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# Multilayered aquifer modeling in the coastal sedimentary basin of Togo

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ABSTRACT

This work is a follow up to the hydrogeological synthesis done in 2012 on the coastal sedimentary basin of Togo. That synthesis notably emphasized the lack of piezometric monitoring in the last thirty years. This has kept us from learning about the dynamics and evolution of the resource in the context of rapidly increasing demand. We are therefore presenting a model for understanding flows, and its main objectives are to provide an initial management tool that should evolve with time as new data (piezometric monitoring, pumping tests, etc.) become available, and to determine what new information can be obtained that will help policy makers to manage the resource better. The results of steady state flow calibration have shown that the aquifer of the Continental Terminal overexploited in the West, can still be exploited in the East of the basin, the Maastrichtian on the whole basin. On the other hand, exploitation of Paleocene aquifers should be done with care.



## 1. Introduction

The exploitation of groundwater in Togo has increased in the last thirty years due to demand increase, and a switch over from exploitation of surface to groundwater. Some of the reasons for this switch, are the temporary nature of surface water flows and the greater protection of groundwater from pollution. The coastal sedimentary basin of Togo, with a total surface area of 3540 km$^2$ (6% of the total area of the country) (Bourgeois, 1981) accommodates more than one-third of the national population (DGSCN, 2011). This part of the country houses most of the economic activity and major industrial installations mainly because of its location on the Atlantic coast. The concentration of population, industry, and other human activities in such a small area, places a huge burden on the water supply system and creates great disequilibrium in supply and demand particularly in the large cities. Given the increasing volumes of groundwater extracted, it is important that this exploitation be done rationally. The sustainability of the resource will depend on how well it is managed. Thus, if the aquifers in this highly populated part of the country are not defined in terms of their hydrochemical and hydrodynamic characteristics, the availability and quality of the groundwater resource will be compromised. This would constitute a great environmental and socio-economic disaster for the country, and the cost of remedial measures will be high. It is therefore necessary to quantify the important water resource parameters and to define a precise framework for rational exploitation by modeling flows as proposed in this paper.

## 2. Study area

The study area forms part of the vast Keta sedimentary basin which stretches along the Atlantic coast from Nigeria in the East to Ghana in the West. In Togo, it is bounded in the North by outcrops of the Crystalline Basement Complex and in the south by the Atlantic Ocean. It widens from the Ghana border in the West, Eastward to the Mono River which marks the border with Benin. The coastal basin forms a group of plateaus which are separated by river valleys located on both sides of a median NNE-SSW trending depression, called the 'Lama depression'. The coastal sedimentary basin is drained mainly by the Zio, the Haho and the Mono Rivers. A lagoonal system stretches along the coast (Fig. 1). The climate of the region is sub-equatorial, with two distinct rainy seasons related to the movement of the Inter-tropical Front. Rainfall in the basin is not uniform, and diminishes appreciably from Northeast (1445 mm in

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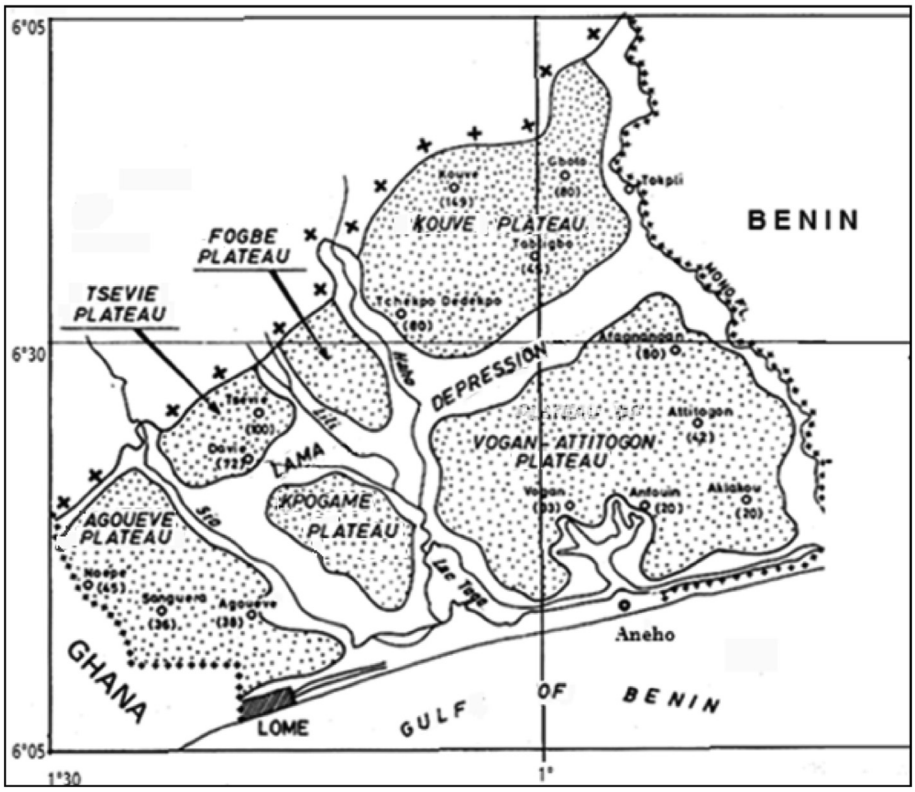


**Fig. 1.** Location of the study area in Togo.

Tabligbo) to Southwest (864 mm in Lome). The average monthly temperature varies between 25 and 29 °C in Lome (Gnazou, 2008).

The geology of the basin (Fig. 2) was established from numerous groundwater and petroleum boreholes and surface mining activities (Sylvain et al., 1986). The Post-Paleozoic sedimentary sequence thus identified, starts from the Maastrichtian to the Quaternary (Johnson, 1987; Costa da, 2005). Three aquiferous formations are identified in the coastal basin formations, separated by thick aquicludes (PNUD, 1975). These are the Upper Cretaceous (Maastrichtian), Paleocene and Continental Terminal aquifers.

## 3. Materials and methods

The modeling Software used is MARTHE designed by BRGM for the hydrodynamic and hydrodispersive modeling of underground flows in a porous medium. MARTHE allows to model flow problems encountered in varying contexts, for example, the management of aquiferous resources, and civil engineering, environmental and mine exploitation problems (Thiéry, 1987, 2012, 2014). In the MARTHE software, extractions from an aquifer are assumed to be negative and positive in the case of injections.

### 3.1. Geometry and limits of the model

The geometry of the model is based on previous geologic and hydro geologic studies (PNUD, 1975; Monciardini et al., 1986; Gnazou, 2008). These formed the basis for preparing isohypse maps of the lower or upper confining beds of the major formations. The model was constructed from this information. The reference maps used are those of the lower confining bed of the Continental Terminal and the upper beds of the Paleocene and the Maastrichtian. The locally productive Eocene limestone and marine sand aquifers are not included in the model. The model includes from top to bottom, the following formations or group of formations:

- Sandy-clayey Formations of the Continental Terminal.
- Eocene marls and clays of the Upper Paleocene.
- Middle Paleocene limestone (P2 Series).
- Lower Paleocene marls.
- Maastrichtian sands, sandstones and limestone (M4 and M0 Series).
- The lower confining beds of the model are made of Maastrichtian clays.

The model considers the whole coastal basin of Togo which is bounded by basement outcrops in the North. In the West, it extends into part of Ghana and includes all of the Agoe Plateau which straddles the frontier. The study area is bounded by the first river encountered in the West of the Plateau. In the East, the model is bounded by the Mono River which forms the border with the Republic of Benin (Fig. 3). Due to a lack of data on this sector, we assumed that flows in the deep aquiferous formations (Paleocene and Maastrichtian) straight above the Mono are parallel to the river. The Mono thus constitutes an impermeable limit of the model with leakage in the shallow aquifer of the Continental Terminal. In the absence of more precise data, the topographic data used is that of the Digital Terrain Model of the USGS (Fig. 3). The spatial extension of the different strata is obtained from a BRGM report (1986). The Continental Terminal is not present in the whole basin especially in the area of the Lama depression where the underlying Eocene strata outcrop.

The isohypses of the lower confining beds of the five strata considered in the model are shown in Figs. 4–8.

South-North (Fig. 9) and East-West (Fig. 10) sections have given