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HYDRODYNAMIC FUNCTIONING OF THE LOBO RIVER RESERVOIR, West-Central of Côte d'Ivoire

Built to improve water supply for the populations of the city of Daloa, the Lobo River reservoir is no longer functioning properly due to human activities near its reservoir. This study, based on a 2D hydrodynamic model, carried out with the Mike21 HD software, allowed the reconstruction of the flows in the Lobo River reservoir. The results of the simulation indicate that the hydrodynamic model could reproduce the variation of water levels at the free surface of the reservoir. Also, the results are very sensitive to the boundary conditions of the model but also to the initial conditions. The results of the influence of pumping on the dynamics of water levels in the Lobo River reservoir showed that water levels are not significantly modified by pumping (less than 1.3 mm). Therefore, pumping has little impact on the hydrodynamics of the Lobo River because the pumped flows are much less than the inflow to the reservoir.

Key words : *Hydrodynamics; Modeling; Reservoir; Lobo River.*

Introduction. Artificial water storage, created by the construction of water reservoirs, is essential for the sustainable health and well-being of populations as it provides water for human consumption, irrigation, fishing practice and energy production. In addition, water retention reservoirs are also used for recreational activities, flood and drought control (Buyukyildiz et al., 2014; Luís and Cabral, 2021).

Like other African countries, Côte d'Ivoire is not immune to eutrophication phenomena (Koffi et al., 2020b; Kouassi et al., 2013). The advanced eutrophication of some water reservoirs used to supply drinking water to the population sometimes makes it difficult to treat these waters due to siltation at the water intakes. Built to improve the supply of drinking water to the people of the city of Daloa, the Lobo River reservoir has been subject to all kinds of anthropogenic pressures for several years. Despite the efforts made by the competent authorities, recurrent problems of water supply are still observed in several districts of the town of Daloa. However, the water reservoir used to supply drinking water to the population has not yet been the subject of hydrodynamic studies to understand its functioning in order to adopt management strategies. Moreover, the combined effect of climate change, the absence of protection perimeters around the water reservoir, rapid urbanization and agricultural activities could affect the morphology and quality of the water. It is in this context that this study was initiated to understand the hydrodynamic functioning of the Lobo River reservoir.

Material and Methods

Study area. Located in west-central Côte d'Ivoire between longitudes 6˚36' 0'' and 6˚36' 36'' West and latitudes 6˚57' 0'' and 6˚57' 30'' North, the Lobo River impoundment is located 25 km from the town of Daloa (Fig. 1). This river is one of the tributaries of the Sassandra River (Koffi et al., 2020a; Yao et al., 2012). The Lobo River impoundment is the main source of drinking water supply for the people of the city of Daloa.

Hydrometric data. Hydrometric data from the Adjoukrou station located upstream of the reservoir were used in this study. These data cover the period 2019-2020. All hydrometric data used in this study are at daily time step.

Bathymetric survey. Bathymetric surveys were conducted using a Lowrance Elite Ti 9 echo sounder. This device consists of three parts. Bathymetric measurements were made at a frequency of 450 kHz to allow the waves emitted by the echo sounder to not penetrate the sediment (Lowrance, 2019). The development of a quality hydraulic model is highly dependent on good bathymetry. To this end, the areas covered by the bathymetry take into account the fluvial and lacustrine portion of the Lobo River impoundment reservoir. In order to obtain a regular grid of points, all the data were interpolated by the nearest neighbor method using the MIKE 21 software.

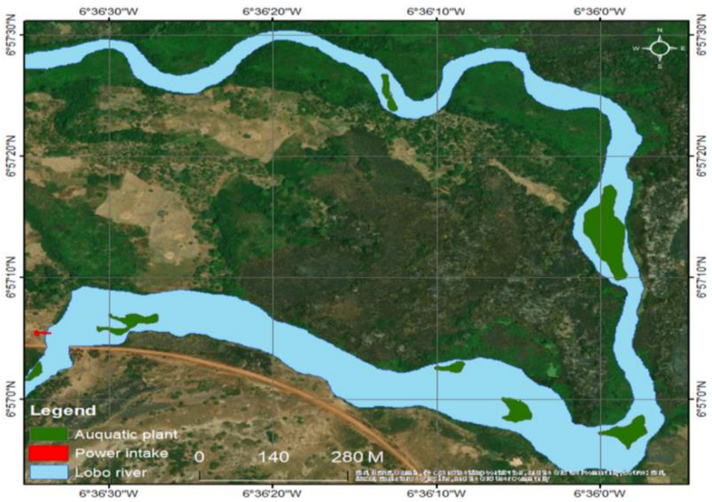

Fig. 1. **Sudy area**

Hydrodynamic model. The distribution of currentology and water levels in the Lobo River impoundment were evaluated through the development of 2DH numerical modeling, performed using MIKE 21 FM software (DHI, 2020). This is a software package that simulates the variation of water levels, flows and sediment transport in two dimensions (2D). It solves the classical two-dimensional Saint-Venant equations by the finite volume method on a flexible mesh grid. The vertically integrated conservation of mass and momentum equations used by the MIKE 21 model are used to describe the flow and water level variations (DHI, 2020). A triangular mesh was used to generate the 2D model topography. Next, the mesh is smoothed to achieve the largest possible angles and feature area. After this step, the mesh is interpolated with the initial bathymetry using natural neighbor interpolation. When generating the model mesh, a correction is made to ensure good mesh quality. The domain mesh consists of 8125 nodes and 14628 elements (Fig. 2).

Boundary and initial conditions. Two boundary conditions were imposed in the hydrodynamic model. The flows are imposed as boundary conditions upstream of the domain. For the upstream boundary conditions, we positioned ourselves far enough (4.2 km from the weir) from the lake area to be able to parameterize the model with the river flow. As for the downstream boundary of the model, a constant water level (-1 m) and the spillway of the reservoir allowed to control the hydrodynamic model. In this study, a water level (-1) was imposed as an initial condition. This value represents the initial elevation at the surface of the Lobo River impoundment.

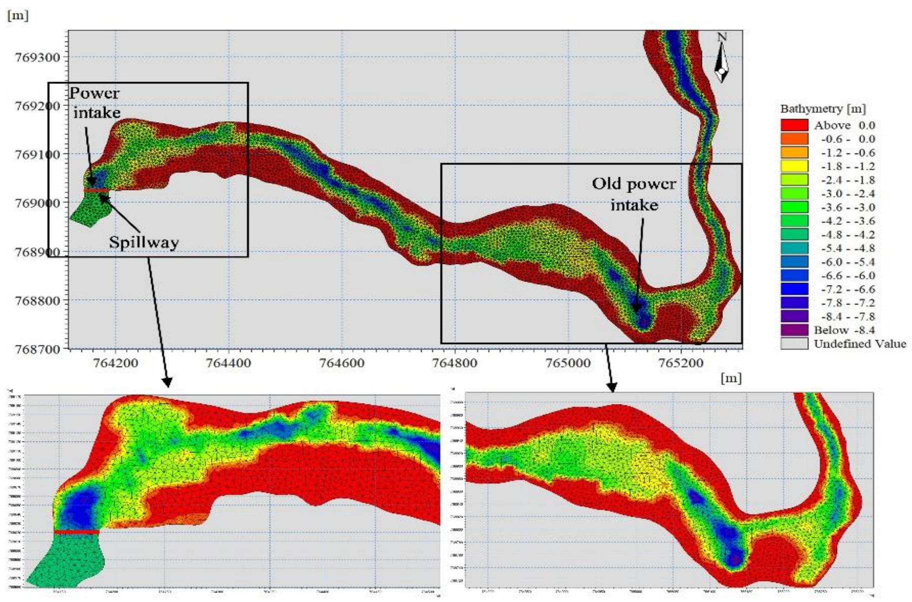

Fig. 2. **Meshing of the study area**

Results

Calibration and validation model. The results of the calibration of the steady-state model show a good synchronization between the observed water level-discharge curve and the one simulated by the model in periods of low water and high water (Fig. 3). Although the model is able to reproduce the water levels correctly, there are some discrepancies between the observed values and the simulated values for flood flows between 20 m^3/s and 47 m^3/s. Also, it should be noted that during the various simulations, the time to reach the steady state for very low flows (0.98 m^3/s), observed in dry periods, is quite long. On the other hand, for a maximum river flow of 55 m^3/s, the time to reach the steady state is quite short. In other words, the lower the flow, the longer it will take to reach the steady state.

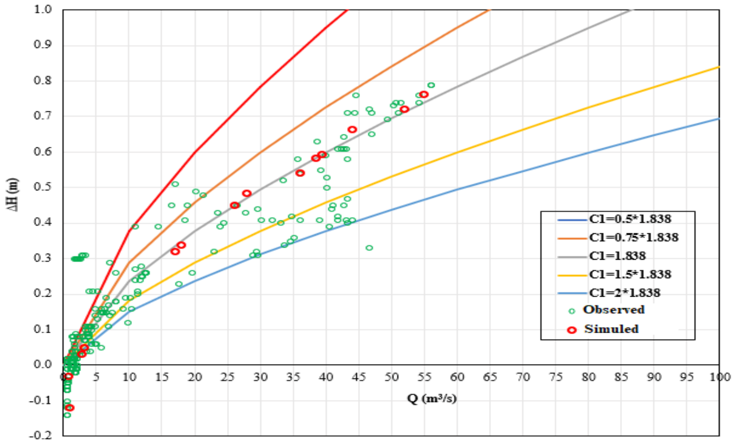

Fig. 3. **Calibration and validation model**

Velocity distribution. The results of the velocity current distribution are shown in Fig. 4. There is a large variation in velocity currents in the reservoir. The velocities decrease from upstream to downstream. The maximum velocities are observed upstream of the reservoir. The speeds are between 0.054 and 0.76 m/s. It is noted that the maximum speeds are observed at the entrance of the reservoir, where they can reach 0.76 m/s. The currents are directed from East to West. However, in the reservoir, the simulated velocities are relatively weak and included between 0,0051 and 0,36 m/s. They remain relatively weak at the banks. In the vicinity of the spillway of the reservoir, we observe that the flow is accelerated by the presence of the weir and the currents are between 0.04 and 0.40 m/s. A hydraulic load allows the water to create a phenomenon of hydraulic jump downstream of the spillway with an increase of the speeds of the order of 0,45 m/s.

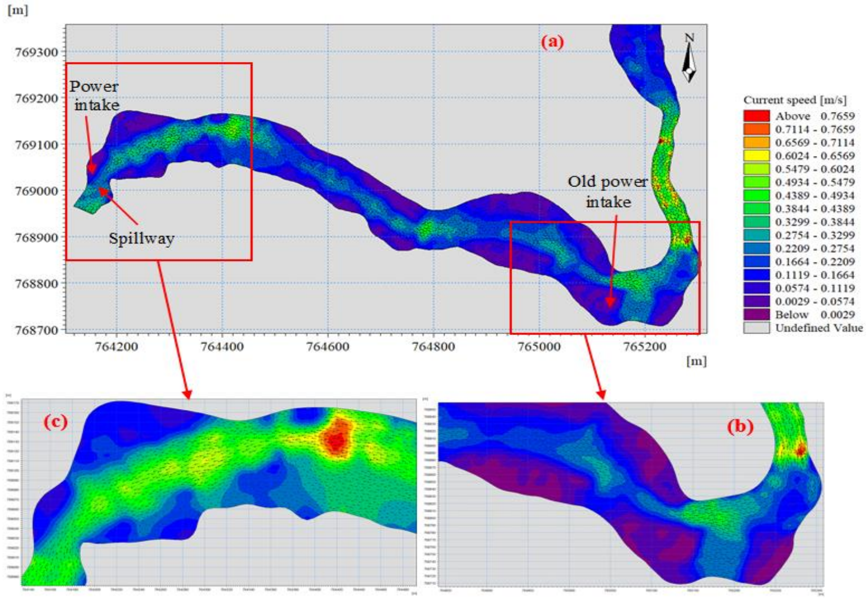

Fig. 4. **Velocity current distribution in the Lobo River impoundment (a). In the area of the old (b) and new (c) water intake**

Impact of pumping on the variation of water levels in the reservoir. The hydrodynamic model took into account the water intake in the Lobo River impoundment. This intake corresponds to a pumping of 675 m^3/h, or 0.1875 m^3/s continuously. The results show that the water levels from the models of the situations without pumping are very close to those of the situations with pumping. During the driest month of the year (February), the water levels in the Lobo River reservoir are not significantly modified by pumping (less than 1.3 mm). Pumping has little impact on the hydrodynamics of the Lobo River (Fig. 5).

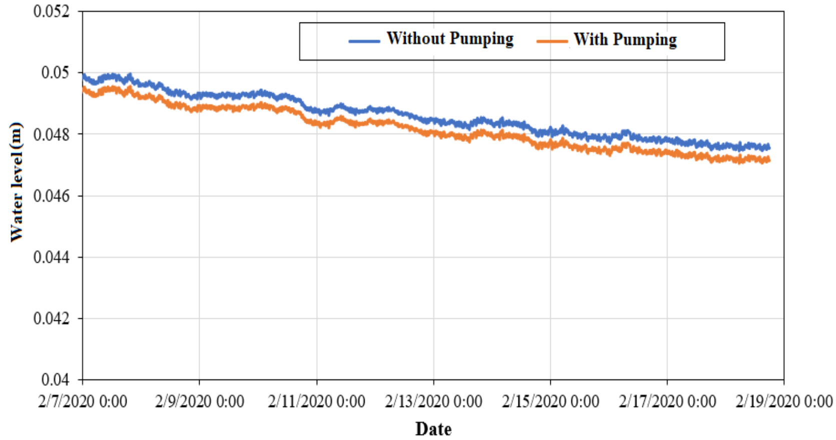

Fig. 5. **Water level in the situations before and with water intake during the dry period (February 2020)**

Discussion. Simulated current velocities in the Lobo Reservoir, using MIKE 21 FM software, range from 0.051 to 0.72 m/s. The currents decrease from upstream to downstream of the reservoir. This result correlates closely with the work of Giovanni (1994); Kouassi et al. (2013); Teal et al. (2015); Guertault et al. (2018); Tang et al. (2021) who report that when a river enters a reservoir its velocities decrease significantly. However, near the inlet and after the weir, current velocities are observed to be higher than in the open ocean. This increase in current speed at the new water intake is due to the pumping carried out by the water distribution company of Côte d'Ivoire (SODECI) for the supply of drinking water to the town of Daloa. After the weir, the currents are of the order of 0.28 m/s. This phenomenon could be explained by the hydraulic load that allows the water to create a hydraulic jump downstream of the weir. It is also noted that the water intake has very little impact on the variation of levels in the Lobo River reservoir. This weak influence of the water intake on the variation of the water levels in the water reservoir could be due to the fact that the water inflow is largely superior to the pumping flow of the water intake.

Conclusion. This study provided an understanding of the hydrodynamic functioning of the Lobo River impoundment. The results of this study showed that water levels are not significantly modified by pumping (less than 1.3 mm). The pumping has little impact on the hydrodynamics of the Lobo River because the pumped flows are much lower than the inflow to the reservoir. For a better management of the reservoir, this study must continue by updating the bathymetry data and the realization of a sediment transport model in order to quantify and determine the preferential zones of sediment deposition in the Lobo River reservoir.

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Гідродинамічне функціонування водосховища річки Лобо в західно-центральному Кот-д'Івуарі.
Коффі Б., Алексіс Б. Л., Ален К. С., Олів'є К. К. Ж., Куасі К. Л.

Створене для покращення водопостачання населення міста Далоа, водосховище річки Лобо більше не функціонує належним чином через людську діяльність поблизу цього резервуара. Це дослідження, яке засноване на 2D гідродинамічній моделі, виконане за допомогою програмного забезпечення Mike21 HD, дозволило реконструювати потоки у водосховищі річки Лобо. Результати моделювання свідчать про те, що гідродинамічна модель може відтворити зміну рівнів води вільної поверхні водойми. Крім того, результати дуже чутливі до граничних умов моделі, а також до початкових умов. Результати впливу відкачування води на динаміку рівнів у водосховищі р. Лобо показали, що вони суттєво не змінюються через відкачування (менше 1,3 мм). Тому відкачування слабко впливає на гідродинаміку річки Лобо, оскільки перекачувані потоки набагато менші, ніж приплив до водосховища.

Ключові слова : *гідродинаміка ; моделювання ; водосховище ; річка Лобо.*

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ОЦІНКА ЗМІНЕНОГО ГІДРОЛОГІЧНОГО РЕЖИМУ ДНІСТРА ЯК ОСНОВА ДЛЯ ВИЗНАЧЕННЯ ПАРАМЕТРІВ ЕКОЛОГІЧНОГО СТОКУ

У роботі розглянуті практичні аспекти впровадження концепції екологічного стоку в Україні згідно з Водною Рамковою Директивою. На прикладі Дністра застосовано гідрологічний метод, який слугує першим кроком встановлення параметрів екологічних витрат води. Проаналізована трансформація водного режиму внаслідок зарегулювання стоку за допомогою індикаторів гідрологічних змін. Апробація такого підходу підтвердила можливість його застосування на річках України за умови наявності тривалих рядів гідрологічних спостережень. Отримані результати можуть слугувати основою для розробки програми гідроекологічних досліджень для встановлення екологічно обґрунтованого режиму експлуатації водосховищ.

Ключові слова: *екологічний стік, індикатори гідрологічних змін, витрата води, гідрологічні характеристики, Дністер.*

Актуальність дослідження. На сьогодні у міжнародній практиці екологічний стік використовується для досягнення доброго стану водних об'єктів та впроваджується для вирішення практичних задач щодо встановлення мінімальних можливих та оптимальних