TRANSFORMING BAUCHI URBAN WATER DISTRIBUTION SYSTEM MAP

S. S. Garba¹*, Z. M. Baba² and J. D. Dodo³

¹Department of Civil and Water Resources Engineering University of Maiduguri, Maiduguri, Nigeria
²Department of Geomatics, Ahmadu Bello University, Zaria, Nigeria
³Space Geodesy and Systems Division, Centre for Geodesy and Geodynamics, Toro, Nigeria

*Corresponding author’s email: ssgarba@unimaid.edu.ng

Abstract
Maps are important in running urban utilities. The map available at utility organization such as Bauchi State Water Board is often inadequate in view of the possibilities of modern maps to meet needs such as design, construction, maintenance and research. The available map was assessed, scanned and georeferenced. Together with high-resolution image (Pleiades image of 0.2m spatial resolution), the water network was digitized. Management staff and technical staff were asked on their knowledge of map and modern mapping facilities. They were also asked on how they use the existing map in their routines. There is lack of general map properties like scale and projection on the existing map. There is lack of understanding amongst the management of modern mapping tools; there was low usage of the map (probably because of the map inadequacy). The existing map was transformed into a digital map and georeferenced. Further, it was digitized allowing for each elements of the water network to be uniquely represented. This study therefore recommends that the material of this research could be integrated into the existing system of BSWB as well as in GIS framework for education and proper utilization of the resources by the immediate community.

Keywords: Map, Geographical Information System (GIS), Global Positioning System (GPS), Georeference, Water distribution,

1. Introduction
Maps are essential in many aspects of urban water utility. It plays a role in the design and layout of pipeline within the existing houses and roads and other urban object. Then in the construction, the laying of the pipes according to specification and reality on ground (House-Peters and Chang, 2011). However, most recently in the analysis of demand forecasting, in maintenance: locating leakages, attending to complains and issues of securities (Elad, 2004); and the simulation and optimization of the system (Atkinson et al., 1998, Makropoulos and Butler, 2005). The advent of map in general has evolved over the years in terms of its production. There has been huge change in the generation of data (the surveying equipment and method, and the availability of remote sensing data); the processing, production and presentation of the map (The GIS, the digital form, and the variable scale and web publication). In Addition, the way the map is used has also changed over the years from simple design plan, to map for maintenance and then to map as spatial analytical tool for decision-making (Duddu, et al., 1998). It is therefore pertinent to raise a question as to where utility organization such as the Bauchi State Water Board (BSWB) stands in relation to the evolving production and usage of map. The first question to ask is whether it has an adequate map suitable for its operation. Secondly, whether it uses it and how frequent? Third, how can one transform available map into a contemporary form?

The objectives of this paper is to measure (understanding- how?) the place of mapping in managing an urban water utility system of Bauchi; to assess the existing map used by BSWB and transform it into a viable instrument of helping the organization achieve its objectives.
The first matter is the transformation of the map. However, there are other issues worthy of investigation relating to a transformed map. First, the used of the transform map in assessing the capacity of the current facility (i.e. the water network) to meet its current and future reach or demand (Martin et al., 2005). Secondly, there is issues of creating a geo-database, the map (on its own is simple a spatial data) that must mix with other data within an organization. This work is not about organizational implementation of GIS. It is limited to the essential GIS process that deals with the transformation of analogue map to a digital one. It is concerned with what will be involve in such transformation and the demonstration of the possibilities.

Pindinga and Sani, (2015) undertook a process of digitizing the BSWD, although their aim was not clearly stated. They attempted to answer the question (in their own word): ‘if any section or part of the water distribution network fails or need emergency repairs or in case of fire outbreak, how can this problem be solved or traced without disrupting other users on the network?” this is simply a location issue which a transformed map should answer. One could question the appropriateness of the five points outside but enclosing the town used for georeferencing the scanned map of the pipeline. Moreover, there was no proper description of the point to allow for reuse. They also conducted a GPS survey of node valves, the T-junctions, busters (it would be good to have incorporated this points in their georeference, but since they were presented separately, it was assumed that they were not). They imported the points into a GIS software and digitized the water lines. The whole process was limited to the scanned map without other external data currently available data (e.g. high-resolution satellite imagery).

2. Methodology
2.1. Study Area

Bauchi town is located at latitude 10° 19’ 02” North and longitude 09° 50’ 41” East. It is the capital of Bauchi State of the Federal republic of Nigeria (Figure 1). This state capital makes it the priority of government developmental area. This is very true regarding water project. It is connected by a road from Jos in the south west, in the north east by a road going Maiduguri. And in the north by a road that goes to Ningi, where the Gubi Dam is located.

Bauchi town water supply in its current form dates back to 1980, with creation of Gubi Dam. The treated water was conveyed to two reservoirs at Warinje hill and then distributed in three directions to the various parts of the Bauchi town (Abdullahi, 2014).
2.2. Materials and Data

Secondary data include Pleiades (50cm spatial resolution) 2012 satellite imagery covering the study area was acquired from Bauchi Geographic information system (BAGIS), (Astrium Geo information services, France, 2012).

Pleiades, a Satellite imagery, product of Astrium Geo information services, France (Airbus, 2017) was acquired by Bauchi Geographic Information System (BAGIS) in 2012. This Imagery covers the total area of about 200km$^2$ of Bauchi local government including the study area. Pleiades 1B was the newest high resolution and the panchromatic (50cm) band and multispectral (12m).

Materials used in GIS involves: Laptop (HP 630 pavilion with 2G Ram capacity), AO Scanner HP design jet with optical scan resolution of 600 dpi. Other instruments include Garmin 76 hand held global positioning system (GPS) and Hi-target GNSS Real time kinematic (RTK) dual frequency differential GPS with $\pm (10 + 1 \times 10^{-6})$mm and $\pm (20 +1 \times 10^{-6})$mm horizontal and vertical accuracy respectively. The software component involves Esri ArcGIS 10.1 version.

2.3. Assessment of Existing Map.

This involves visual assessment, identifying present or absent of map property, identifying whether there are signs of usage. The map properties used for the assessment are map projection, direction of orientation (north), the title, scale bar, note, symbol legend and map frame (grid). The presence of pencil or pen mark or new drawing would indicate usage of the map.
2.4. Control Survey
A control survey was conducted using a Hi-target GNSS Real time kinematic (RTK). This would be used to georeference the scanned map. Ten control points were measured. In order to avoid any ambiguity, intersection points such as roundabouts were used in selecting the points.

2.5. Interviews with Management and Technical Staff of BSBW
Questionnaires were administered at two levels in order to gain understanding of the system in relation to the map they use, how they use it and matters relating to its updating. A set of questionnaire was administered to the seven Management staff and another set to 13 technical staff. However, there were further consultations with the Assistant General Manager (AGM) operation and maintenance (O & M) representing the management staff and Chief Technical Officer (CTO) represented the technical staff. The questions asked includes: the status of the existing map, pattern used in house numbering, relationship between the water board and their customers, system of record keeping, the relation between water board and the state GIS office. Other questions are whether there is any proposal on the ground to upgrade the system, what are the criteria used in the distribution and extension of water utilities, and the present problems associated to urban water distribution system.

2.6. Data Processing
2.6.1 Scanning
The existing map was scanned with an A0 scanner. This captured the existing map at once and provide a raster data of the scanned map.

2.6.2 Georeferencing of the scanned map
The result of the control survey (section 2.4), that is the 10 control points were used to georeference the scanned image and check the Pleiades satellite imagery. This process adjusted the scanned and satellite images geometrically to same location and in the same coordinate system as the control point. (Mathew, 2007).

The projected coordinate system selected for this work is the Universal Transverse Mercator (UTM), the reference sphere is the World Geodetic System WGS 1984 (WGS84), and the area of study lies in zone 32. This projection system is one of the most used (Esri, 2004), thus makes it easier to work with other images and transfer the data. The spline transformation (Esri, 2016).was used in the transformation of the scanned map.

2.6.3 Digitization
Digitization was carried out using both the scanned and the satellite images. First, three layer were created:(1) features that are representing points like the valve, hydrants, nodes and chambers; (2) line layer was used to represent the like the roads and pipelines. Then (3) polygon layer for representing area of Gubi dam and the political boundaries (wards).

The layers were placed on the images and the features were traced and marked on respective layers in accordance to the scanned images, and verified and adjusted according to the satellite image. Objects such as Gubi dam was traced using Pleiades image. In the process of digitizing the pipeline, the pipelines were categorized into four classes according to their diameter (Table 1, according to CTO, 2016).
Table 1: Four categories of water pipes

<table>
<thead>
<tr>
<th>Name</th>
<th>Pipe diameter (mm)</th>
<th>Alternative pipe categorization</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service lines</td>
<td>less 150</td>
<td>Tertiary</td>
<td>Connection to houses</td>
</tr>
<tr>
<td>Laterals</td>
<td>150 to 300</td>
<td>Secondary</td>
<td>Connected to Primary pipes</td>
</tr>
<tr>
<td>Main lines</td>
<td>500 to 700</td>
<td>Primary</td>
<td>3 lines</td>
</tr>
<tr>
<td>Major pipe</td>
<td>800mm</td>
<td></td>
<td>From Gubi Dam to Reservoir at Wurinje</td>
</tr>
</tbody>
</table>

Provided by the CTO and Abdullahi et al (2014)

3. Results and Discussion

This section described the outcomes of the study because of data collected, processed and analysed.

3.1. The Assessment of BSWB Water Utility Map

The original map from BSWB is shown in Figure 2. The wrinkle on the map is an evidence of how long the map has been in use (above 15 years), although the thickness and quality of paper used was of low quality (a thicker paper may not show such wrinkle). There was no pencil or pen mark on the map. Hence, no evidence that there were attempt to update the map even when new connection were made. It also shows no sign of marking of complains. There is slight brown thick strip in the middle, arising from a use of tape to deal with tear of the paper. However, it is generally neat, which is an indication of low usage. Since the map was created at the time of water project in Bauchi, in 2000, it was most likely a design plan, rather a proper map, hence the lack of map property. In that case, it was likely to guide the laying of the pipelines. Thus, the map was a byproduct that became useable.
3.2. Control Survey and Georeferencing

The control survey produced the following coordinates (Table 2). The root mean square error (RMS) after the georeferencing the scanned image was 0.136m. A visual observation of the 10 points, shows all are located at their position on Pleiades image.

Table 2: The control points used for georeferencing

<table>
<thead>
<tr>
<th>Control Point No</th>
<th>Easting (m)</th>
<th>Northing (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>592124.714</td>
<td>113837.111</td>
<td>Awalah roundabout</td>
</tr>
<tr>
<td>2</td>
<td>587423.129</td>
<td>1136609.199</td>
<td>A.T.B.U Junction</td>
</tr>
<tr>
<td>3</td>
<td>596834.525</td>
<td>1139847.296</td>
<td>Inkil rail-road links</td>
</tr>
<tr>
<td>4</td>
<td>587221.555</td>
<td>1140265.716</td>
<td>Zaranda Junction</td>
</tr>
<tr>
<td>5</td>
<td>592665.429</td>
<td>1140368.022</td>
<td>Central roundabout</td>
</tr>
<tr>
<td>6</td>
<td>592736.109</td>
<td>1137979.111</td>
<td>Railway roundabout</td>
</tr>
<tr>
<td>7</td>
<td>590059.199</td>
<td>1141053.403</td>
<td>Eagle roundabout</td>
</tr>
<tr>
<td>8</td>
<td>590154.039</td>
<td>1137620.252</td>
<td>Wikki oil Junction</td>
</tr>
<tr>
<td>9</td>
<td>594090.211</td>
<td>1144195.465</td>
<td>Gida dubu Junction</td>
</tr>
<tr>
<td>10</td>
<td>594821.395</td>
<td>1140175.865</td>
<td>H/Assembly Junction</td>
</tr>
</tbody>
</table>
3.3. Interviews with Management and Technical Staff of BSWB

3.3.1 Management staff

There are seven (7) management staff in BSWB of which all are males, these included the managing Director/General Manager (MD/GM) and his four assistants (AGMs) heading other departments, the remaining two are billing and area manager.

All of the above management staff responded that there was a proposal for updating the existing water distribution map, and they presently operate in analogue system of mapping. Five out of seven responded that the state GIS (BAGIS) could help in the development of Bauchi water information system (BAWIS). The General Manager (GM) and four others expressed that they never used high-resolution satellite imagery for mapping, and all of them agreed that the board does not have any modern tool of assessing the spatial accessibility of the utilities to the consumers. All the seven management staff agreed that the house I.D number had been allocated in the newly built settlements and the implementation of Geospatial water information system would improve the state revenue generation.

3.3.2 Technical staff questionnaire

A total number of thirteen (13) results of the questionnaires were received from the technical staff of BSWB of which all are males. The result shows that majority of the technical staff are male with the qualification of certificates, national Diploma, H.N.D and on salary grade level ranges from level six to fourteen (6-14) these staff expressed the problems such as lack of map updates, in adequate tools and changes in neighborhood. They further indicated that the map does not cover the new settlement. It thus indicates that the water distribution is inadequate to serve the urban population. Ten out of Thirteen responded that they refer to the map in locating the water utilities. Nine have encountered problem in locating the underground utilities more than Four times (four and above) and Four staff expressed that they have encountered two to three (2 – 3) times problem in locating the underground water utilities. Six out of thirteen associated the problem in locating the network of underground water utility is to the lack of updated map and four out of thirteen related it with inadequate tools and three to changes in neighborhood. All the responses agreed that the current map does not cover the urban settlement and the water distribution is inadequate to serve the population. Five out of Thirteen responded that (yes) they refer to the map when there is complain, and such map defined the location to meet the complainant.

3.4. Transformation of the Existing Water Distribution Map

The process of digitization produced a map (Figure 3), which is a composition of the pipelines, nodes, valves, chambers, reservoirs and hydrants. In addition, the reservoirs, the Gubi Dam and major roads. Each of these elements can be separated for analysis. The roundabout and major roads appeared on the map to provide a reference guide for locating some water facilities beside the road. Gubi dam is a source which supply water through the connection of 800mm diameter pipeline from the treatment plant to the reservoirs at Warinji hill and distributed to the town through the network of pipelines of different diameter as shown in the Figure2 below. In the figure below shows the location of water facilities such as valve (V), hydrants (H), Chambers (C) and pipelines (P). Each facility was allocated a unique identifier (ID) and labeled with successive identification numbers after the first alphabets (i.e. $V_n$, $H_n$, $C_n$ and $P_n$), these number were labeled on the maps for easy recognition of these facilities on earth surface.
3.5. Discussion

The management staff formulates policy and run the agency. It was good that they understand the need to upgrade the existing map (as discussed in 3.1). However, it is doubtful if they can demand for an adequate map. Since they are unaware of contemporary GIS tools. This may lead to the repeat of what happened when the agency received the current map. That means the management could ask for GIS facility from a contractor, but without a proper knowledge; they are likely to receive something inadequate. The quality of the current staff is inadequate with regard to digital mapping process. It is a matter of not knowing the GIS. However, their qualification indicates that it will be easy to train them, since there are HND holders and degree holders. The existence of Bauchi State Geographic Information System (BAGIS) shows the availability of resources, which BSWB could collaborate to meet its mapping required. This reinforces the point on lack knowledge of GIS among the Management Staff.

The technical staff has shown low usage of map. It could have risen from the poor nature of the map. This means that the map is inadequate and not helpful. Although the agency did not sponsor this research, however, it has shown great interest and cooperation at all levels.

4. Conclusion

The assessment of the current map shows that it does not qualify to be a map because it lacks properties of a map. The agency lacks knowledge of contemporary properties of a map and its production and its usage. This lack of knowledge of GIS and its use by technical staff and the inadequacy of the current map are part of the low usage of map. This work shows that
fundamental resources for map transformation and production are available to the agency. Since this research has demonstrated how it could be done. This work also has shown how collaboration with other government agency is needed and possible. The process of this research serves as a means of educating the agency on the need for a contemporary digital map. It also an example for other utility agencies in many cities in Nigeria.

The following are recommended: there is need for education of the utility agencies involve in the development of water network or similar utility on the role of contemporary digital maps in policy articulation, maintenance, investigation of system, research and related matters. Secondly, the material of this research can be adopted by BSWB as base material for its used. And finally, formal training in our universities for those intending to work in utility agencies should include GIS training with case studies such as this.

References


