Geomatics Support View in Unlocking the Potentials for Multiple Unlocking of Dams and Reservoirs in Nigeria

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Key words: Hydrological Zone, GNSS Surveys, TIN Model, Planimetric Traverse, Geospatial Data

SUMMARY

The federal government of Nigeria in March 2015 initiated plans to convert all the dams and reservoirs in Nigeria to multipurpose use. This will enable all the dams/reservoirs to be used for hydropower, irrigation, water supply, flood control, sanitation, recreation, etc. Unfortunately most of the River Basins in Nigeria currently, are poorly gauged and there is also not adequate geospatial data for planning and development. In Nigeria there is increase need for portable water supply for drinking, household and commercial uses. Water demand for agriculture is on the increase as the irrigation of land take up large volume of water from the reservoir which is meant for hydropower generation. There is increasing concern on the demand side as essential food commodities are disappearing from the market and prices of available commodities are now outside the reach of the average Nigerian. Much of our power energy supply is now expected to come from hydro-power due to militants blowing up gas pipelines in the Niger delta region. In order to derive the needed energy supply, more multipurpose dams need to be either constructed or existing once converted for multipurpose usage. As water becomes scarce as a result of the multiple usages, there will arise competition between clean water supply, energy, and agriculture. There is therefore the need to develop cross sectorial research, and creation of adequate geospatial database to ensure that the decision to be taken on water use does not adversely impact on other sectors as well as the environment. Frequency of extreme weather events, the incidence of flooding and flood disaster on River Basins, urban area and coastal environment will be on the increase. The interconnectivity between water, food, and energy and climate make it imperative that adequate geospatial data be generated in order to effectively unlock the potentials for multiple utilizations of dams and reservoirs in Nigeria.

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1. INTRODUCTION

Nigeria currently with a population of about 170 million people require a large volume of portable water for drinking and energy particularly for electricity and enough food to feed such a large population.

In the country, the demand for water, food and energy will continue to rise as a result of increase in population growth. With the rapid decline in revenue from crude oil (almost the sole export commodity) and mismanagement of the economy over the last few years, coupled with continuous bombing and destruction of crude oil and gas facilities, Nigeria have slided into recession.

The rapid drop in the prices of crude oil, the lack of coordinated National policy on agriculture and the summersault from a rebranded largest economy in Africa to a recessed economy is bringing back fears about food security.

There are increasing concerns on the demand side as essential food commodities are disappearing from the market and prices of available commodities are now outside the reach of the average Nigerian. Today, much of the energy supply in the country is expected to come from Hydropower as a result of the current unstable gas supply due to militancy in the Niger Delta Region.

In order to derive the needed energy supply, many more multi-purpose Dams need to be developed not only for water supply but Hydropower generation as well as for irrigation and fishery. In this complex system, reservoirs are expected to be used for irrigation, by use of pumps and irrigation ditches, provide portable water supply to communities and Power turbine for energy generation. As water becomes scares as a result of the multiple usages there is competition between energy, agriculture and domestic water availability (Ehiorobo and Izinyon 2016).

There is therefore the need to develop effective cross-sectorial mechanism to address the problem and ensure that decisions taken on water release and water use are coordinated in such a way as to provide an integrated multi sectorial strategy. Geomatics data and tools are key ingredients within cross sectorial outcome and acts as a key support mechanism for the development of an integrated multi-sectorial strategy for effective water use.

1.1 Dams in Nigeria

A compendium of Nigerian Dams compiled by the Department of Dams and Reservoir Operation put the number of Dams in Nigeria at 198 (Federal Ministry of Agriculture and Water Resources 2007).

Table 1: Classification of Dams in Nigeria Based on I Cold Classification

Dam	Dam Height in	Reservoir	Flood discharge in	Crest length

size	meters	Capacity in million cubic meter	cubic meters per second	in meters
Large	>15	>1	>2000	>700
Small	<15	<1	<2000	<500

Nigeria is divided into 8 hydrological zones. The number of large and small Dams in each hydrological zones are shown in Table 2.

Table 2: Distribution of Dams per hydrological zones

S/NO	HYDROLOGICAL ZONE	NO OF LARGE DAMS	NO OF SMALL DAMS	TOTAL NO	REMARKS
1	1	8	15	23	
2	2	26	14	40	
3	3	3	4	7	
4	4	12	21	33	
5	5	1	6	7	
6	6	13	35	48	
7	7	2	9	11	
8	8	13	16	29	
	TOTAL	**78**	**120**	**198**	

From the table it can be seen that zones 3 and 5 have the least number of dams while zones 2 and 6 have the highest number of dams. The limited number of dams in hydrological zones 3 and 5 is mainly due to the nearness of the area to sea level as well as the topographical and geological characteristics of the region (Ehiorobo, 2016).

1.2 Problems of Data Availability for Design and Conversion of Dams and Reservoirs to Multipurpose Use and Development of Water Atlas

River flow records are vital assets critical for the sustainable management of water resources. They serve as both indicators of past hydrological variability and fundamental contributors to hydrological models for future behavior prediction. The completeness of such record is critical for their effective utilization.

Even very short gaps precludes the calculations of important summary statistics, such as monthly runoff, totals or n-day minimum flows and inhibits the analysis and interpretation of flow variability (Mash, 2002).

The establishment of twelve River basins in Nigeria was to harness the nation's water resources and optimize its agricultural resources for food sufficiency. This development raised hope among the various stakeholders that the RBA would apart from agricultural needs provide other basic needs such as Hydrological data collection and management associated with water resources.

Over the years however, the River Basins and other rivers in Nigeria have been poorly gauged (World Bank Report, 2003) and poorly mapped. Discharge measurements were neglected and poorly carried out. Data were poorly managed and stored.

It is therefore necessary to carryout detailed mapping and hydrological data collection for effective management of the River basins and the infillings of the missing discharge data in many of the rivers to enhance their effective use in the development of dams and reservoirs for multipurpose use.

1.3 Environmental Consideration in the Use of Dams for Water Resources, Energy and Food

Dams fundamentally alter river courses. Construction of dams particularly large dams involve tradeoff between economic, social and environmental benefits and costs. With respect to environmental issues local conditions and the size and type of dam all influence the environmental impact and with respect to hydropower projects, is project size related. It has been suggested that while reservoir have few negative effects on human water supply, they have a substantial impact on aquatic biodiversity and ecosystems. Such impacts can occur both upstream and downstream of the dam and in reservoirs.

Essentially impact occur consequent upon inundation storage, changes to flow and the flow regime, water quality impact, and changes to the morphology of the river system. Other environmental consideration may be those attributable to climate change.

World economic forum 2011, argues that in the backdrop of climate change and climate variability's, how should our water best be stored and which storage should be used to minimize risk due to long term climate variability and change?

Such storage guarantees reliability of water supply which in turn means food security, electricity generation and industrial growth. Climate change also has an implication for existing dam infrastructure i.e. dams designed in the past without accounting for the increasing variability of climate change are now at risk (i.e. 100 year flood may be more severe meaning that the infrastructure is under designed). Studies carried out by various researchers does suggest that climate change will increase the intensity of extreme weather events (Ehiorobo et al 2012, 2013) and has the potential to cause mass migration, create food and water insecurity and cause several other environmental and social impacts (Voigt 2009, Khagram et al 2003, Allonche et al 2014).

2. GEOMATICS SUPPORT IN EFFECTIVE UTILIZATION OF DAMS AND RESERVOIRS

In order to unlock the potentials for multiple utilisation of dams and reservoirs in Nigeria, there is the need to ensure mapping of river basins at appropriate scales, continuous monitoring and evaluation of the Dam and Reservoir in the following area.

– Provision of sufficient portable and qualitative water from Reservoir

- Groundwater recharge from Reservoir
- Effectiveness of Dams and Reservoir utilization for hydropower development
- Study of siltation in Reservoirs
- Effective utilization of Dams in flood control and regulation of river flow
- Monitoring for structural integrity in Dams

To meet the demands for the desired quantity and quality of water at particular locations and times, Engineers, Hydrogeologists, Geomatics Engineer/Surveyors, planners and other professionals have to be involved in designing, constructing, removing and operating structural and implementing non-structural measures that will permit improved management of the natural water supplies. Water resources planning must take into account multiple users, multiple purposes and multiple objectives. For water development, we need to study river basins, lakes, estuaries and other water resource systems taking cognizance of their sensitive nature and adaptability to exogenous forces.

The task of the Geomatics Engineer or Surveyor in the above projects is a servicing one. The task consists primarily of providing the necessary basic information for the planning, development, management and maintenance of the above schemes. It is his duty to organize all the necessary surveys required, utilizing appropriate instrumentation and techniques that will give optimum results. He must apply a system of weight to each survey and should have a thorough insight into the correlation between the various types of surveys required to acquire the necessary information. His task in this scheme varies from the establishment of Geodetic controls, to mapping of the various constituents involved in the water development. The accuracies obtainable in each phase of his work will depend on a properly designed and planned project. For instance, the Head in a hydroelectric project is essentially a matter of potential (work) and the gradient of a canal is required with reference to level surfaces. For irrigation in flat ground, heights may be required with an accuracy of $\sqrt{s}$ cm over a distance of s Km.

For such purposes, Geodetic instruments and methods are required. However, for the determination of the longitudinal section of a stream, reservoir area mapping, less precise instruments and methods may be used. In order to effectively provide the necessary Geodetic information for the above projects, it is necessary to establish a system of both planimetric and vertical controls. With an appropriate control network in place, we can carry out the following tasks.

a) Determination of the longitudinal section of a stream
b) Determination of water level from time to time
c) Acquisition of Geodetic information in reservoir area and mapping of reservoir area
d) Setting out of dams, spillways and other elements of the project
e) Monitoring of dams deformation and subsidence
f) Preparation of as-built drawings from TLS surveys for conversion of existing water dams to multiple uses.

3. GEOMATICS SUPPORT FOR MULTIPLE UTILIZATION OF DAMS AND RESERVOIRS

3.1 Control Surveys for Water Development Schemes

Usually, planimetric and vertical controls are established along the river banks especially in the area where a dam is to be constructed and covering the area to be encompassed by the reservoir. In the past, planimetric controls were established using a combination of triangulation and trilateration or traverses while for vertical controls, 1st or 2nd order level networks were used. Control points, since they are going to be used for setting out dams and reservoirs, should be closed to the boundary of the dam and reservoir, but should be above normal flood level. A type of control established around Ikpoba Dam and reservoir in Benin City, Nigeria is presented in Figure 1.

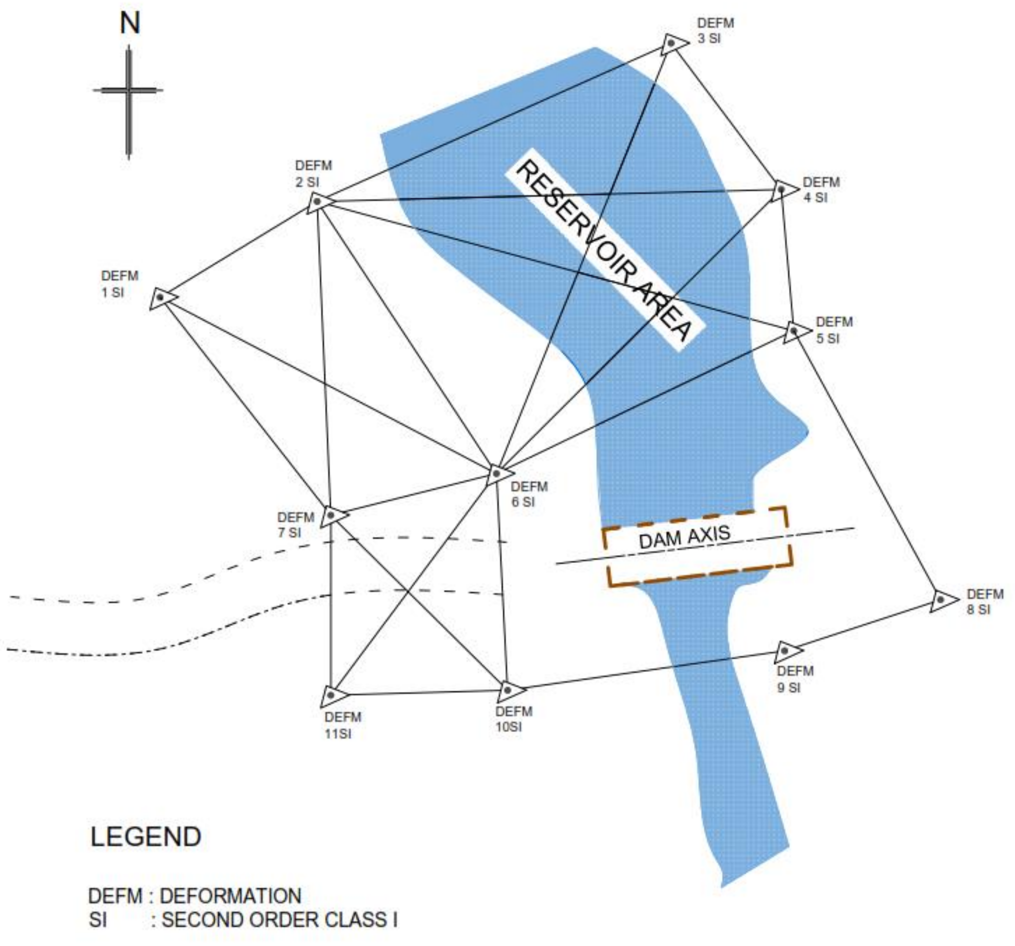

FIG 1 GENERAL LAYOUT PLAN OF CONTROL MONUMENTS FOR DEFORMATION STUDIES AT THE IKPOBA RIVER DAM

In designing the above network, a good apriori estimate of the accuracy standard instrument requirements and methodology for field measurement was carried out. The method employed in this case as reported in (Ehiorobo 2000, 2004) was to estimate various network designs using apriori estimate for the standard deviation of the proposed measurement. This was done at that time on the basis of classical geodetic survey method. The network has been reobserved by Differential GNSS observation method. The data collection of the GNSS campaign required the use of LEICA 500 dual frequency GNSS receivers to coordinate the eleven control points by static Differential GNSS technique. The reference and control points were occupied simultaneously while the dual frequency receivers and observations were carried out for not less than 1 hour and with a sampling rate of 15 seconds in each case. GDOP was set below 5.0 in each case and the window for the vertical angles of the satellite observations was limited to 15°.

The data processing procedure included

- Model validation
- Ambiguity resolution which was carried out using FARA statistics
- Coordinate computation with the variance-covariance matrix

The software used for computation and adjustment SKI PRO with MOVE 3 reads the navigation file and then the observation file epoch by epoch. The baseline adjustment and the quality control are cycled through event epoch. The data processing procedure include estimation and quality control (Ehiorobo 2009). The estimation output consisted of 3-D coordinates of the rover position for the eleven control points while the quality control component consisted of the variance – covariance matrix which gave the quality of the coordinate estimator.

3.2 Geodetic Information Required for Reservoir Development

The primary purpose of a reservoir is to provide a means of regulating surface water flows. The capacity of a reservoir together with its operating policy determines the extent to which stream flows can be stored for later use. In order to fully develop a reservoir for optimum utilization, the following problems should be solved by generation of adequate data and plans.

Some of the area requiring Geomatics support include the following:

1. The establishment of the contour line defining the catchment area of the reservoir based on the level normal hydrostatic head, and setting out the contour line on the ground.
2. Determination of area under flooding and the capacity of the reservoir
3. Establishment of boundaries of area likely to be overflooded and their effects on settlement and utility lines and preparation of master plans for flooding for settlements in mitigating flood plains.
4. Preliminary surveys for the design of engineering defense walls against over flooding of residential areas, industrial sites, etc.
5. Preliminary and final surveys for the design of projects for the development of fishing industries within the reservoir areas.

In order to effectively solve the above problems, topographical maps produced by a combination of ground surveys and satellite remote sensing are used.

In the mapping of the Ikpoba dam reservoir area, analysis was carried out using data from GNSS surveys in combination with SPOT imageries. In the mapping of the reservoir area, the GNSS control coordinates were used as ground controls for imageries interpretation and analysis.

The XYZ coordinates were stored in Microsoft Excel file format and imported into ArcGIS environment using the XY menu. The project coordinates was specified in (Nigeria West Belt) and then exported into personal Geodata base as shape files for the reservoir area. The shape file containing the elevation data was then added and Triangulated Irregular Network (TIN) created using the Z – coordinates. Digital Elevation Model (DEM) was generated by converting the TIN into RASTER. Contour lines were generated by using the created TIN to interpolate for the contour with the aid of 3D Analyst extension. ARC-scene was then used for the visualization of the 3D model generated from the TIN. A topographical map of Ikpoba dam and reservoir area is presented in Fig. 2 below. The TIN model and DEM models are presented in Fig. 3 and Fig. 4 respectively.

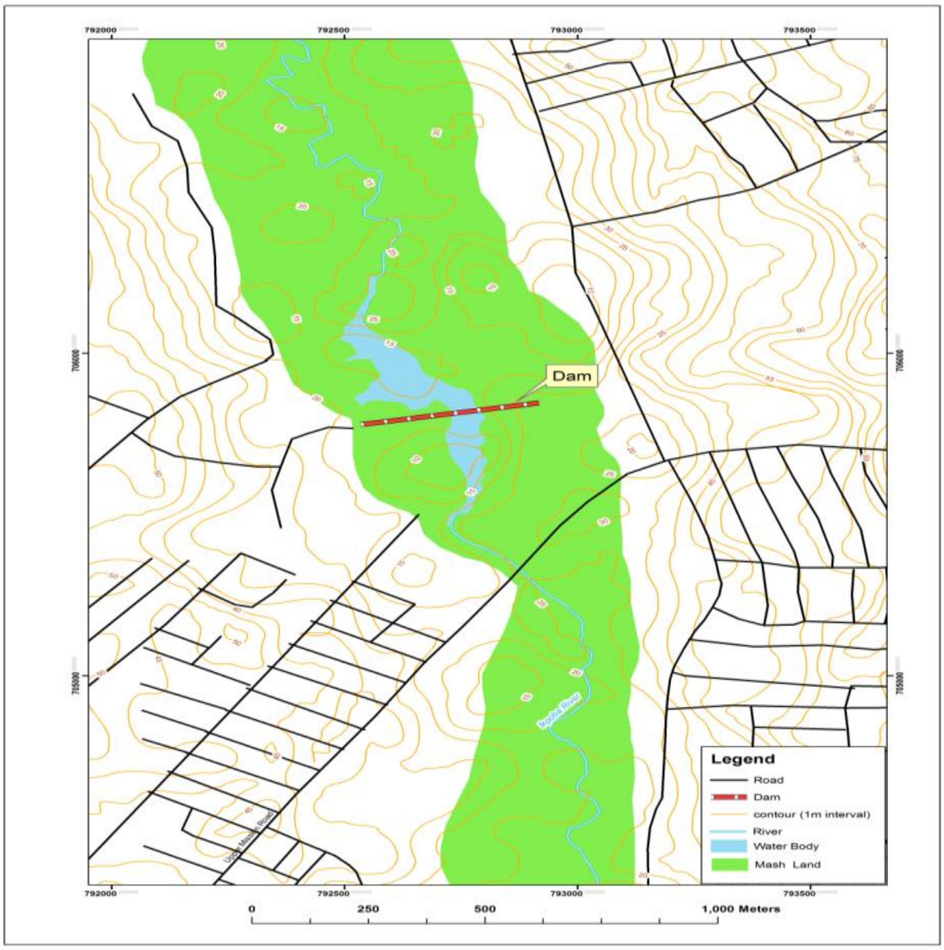

Figure 2: Topographical map of Ikpoba dam and reservoir area

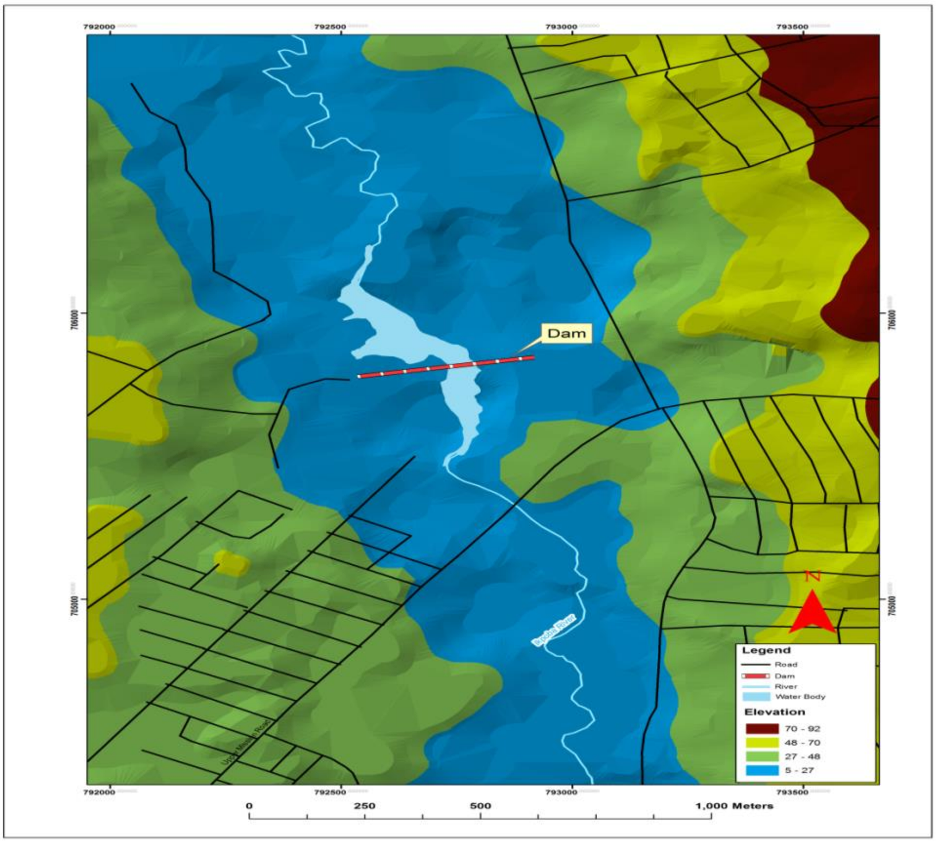

Figure 3: TIN of Ikpoba dam and reservoir area

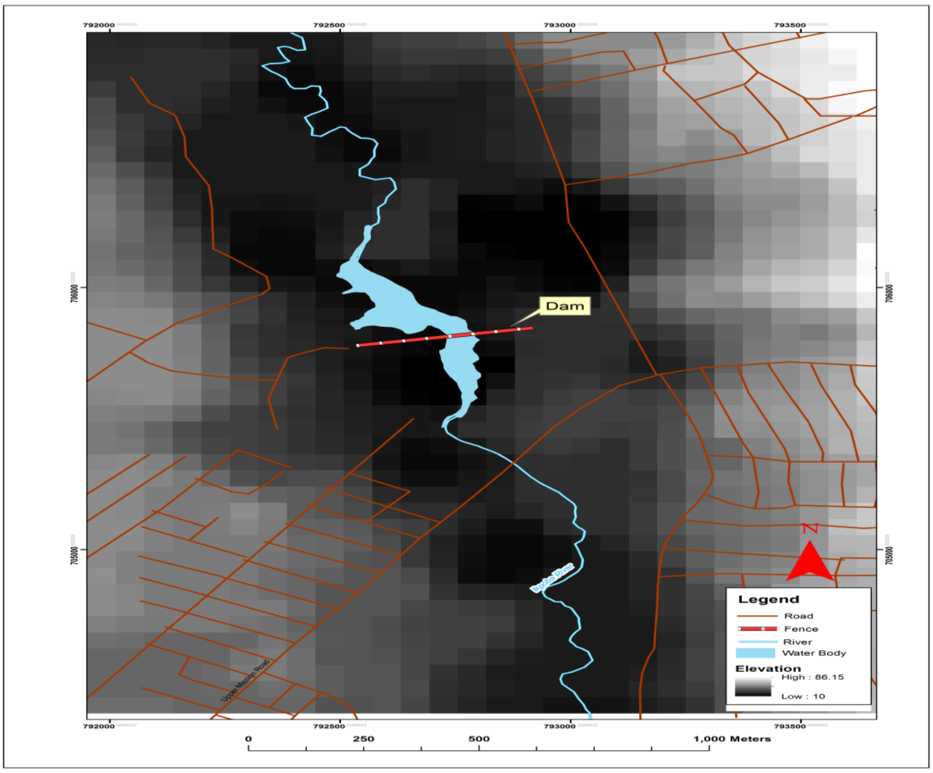

Figure 4: DEM of Ikpoba dam and reservoir area

3.3 Hydro Electric Power Production

The production of hydro-electric energy during any period at any particular reservoir site is dependent on the installed plant capacity and the flow through the turbines. Q, the average productive storage head H, the number of hours in the period t and a constant ɳ for converting the product of flow head; and plant efficiency to kilowatt – hour of electric energy.

Average power output N is given in Henderson (1966) as:

$$N = 9.18\eta\, QH \tag{1}$$

Also, from Levchuk et al (1983)

$$annual\ output\ E_a = \frac{981}{3600}\, W_a\, \eta\, H \tag{2}$$

Where W_a is runoff.

Also, total discharge q is given as;

$$Q = \frac{W_T + V'}{t} \tag{3}$$

where W_T is Transitional runoff and V' is Effective capacity of reservoir

Putting (2) in (3), we have

$$N = 9.81\eta\frac{(W_T+V\prime)H}{t} \tag{4}$$

Now, let us examine the effects of W_T. V' and H on the accuracy of determining power output.

Taking log of both sides of (3) and differentiating, we have;

$$\frac{dN}{N} = \frac{dH}{H} + \frac{dWT}{W_T+V\prime} + \frac{dV\prime}{W_T+V\prime} \tag{5}$$

V' and H are functions of Geomatics measurements hence, Transforming (5) to mean square or standard deviation, we have

$$\left(\frac{MN}{N}\right)^2 = \left(\frac{MH}{H}\right)^2 + \left(\frac{MW_T}{W_T+V\prime}\right)^2 + \left(\frac{MV\prime}{W_T+V\prime}\right)^2 \tag{6}$$

Taking cognizance of kinetic losses in the head, for canals and turbines we can conclude that the values M_H will not be greater than 0.5m and therefore in Dam with height of the head greater than 50m, the effect of

$$\frac{M_H}{H} \tag{7}$$

On the determination of power output will not be greater than 1% but in low Head Dams, the effects can be serious and thus precise levels should be used to determine the height of the Head. The errors due to V' will depend on the scale and accuracy of producing the map of the reservoir, planimetric error in area and final computation of volumes. Hence more accurate methods should be used in the computations of the capacity of the reservoir. The error in W_T arises from hydrological data.

3.4 Determination of the Longitudinal Section of a Stream

The longitudinal profile of a stream consists of a vertical section of the stream by a line of dynamic flow. This profile form the basis for the working document in the design of hydroelectric stations, regulation of rivers for the improvement of navigation, development of irrigation projects, timber rafting, etc.

In order to effectively carry out the task of producing the longitudinal profile of a stream, it is first necessary to run a high order level line along one of the river banks (for small streams) and along both banks for larger rivers. Therefore, from these higher order stations we can establish lower order points close to the stream. These are in turn used as controls for taking water levels in the stream.

3.5 Geodetic Information in the Determination of Water Levels in Streams

Water level measurement posts are usually fixed at some defined points along the stream. The length of sections between gauge stations will depend mainly on the intensity of changes in water level. Levels are run from known points to the gauge stations in order to reduce the water height and the shore control stations to a common datum.

3.6 Acquisition of Geodetic Information in an Irrigation District

In an irrigation district containing various soil types, if there is a variety of crops that can be grown in the districts, it is necessary to decide which crops should be grown in which zone. In order to estimate how much of resources input should be allocated to each crop that should be planted and where each crop should be planted, it is necessary to divide the whole irrigation districts into blocks. The first step is to run a third order planimetric traverse control around the boundaries of the irrigation district. Thereafter, subsidiary traverses are run to divide the district into blocks in accordance with soil types. Such traverses should normally be tied to the national Geodetic framework of higher order accuracy. Grid leveling of the area is thereafter carried out for effective planning and flood and erosion control.

4. CONCLUSION

In acquiring Geospatial information for irrigation and water development schemes, it is necessary that adequate pre-observation analysis be carried out in order to effectively design the measurement system required in the design, construction and management of all water schemes whether for water supply, power generation or irrigation projects or other combination. Such a measurement system involves a combination of survey designs, instrumentation, calibration procedures, observational techniques and data reduction methods. Most of the survey work revolves around the determination of stream slope and profiles and reservoir development.

Geospatial Information is of vital importance in all processes connected with irrigation and water resources development schemes hence great attention should be paid by the design and construction authorities to the caliber of professionals providing such information.

The demand for water, food and energy is increasing not only in Nigeria and Africa as a whole but in the world at large. In order to cope with the challenges posed by this demand, it is necessary to understand the interconnectivity between the demand and the supply for the three i.e. water, food and energy.

Scarcity of water resources as a result of water use from reservoir for irrigation requires continuous studies and monitoring. There is the need for cross sectorial collaboration between various stakeholders including Government agencies, NGOs, Academic and research institutions, policy makers and the end users.

As water becomes scarce as a result of the multiple usages, there will arise competition between clean water supply, energy and agriculture. There is therefore the need to develop cross sectorial research that will address the problem and ensure that decision taken in one sector does not adversely impact on the other sectors as well as on the environment.

We hope with proper collaboration and research in the above thematic areas and provision of adequate geospatial data we will be able to unlock the potentials for multiple utilizations of dams and reservoirs for water supply, Irrigation, flood control, energy (Hydropower generation) tourism, mine tailing, etc.

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