Analysis of the hydrological processes of a semi-arid region lake, the case of Lake Ngami, Botswana

Prepared for the Botswana Symposium on Wetlands and Wildlife 2015, Maun Lodge, Maun, Botswana, 17 – 19 March 2015.

Edwin Mosimanyana[1], Chandrasekar N. Kurugundla[2], Michael Murray-Hudson[1]
[1]Okavango Research Institute, University of Botswana.
[2]Department of Water Affairs, Maun, Botswana.
emosimanyana@ori.ub.bw

Background

- Accurate information on the condition and trends of a country's water resources – quantity and quality – is required as a basis for both economic and social development, and for maintenance of environmental quality (WMO/UNESCO, 1990).
- Quantitative assessment of water resources is underpinned by the water balance concept, which is fundamental to the study of hydrological processes.
- Water balance analysis provides a foundation for effective water-resource and environmental planning and management (Healey et al., 2007).
- It aims at quantifying the hydrological fluxes into and out of a defined hydrological system, together with the related changes in storage
- In general, the water balance of a given system can be summarized as,

$$\frac{\Delta V}{\Delta t} = P + I_S + I_G - E_O - O_S - O_G$$

- $\Delta V/\Delta t$ is change in storage with time, P is precipitation, I_s and I_G are surface and groundwater inflow respectively, E_O is evapotranspiration, O_S and O_G are surface and groundwater outflows respectively.
- Change in water levels can be used as a proxy for change in volume.
- Lake Ngami, located at the southwest corner of the Okavango swamp in north-western Botswana, is characterized by episodes of being inundated and subsequently being desiccated.
- This, together with its remote location, has rendered hydrological and meteorological monitoring around the lake almost non-existent

Objectives

- The main objective of this study is to assess the hydrological fluxes of Lake Ngami on a monthly and annual time scales using the water balance concept.

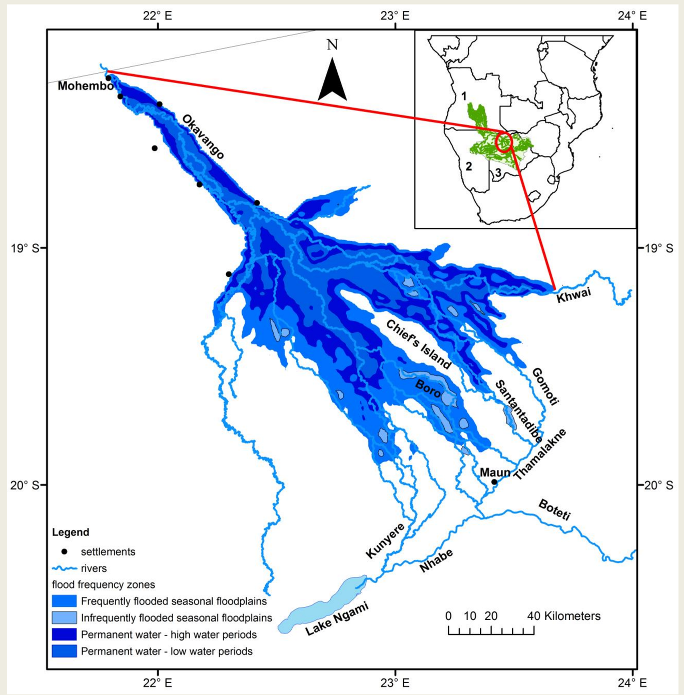
Methods

Study area

- Lake Ngami, is an endorheic, shallow depression lake at the distal end of the Okavango Delta in the Okavango Delta Ramsar Site in northwest Botswana
- The limits of the lake are marked by a series of concentric ridges raised about 2 – 3 metres above the surrounding flat land (Akanyang, 1997)
- Main flux into the lake are the Kunyere and Nhabe Rivers, which join to form Mogapelwa river just upstream of the inlet into the lake at Toteng. The two rivers are some of the rivers that drain the Okavango Delta, which gets most of its water from the Angolan highlands.
- Direct precipitation on the lake surface is another source of input into the lake.
- Main flux out of the lake is direct evaporation and seepage to groundwater
- High porosity of Kalahari sands in the basin, and near flat topography, precludes surface inflow into the lake.
- The lake has been declared an Important Bird Area by Birdlife Botswana
- Characterized by alternating episodes of filling up and desiccation, latest dry period lasted between 1989 and 2004.
- Lake size expands with the incoming flood pulse from the Okavango Delta, reaching its maximum extent around July/August, which is the dry season in Botswana, and contracting thereafter.

Data Analysis

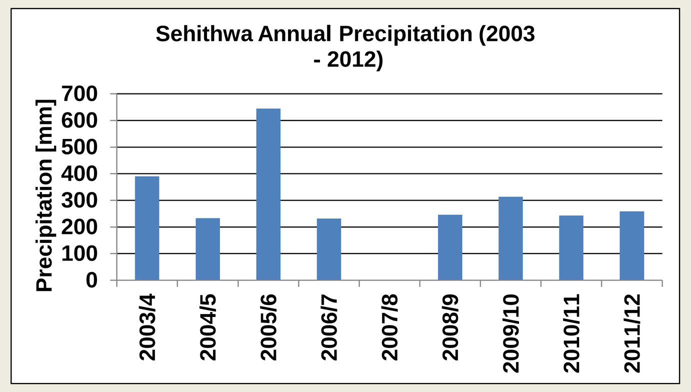
- Existing hydrological and meteorological time series data were used to quantify inflows into and outflows from the lake
- Meteorological data on minimum and maximum temperature, sunshine duration and

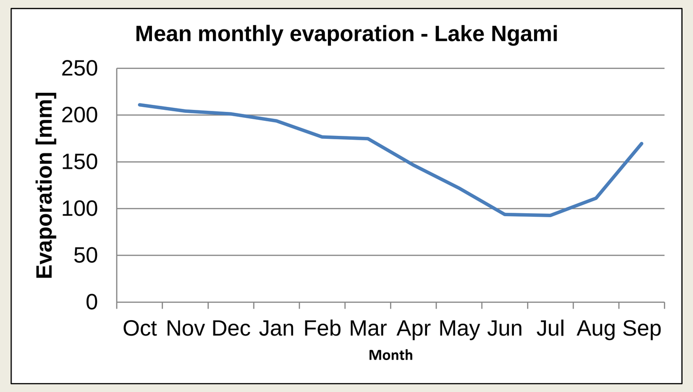


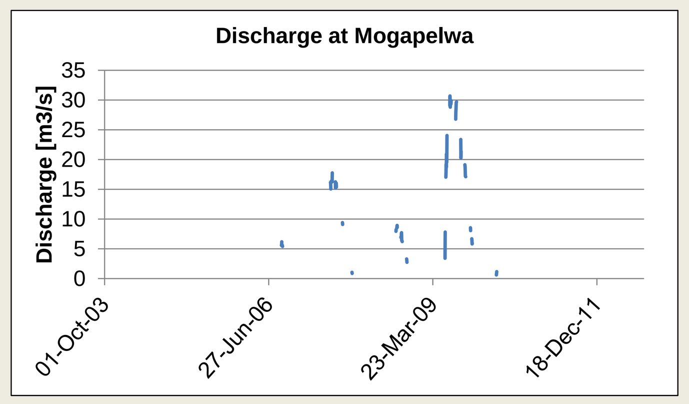
- relative humidity obtained from Department of Meteorological Services' (DMS) Maun meteorological station, approximately 100 km northeast of Sehithwa
- Precipitation data, measured by the Botswana Police Service in Sehithwa, obtained through DMS
- Discharge data at Mogapelwa obtained from Department of Water Affairs, but too scanty
- Lake direct evaporation from the lake estimated using the Hargreaves-Samani reference evapotranspiration method
- $$ET_o = 0.0135\, K_T\, (\bar{T} + 17.78)\, (T_{max} - T_{min})^{0.5}\, R_a$$
- Where ET_o is reference evapotranspiration (mm day^{-1}), K_T is an empirical constant set at 0.162 for interior regions, $\bar{T}$ is mean temperature (°C), T_{max} and T_{min} are maximum and minimum daily temperature (°C) respectively and R_a is the extra-terrestrial radiation (mm day^{-1}).
- Calculated ET_o was multiplied with a coefficient for open water, K_w to estimate evaporation,

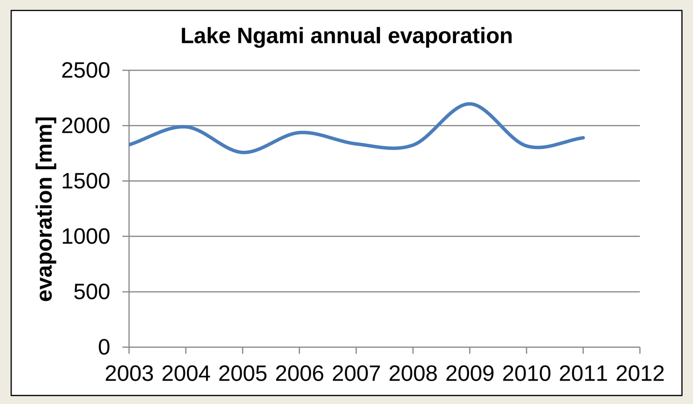
$$E = K_w\, ET_o$$

K_w was set at 1.05 as per Allen et al. (1998).









- Total surface area of the lake was estimated from a 2012 bathymetric survey.
- **Average depth was estimated to be 3.99 m, while surface area was 287 km^2, giving an average storage of 1.14 km^3 at the time.**

Discussion

- Data limitations restricted the depth of analysis that could be carried out.
- The data used in the analysis shows that annually, direct precipitation on the lake is highly variable over the analysis period.
- However, this is a reflection of general precipitation patterns in the semi-arid regions.
- As was to be expected, the monthly evaporation rates mirrors the net radiation balance, highest during the summer period (October to March) and going down during the winter and summer transition period (April to August).
- It is notable that the period of lowest evaporation rates coincides with the largest areal extent of the lake, which is also the dry period in Botswana. Any management interventions put in place on Lake Ngami must factor in this.
- At the annual time scale, evaporation rates vary within a narrow range. The possible implication of this is that were the inflows into the lake to somehow diminish, evaporative losses will accelerate the desiccation of the lake, which has happened in the past.

Recommendations

- Monitoring, both hydrological and meteorological, around the lake must be enhanced.
- Ideally a weather station in the lake or on the shore of the lake must be installed
- Frequency of discharge measurements at Mogapelwa must be increased considerably, particularly during periods of high inflows. This will also enable estimation of residence time of water in the lake.
- Continuous water level monitoring in the lake must be implemented
- Groundwater level monitoring around the lake to enable surface water groundwater interaction assessment must also be implemented.

Acknowledgements

The Office of Research and Development, University of Botswana, provided funding for this study. Departments of Meteorological Services and Water Affairs, Botswana, provided meteorological and hydrological data respectively.

References

i) Akanyang, P. (1997). The geology of Lake Ngami area: An explanation of Quarter Degree Sheet 2022B. Lobatse, Botswana: Geological Survey Department, Ministry of Mineral Resources and Water Affairs.
ii) Allen, R. G., Pereira L. S., Raes, D., Smith, M. (1998) Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56, FAO, Rome.
iii) Healy, R. W., Winter, T. C., LaBaugh, J. W. and Franke, O. L. (2007). Water budgets: Foundations for effective water-resources and environmental management: . U.S. Geological Survey Circular 1308. 90
iv) WMO / UNESCO (1990) Report on water resources assessment. Oxford, UK