

## Chapter 4.13

# Flow-Based Structural Modelling and Dynamic Simulation of Lake Water Levels

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### ABSTRACT

The continuing decline in lake water levels is both a concern and daunting challenge to scientists and policymakers in this era, demanding a rethinking of technological and policy interventions in the context of broader political and socio-economic realities. It is self-evident that diverse factors interact in space and time in complex dynamics to cause these water-level changes. However, the major question demanding sound answers is how these factors interact and by what magnitude they affect lake water balance with time. This chapter uses Lake Victoria's hydrological system to shed light on the extensive and flexible

modelling and simulation capabilities availed by modern computer models to understand the bigger picture of water balance dynamics. The study used the 1950-2000 hydrological data and riparian population growth to develop a dynamic simulation model for the lake's water level. The intuitive structure of the model provided clear insights into the combined influence of the main drivers of the lake's water balance. The falling lake water levels appeared to be mainly due to dam outflows at the outlet and reduced rainfall over the lake. The ensuing conclusions stressed the need for checks against over-release of lake water for hydropower production and measures for sustainable land and water management in the entire basin.

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## INTRODUCTION

Lakes are important reservoirs of large quantities of water and other resources of priceless value to society. Computer models have been crucial in understanding dynamic processes and their combined influence on large water bodies. Computer-based modelling and simulation under various assumed scenarios have been useful in the wider decision-making process for water resource management. To be useful for decision-making in this era, these models must have the expanded capability of accommodating multidisciplinary and multi-stakeholder inputs. Strategic policy and technical decisions can be better informed using simulations based on accurate data and sound mathematical relationships.

There is a need to understand and simulate the multiple scenarios that affect the water balance of large water bodies such as lakes, especially for strategic management and policy interventions. This becomes even more critical at this time when lake water levels are seriously affected by environmentally degrading human activities in their basins and global climate change. By providing the flexibility needed to construct and improve model structures as new knowledge becomes available in an interdisciplinary and multi-stakeholder setting, structural models can greatly add value to lake management decisions. The necessity to expand the hydroinformatics agenda by ensuring a more participatory process calls for a tool that can facilitate the exploration of the combined impact of the diverse factors and views influencing water management decisions in a transparent and versatile manner. The motivation of the moment is to transcend the usual *black-box* limitations of statistical analysis by using conceptual models to shed more light on the dynamic structural connections between the main system drivers within a given systems boundary.

This chapter uses a case study of Lake Victoria to demonstrate how a structural modelling approach with system diagrams showing dynamic

interrelationships can improve the understanding and simulation of changes in lake water levels. The inflow and outflow processes, population growth, and accompanying state variables were modelled using STELLA, a dynamic modelling and simulation software system that has found many favourable applications to studies of complex dynamic systems. A brief background to the study highlights the main features of the study area and a review of the relevant literature. The methodology used to construct a conceptual model for the lake's hydrological subsystem is described and the results got by simulating various assumed scenarios of water withdrawal and climatic variables are discussed. The chapter concludes with recommendations for improving the modelling approach to better support interdisciplinary research and holistic studies of the complex environmental problems facing lakes.

## BACKGROUND TO THE STUDY

By surface area, Lake Victoria is the largest tropical lake and the world's second largest freshwater lake. It supports a dense riparian population exceeding 30 million and growing at an annual rate averaging 3%. The Lake Victoria basin has the highest population density increase of the world's rural areas (GNF, 2005). It is evident that there is increasing pressure on the lake to meet the demands of the fast-growing population, economy, and ecosystem services. Like many lakes in the region, Lake Victoria is affected by problems of loss of species biodiversity, invasive species, eutrophication, and a water-level decline reported to be beyond two metres over the last decade. Destructive human activities aggravate this degradation (LVEMP, 2005).

The falling water level of Lake Victoria is outstanding among its many problems known in the public domain. Even the eleventh World Lakes Conference convened in Nairobi in October 2005 reached an international consensus that an

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