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Analysis of the propagation of the tidal wave in canal of Vridi (Ebrié lagoon, south-east coast of Côte d'Ivoire)

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--*ABSTRACT*---

The goal of the present study is to characterize the tidal in the channel of Vridi before its deepening and widening project by the harmonic analysis of time series of water levels. The form of number F is 0.27. This means that the mixed nature of tide in Abidjan. The harmonic
component which shows the greatest amplitude in channel of Vridi is the semidiurnal component M2 of period 12.42 hours. This tidal wave traveling along the channel of Vridi with a decreasing amplitude and a speed of about 0.48 m/s.

KEY-WORDS: Tidal wave, water level, harmonic component, channel of Vridi.

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I. INTRODUCTION

The Ebrié lagoon, with its opening to the Atlantic Ocean since 1950 by the Vridi Canal, is central to the Ivorian economy. Indeed, the lagoon provides one of the most important harbors of sub-Sahara Africa. This artificial Vridi Canal with a width of 300 m and a length of 2.7 km has facilitated an exchange between the marine and fresh water bodies of the Ebrié lagoon, through the propagation of the tidal wave. But since the year 2015, the Abidjan harbor conducted work to expand and deepening the Vridi Canal to accommodate the biggest ships of world. It is in this context that this current study is being taken. The object is to determine the characteristics of the tidal wave in the Vridi Canal before these works in progress.

II. MATERIAL AND METHODS

2.1. Presentation of the study area

The Ebrié lagoon is the largest of the lagoons of Côte d'Ivoire with an area of 566 km^2. Its total volume is 2.7 10^9 m^3 with an average depth of 4.8 m (Tastet, 1979). The harbor area of the Ebrié lagoon is located in Abidjan between 3°40' and 4°50' west longitude and between 5° and 5°20' north latitude (Figure 1). It presents a central basin (area harbor) linked to the Vridi Canal around which plenty of bays are located. The Abidjan harbor has two tide gauges located in The Vridi Canal. The tide gauge Mg1 is located at the entrance of the Canal (sea side) and the tide gauge Mg2, on the lagoon side. There is a distance of 25 km between the two tide gauges.

Several studies has demonstrated that the circulation of water bodies in the Ebrié lagoon depended mainly of the tidal wave and to a lesser extent of Comoé River discharge through that lagoon (Pouvreau, 2002, Affian, 2003, Mondé, 2004 and Wango, 2009).

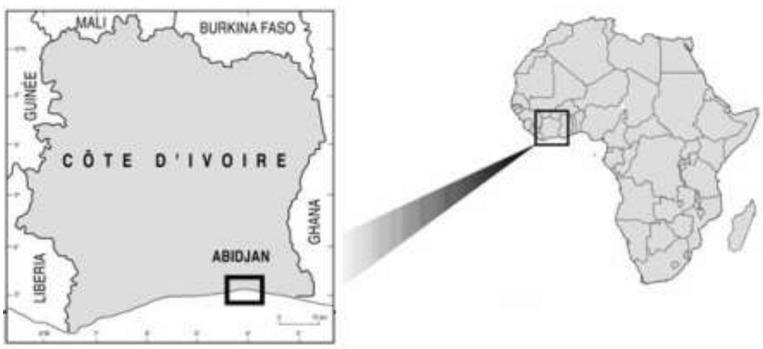

Figure 1: Location of the Ebrié lagoon and the Vridi canal (Mg1: tide gauge of sea side and Mg2: tide gauge of lagoon side)

2.2. Origins and digitization of printed recording of tidal level

The printed recording of tidal levels of two tide gauges come from center of archive department of SHOM (Service Hydrographique et Océanographique de la Marine). They are calibrated in the same way in local time (Greenwish mean time) and in height relative to the chart datum which is 1.14 m below the mean level (N'gbesso, 1976). The chart datum is the reference plane to which depths on a published chart, all tide height predictions, and most water level measurements are referred.

In order to extract the water heights from the printed recording sea level, the Nunieau software has been used. It is a software developed in Matlab language by the CEREMA (Centre d'Etude et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement). This image processing is based on a color recognition algorithm. The aim of the processing is to obtain a time series of water levels.

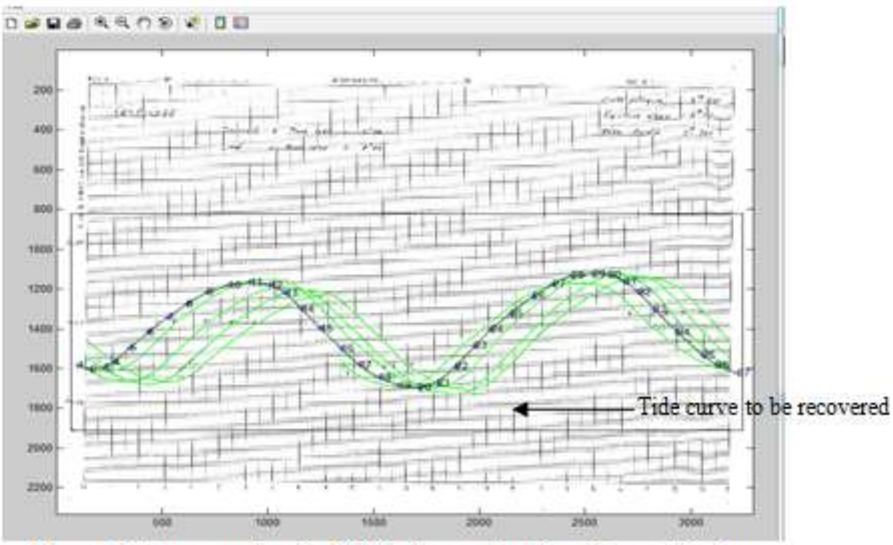

Figure 2: An example of a digitization project in software Nunieau

2.3. Tide analysis and prediction

The series of water level were treated by harmonic analysis (Mahan, 2009 and Foreman, 2004). Then, it is possible to extract deterministic oscillations from time series of water level. This method is based on the representation of the tide in the spectral domain. Indeed, the tide is formed by a large number of harmonic components whose frequencies are precisely defined. The harmonic analysis method adopted in this work is described by Pawlowicz & al. (2002) and Leffler & Jay (2008). A MATLAB version of this program is also available at: http://www2.ocgy.ubc.ca/~rich/#T_Tide. This program allows obtaining a prediction of the tide with estimation of errors.

III. RESULTS AND DISCUSSION

3.1. Predictions of tide

This tide gauge served as a reference for tidal predictions in Abidjan with a tidal range of 0.69 m (Ngesso, 1976). Figure 3 below shows the original time series of tide gauge Mg1, the tidal prediction from analysis and the original time series minus prediction. The monthly standard deviation of the residues (original time series minus prediction) is about 5 cm. According to the Gloss (2009), when the standard deviation of the residues is less than 10 cm, the original time series of water level are of good quality. The ratio prediction/original data of 99.8% for tide gauge 1 (Table 1) and of 97.9% for tide gauge 2 (Table 2), confirms this result. But this residual variation of the water level is due to weather conditions such as atmospheric pressure, wind, swell, seiches, river discharge,…

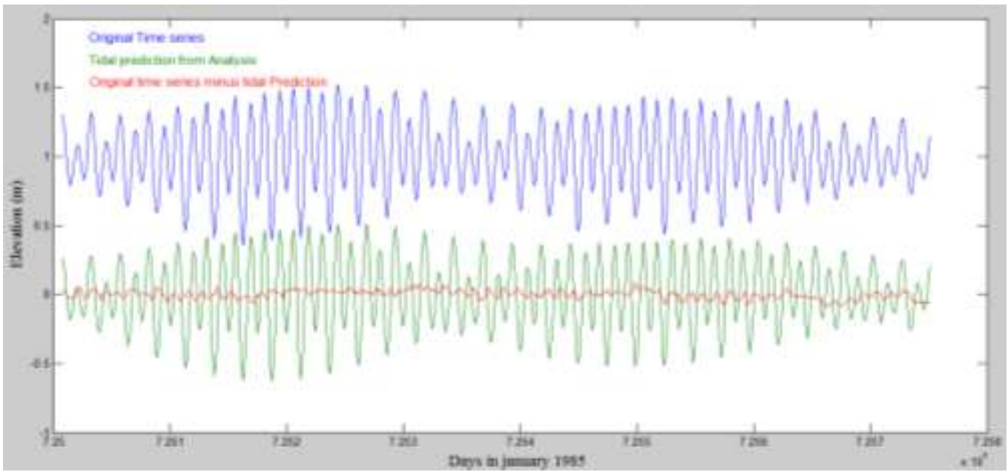

Figure 3: Water level measured (blue), predictions (green) and residues (red) from tide gauge Mg1

3.2. Harmonic components

Tables 2 and 3 have the results of the harmonic analysis of the water levels of the two tide gauges. Only the harmonic components with an amplitude ratio greater than 5% (harmonic component of M2 is equal to 100%) will be presented (Tables 1 and 2). The amplitude of M2 is equal to 32.25 cm for the tide gauge Mg1 and 19 cm for Mg2. The tidal wave M2 had a phase of 126° at the station Mg1 and 171° at the station Mg1, a difference of 45° between the two tidal gauges. While comparing the phase of the wave M2 at the two stations, we notice that the wave is propagated in the Vridi Canal with an increasing phase. This result confirms that of Mahan (2009) obtained in the San Pedro harbor. This difference in amplitude and phase is due to an underestimation of the effects of shallow depths.

Table 1: Water level harmonic analysis for the tide gauge Mg1. A Tidal amplitude and phase with 95% CI estimates and percent var predicted/var original=99.8 %

tide	freq	amp	amp_err	pha	pha_err	snr
***MSF**	0.002822	0.028	0.025	131.24	56.63	1.2
***O1**	0.038731	0.0212	0.003	308.22	8.9	40
***P1**	0.041553	0.0347	0.004	0.33	6.18	90
***K1**	0.041781	0.1048	0.004	353.26	2.21	8.70E+02
***N2**	0.078999	0.0658	0.015	137.66	13.81	18
***M2**	0.080511	**0.3225**	0.014	**126.19**	2.6	5.10E+02
***S2**	0.083333	0.1497	0.013	162.54	5.35	1.30E+02
***K2**	0.083562	0.0407	0.012	184.94	16.55	12

Table II: Water level harmonic analysis for the tide gauge Mg2. Tidal amplitude and phase with 95% CI estimates and percent var predicted/var original=97.9%.

tide	freq	amp	amp_err	pha	pha_err	snr
MSF	0.002822	0.0196	0.025	140.32	84.65	0.61
***O1**	0.038731	0.0146	0.003	335.96	13.11	18
***P1**	0.041553	0.0237	0.004	27.16	8.52	31
***K1**	0.041781	0.0715	0.004	20.09	3.1	3.00E+02
***N2**	0.078999	0.0288	0.008	182.27	14.98	14
***M2**	0.080511	**0.1899**	0.007	**170.6**	2.33	7.9e+02
***S2**	0.083333	0.0927	0.008	210.33	4.43	1.4e+02
***K2**	0.083562	0.0252	0.006	232.73	14.69	17

The number of form F determined from table 1 is the ratio of amplitudes: F=(K1+O1)/(M2+S2) which makes it possible to evaluate the relative importance of the diurnal components compared to the semi-diurnal components and thus to determine the type of tide. The number of form F calculate is equal to 0.27> 0.25 shows the mixed nature of the tide in Abidjan such as San Pedro harbor (Mahan, 2009; Mahan and Abé, 2007).
9s pour que l'onde de marée M2 parcours le canal de Vridi long de 2.7 km.
On en déduit une vitesse de M2 de l'ordre de la vitesse de l'ordre de 0.48 m/s. Cette vitesse de l'onde M2 produira des courants de marées relativement important dans le canal de Vridi par rapport au reste de la lagune.

3.3. Propagation of the tide

Harmonic analysis of water levels showed that the semi-diurnal harmonic component (M2) is the largest component of the tide at each tide station.

The travel time of the tidal wave between the two stations is estimated by the relative phases of the tidal wave M2 is:

Time (hours) = (phase1-phase2) * (period of M2/360), with phase1=phase of M2 at station Mg1 and phase2=phase of M2 at station Mg2. The period of this wave is 12.42 hours.

Numerical application:

T = (171-126) * (12.42/360) = 1.5525 h

T=1h33mn09s.

The wave M2 goes from Mg1 to Mg2 in 1h33mn09s. When the tide is high at station 1, it will average last 1h33mn9s to be also high at station Mg2.

The estimated distance (D) between the two tide gauges is about 2.7 km (2700 m) for a travel time of 1h33mn09s (5589 s). The horizontal rate of travel of the tidal wave is of:

V = D/T with V speed of tidal wave M2 (m), d horizontal distance between Mg1 and Mg2 and T travel time of M2.

V =2700 m / 5589 s = 0.48 m/s

The tidal wave M2 moves into the Vridi Canal with a speed of the order of 0.48 m/s. This slow speed is comparable to that measured by Affian (2003) in the Vridi Canal with a Doppler current meter (DCM12).

IV. CONCLUSION

The water levels extracted from printed recording water level made it possible to calculate the harmonic components of the tide at the entrance of Vridi Canal. The tidal wave M2 is the dominant harmonic component on the Ivorian coast with an amplitude of 32.25 cm, a speed of 0.48 m/s for a travel time in the Vridi Canal of 1h33mn09s. These are the characteristics of the tide in the Vridi Canal before the work in progress in the Vridi canal.

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