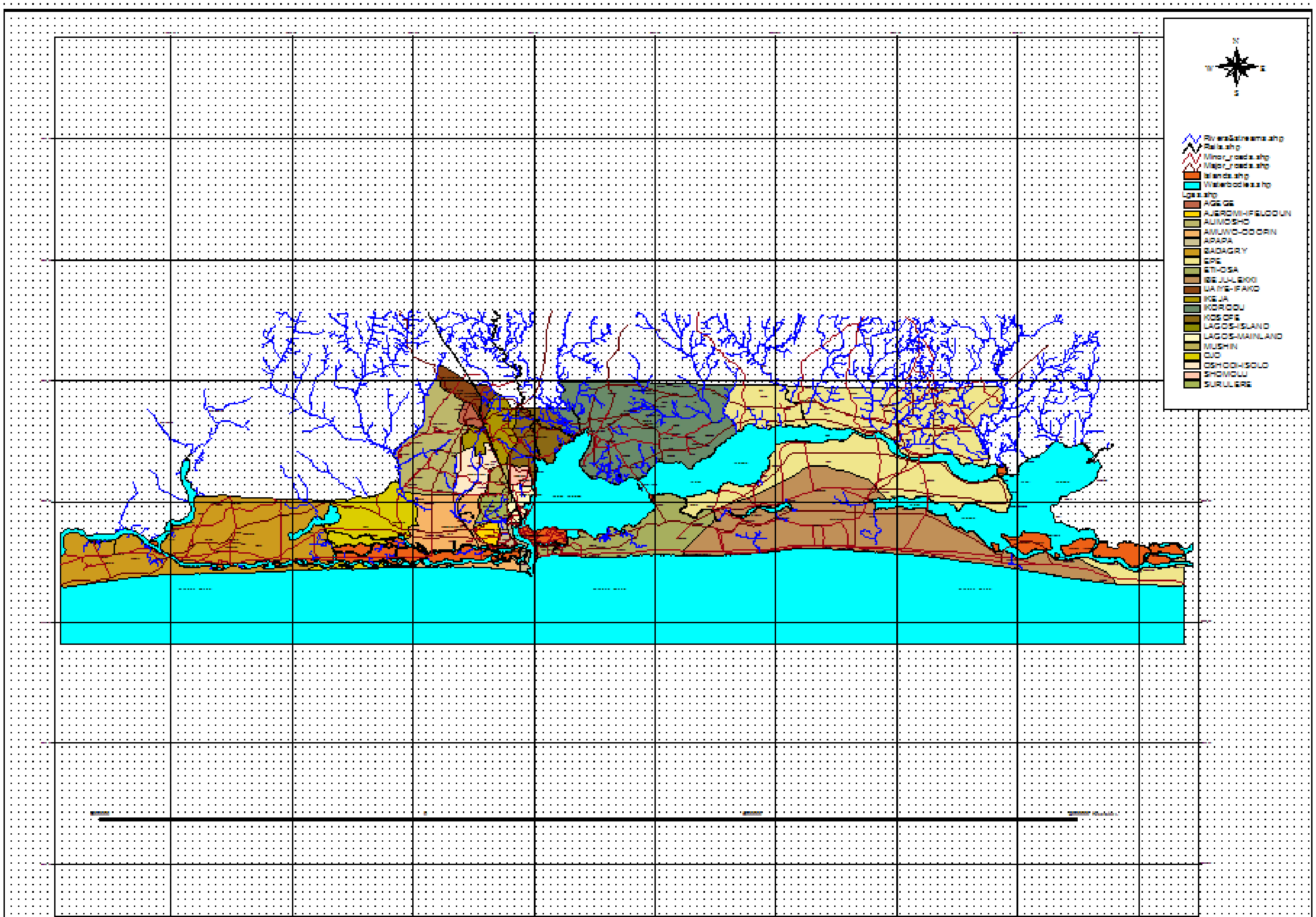


FIG. 1 - BASE MAP OF LAGOS STATE

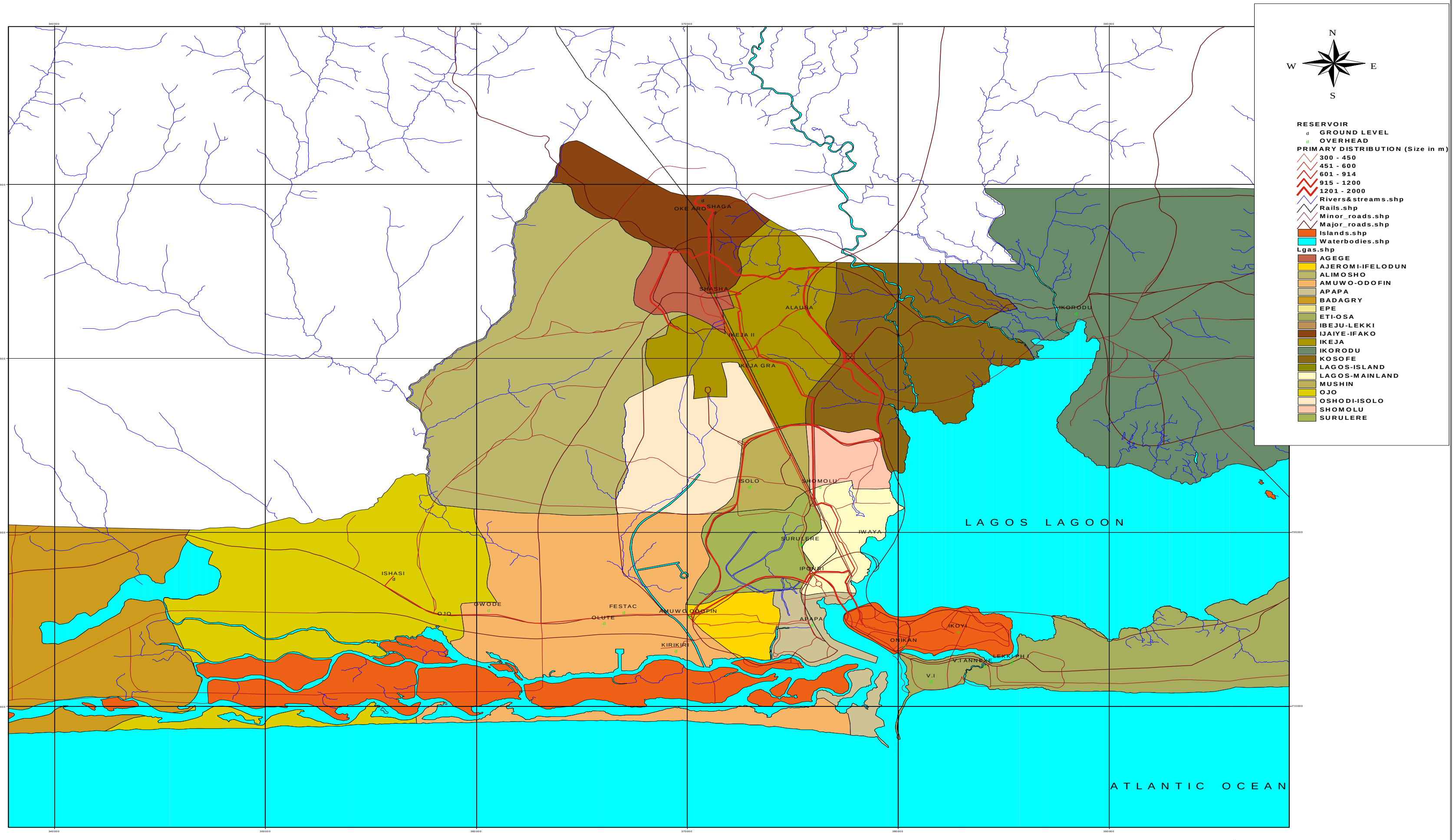


FIG. 2 - MAP SHOWING WATER DISTRIBUTION FACILITIES IN LAGOS METROPOLIS

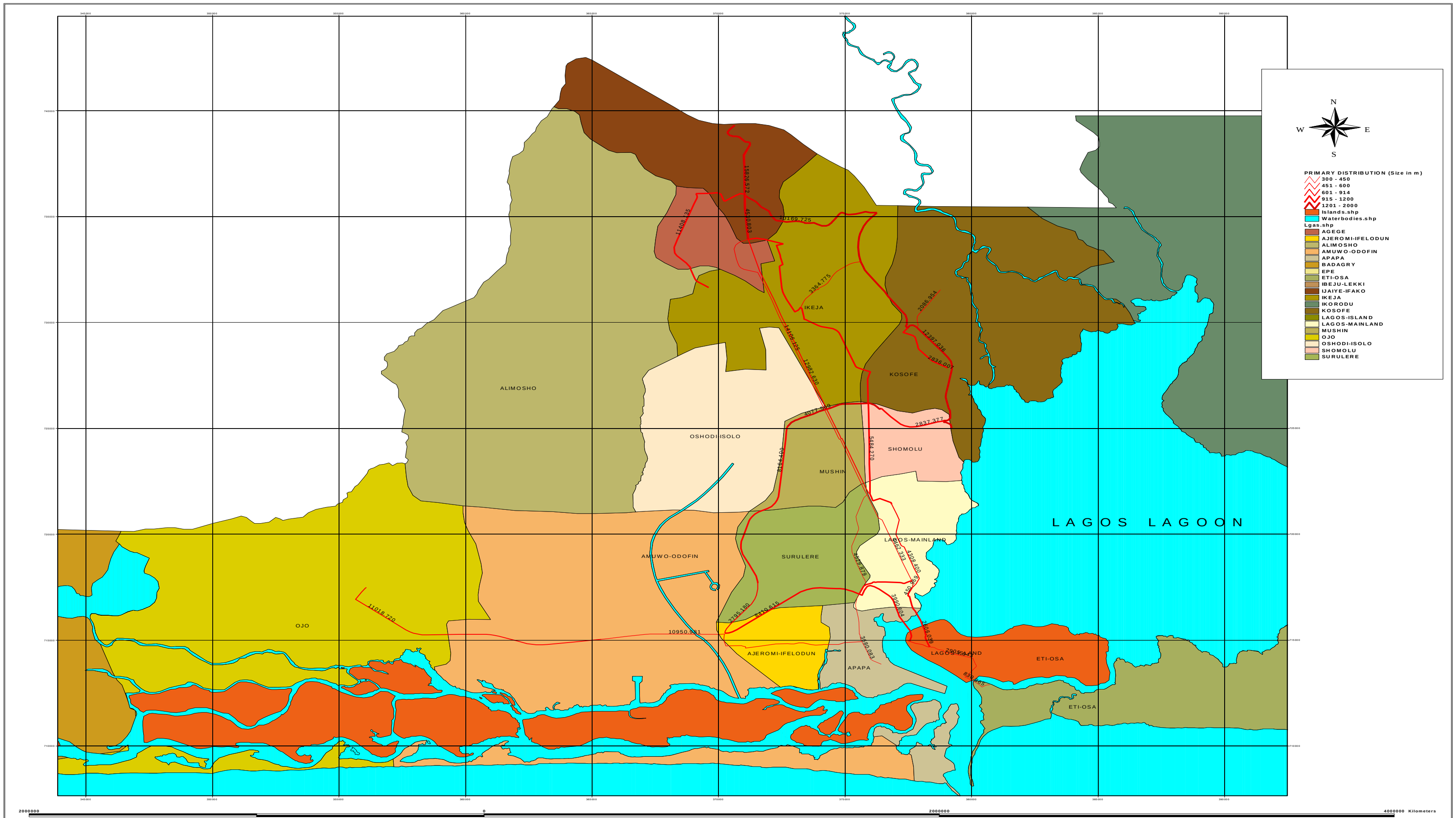


FIG. 3 - PIPE DISTRIBUTION NETWORK IN LAGOS METROPOLIS

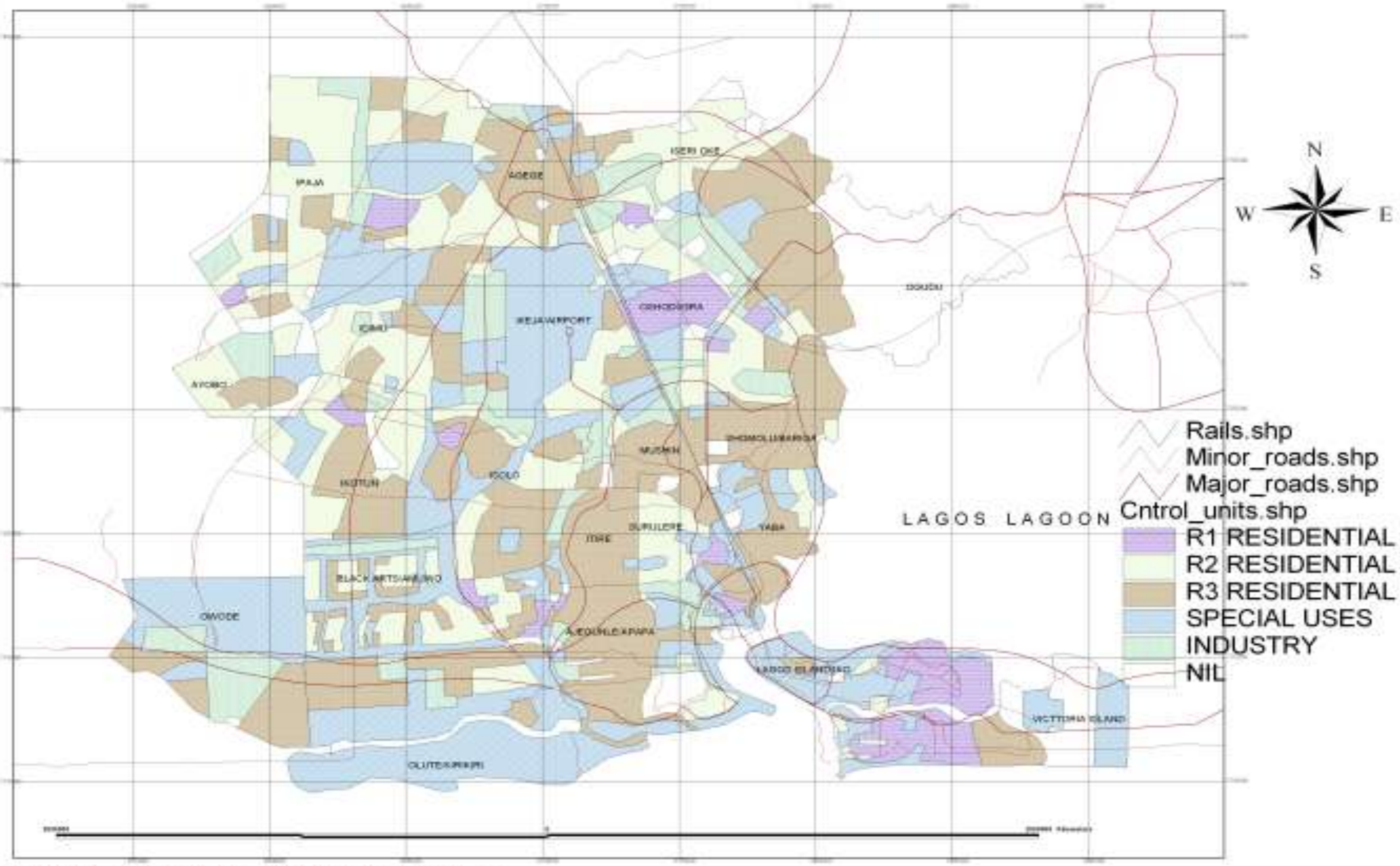


FIG. 4 - LANDUSE PATTERNS IN LAGOS METROPOLIS

FIG 5 - WATER DEMAND AND SUPPLY CHART, LAGOS METROPOLIS

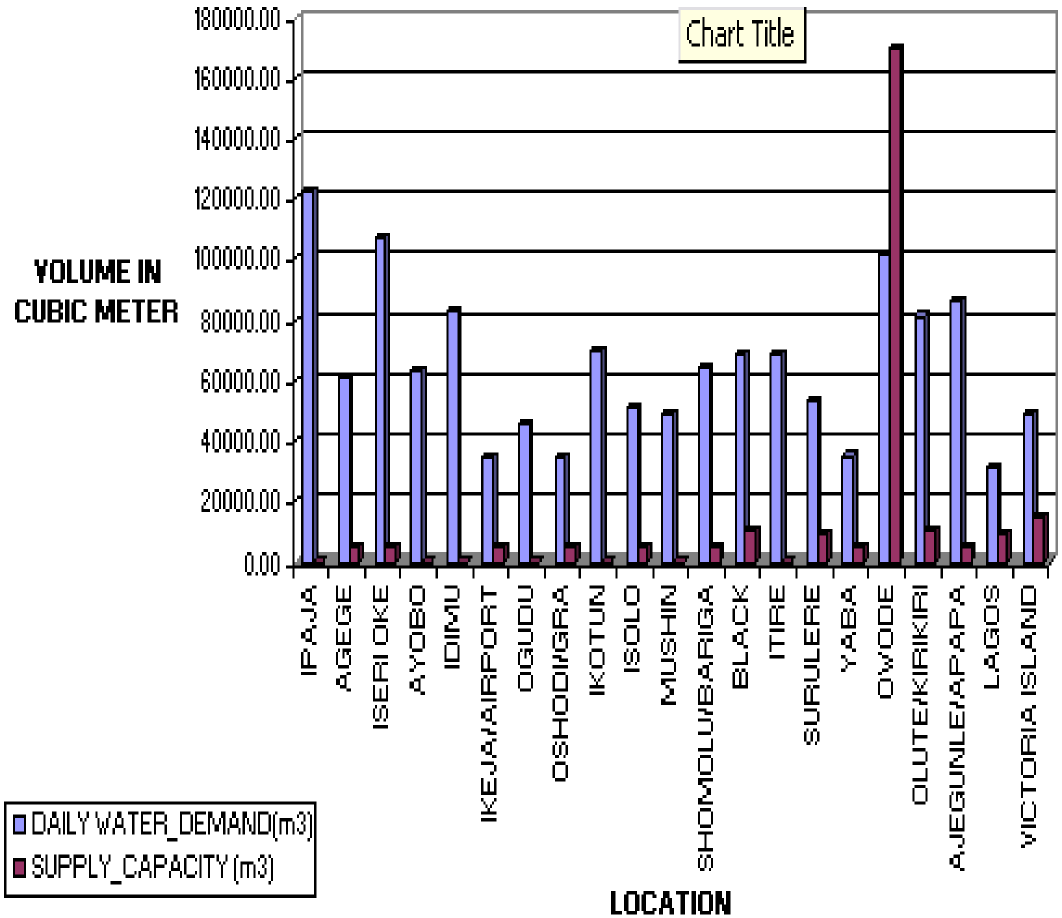


FIG. 7A - POPULATION, AVERAGE WATER DENSITY, NUMBER OF RESERVOIR, SUPPLY DENSITY IN OWODE.

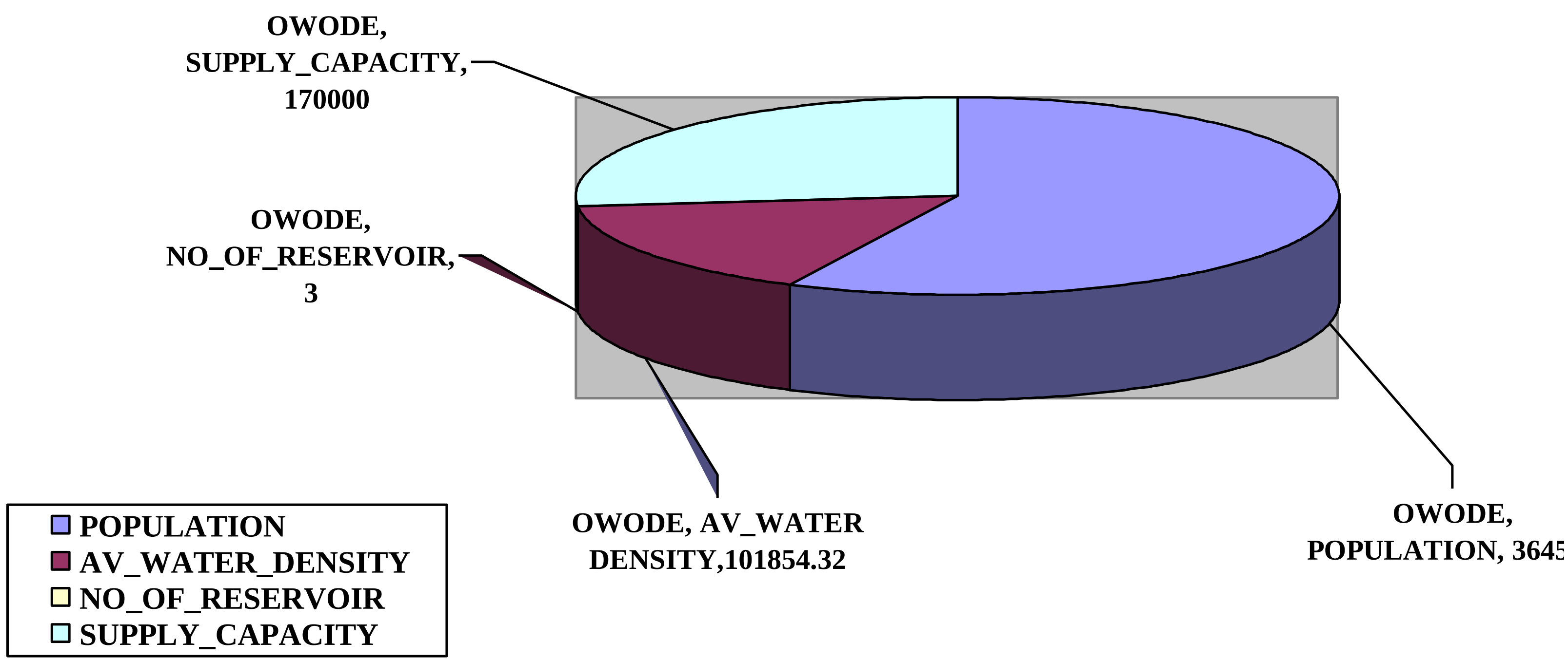


FIG. 7B - POPULATION, AVERAGE WATER DENSITY, NUMBER OF RESERVOIR AND SUPPLY DENSITY IN IPAJA.