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Influences of Anthropogenic Pressures on the Morphology and Hydrochemical Parameters of Bingerville Bay (Côte D'Ivoire)

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Abstract: Bays are aquatic environments in which the depth tends to decrease due to numerous sediment deposits. Anthropogenic activity has a negative impact through pollution and changes to the morphology of this environment. This study was carried out in Bingerville Bay, in order to study the morphology and hydrology through hydrochemical parameters. The morphological study of the Bingerville estuary was carried out in order to characterise the morphology of the bottom of the bay using bathymetric maps (2D, 3D, slope and physiographic maps). These maps will be interpreted to establish a qualitative and quantitative study of the different channels obtained : U-shaped channels (transport and deposition event), V-shaped channels (erosion and transport event) and intermediate channels. A study of the bathymetric maps reveals a depression that is the result of human activity (dredging and development of the bay). They also show the deterioration in water properties due to changes in hydrochemical parameters compared with WHO standards. This variation in parameters is also linked to morphological changes in Bingerville Bay as a result of human pressures.

Keywords: *Bathymetry, Physico-Chemical Parameters, Morphology, Bingerville Bay, Côte d'Ivoire.*

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I. INTRODUCTION

The morphology of the bottom of the Ebrié lagoon, including the bottoms of the various bays it contains, tends to be renewed thanks to the various fluvial inputs from the three main rivers, the Mé, Agneby and Comoé, which flow into it. The bays are indentations in the coastline that sink into the mainland. They are a receiving environment (deposition environment) for dissolved, solid and suspended matter. The Ebrié lagoon, located close to the estuaries, has several bays. It is bounded by the bays of Adiopo-Doumé (west) and Bingerville (east). These bays represent almost a fifth of the surface area of the Ebrié lagoon, excluding the Aghien and Potou lagoons, i.e. 100 Km^2 out of 523Km^2. They are more common on the north shore (Cocody, Banco, Bingerville, Adiopo-Doumé bays, etc.). The reason why we were so enthusiastic about this study is that bays are subject to enormous anthropogenic (fishing, sand extraction, pollution) and natural pressures. These bays are the main outlets for domestic water. The majority of human activities will therefore tend to modify the morphology and hydrochemical parameters of Bingerville Bay. Numerous studies have been carried out on these aquatic ecosystems with a view to understanding how they function and implementing protection strategies. These include the work of [1-8]. Very few research investigations have been carried out in Bingerville Bay. The aim will therefore be to characterise the morphology of the bay and variations in physico-chemical parameters. Morphological changes resulting from human activities most often influence the distribution and variation of hydrochemical parameters. Variations in these parameters have a direct impact on water quality and on the dynamic nature of the Ebrié Lagoon. This dynamism plays an important role and, through this research work, will make it possible to monitor the morphology of Bingerville Bay in the future.

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II. STUDY AREA, MATERIALS AND METHODS

Located between the town of Bingerville (west), the village of Abatta and the village of Akouedo (east), the Bingerville estuary is a vast body of water. It is also located between the bay of M'Badon and the Anna lagoon, on the north bank of the Ebrié lagoon between longitudes 398912 m and 401216 m and latitudes 589482 m to 591790 m (figure 1). Its surface area is estimated at 2.59 km^2.

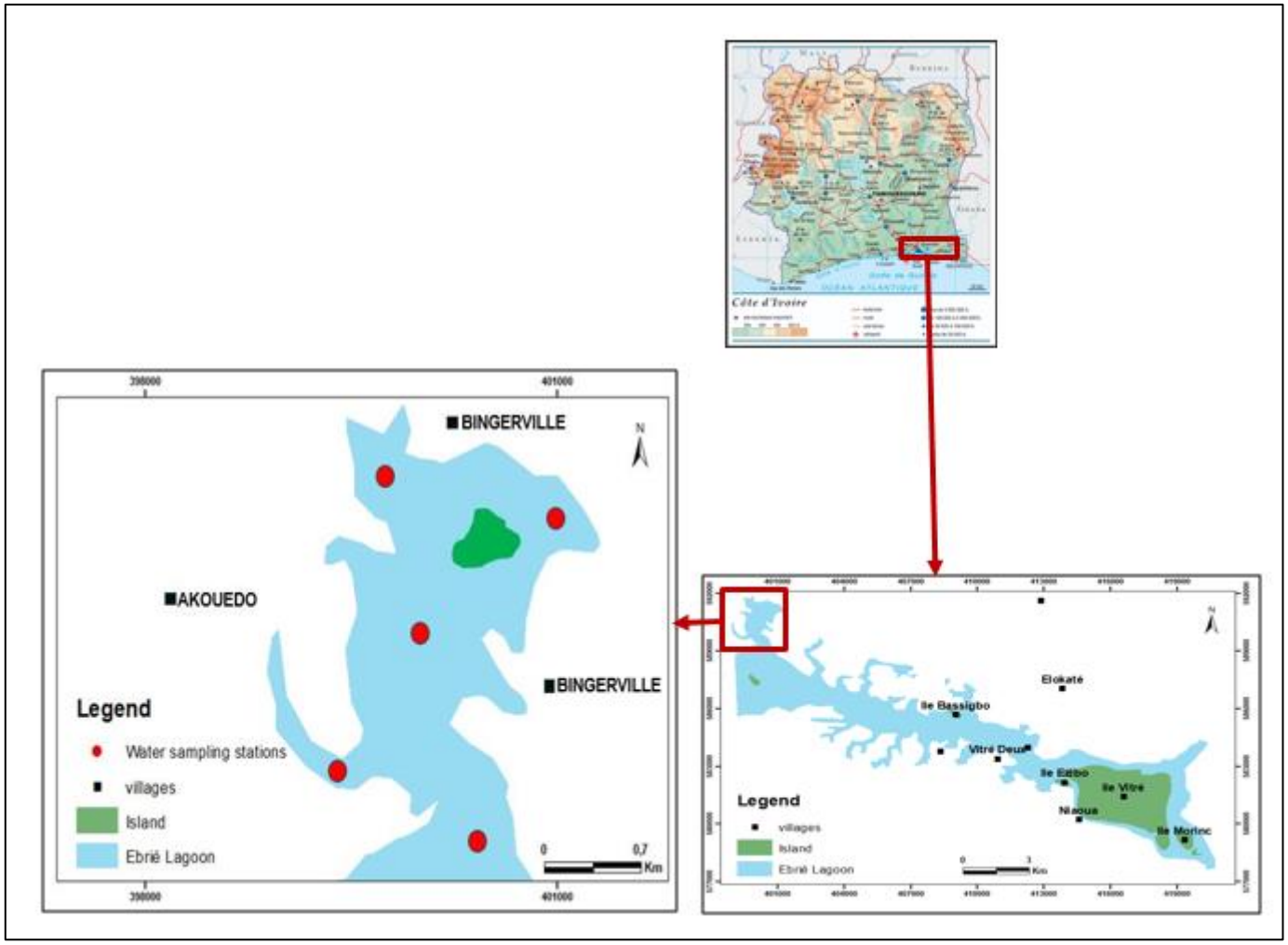

Fig 1: Location and Water Sampling Stations in Bingerville Bay

The morphological study of Bingerville Bay was carried out using several soundings made with an echo sounder. One thousand four hundred and forty-two (1442) sounding points were taken throughout the bay during 2018. The echo sounder consists of a transducer and a central unit. The transducer emits a signal (wave) by converting electrical energy into acoustic energy while recording the data in digital format (figure 2). After correction, depth data is obtained and processed by the Surfer 11 software. The result is the probe position map. This map will be used to produce other bathymetric maps.

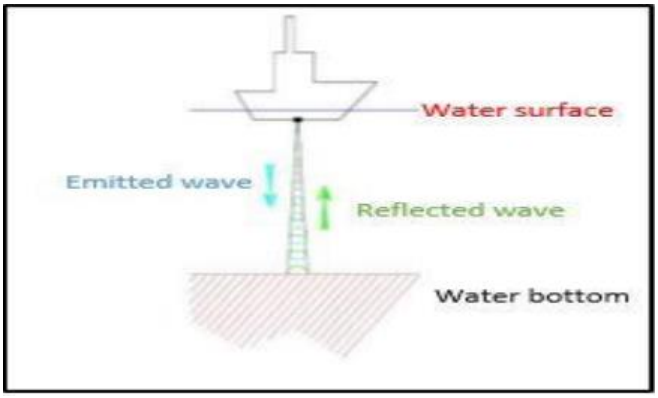

Fig 2: Principle of the echo sounder [9]

To analyse the hydrochemical parameters of the water in the Bingerville estuary, a Niskin bottle was used to take water samples from a depth of one (1) metre. A multi-parameter was then used to measure conductivity,

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temperature, pH and dissolved oxygen. The values of these various measurements are recorded in Table II.

III. RESULTS

A. Morphological Characterisation of Bingerville Bay

➢ *2D Bathymetric Map (Two Dimensions)*

From a morphological point of view, Bingerville Bay has a main channel running in a N-S direction with depths ranging from 0 to 26m. This channel cuts perpendicularly across the main channel of the Ebrié lagoon system as far as the entrance to the estuary. In the central part of the bay, there are great depths from (15 to 26m) and medium depths from (8 to 15m) represented by dark blue and light blue on the map. These great depths, also known as depressions, are due to the dredging activities carried out in Bingerville Bay. The light blue colour characterises the shallower depths (0 to 8 m). These depths can be observed almost throughout the bay (figure 3).

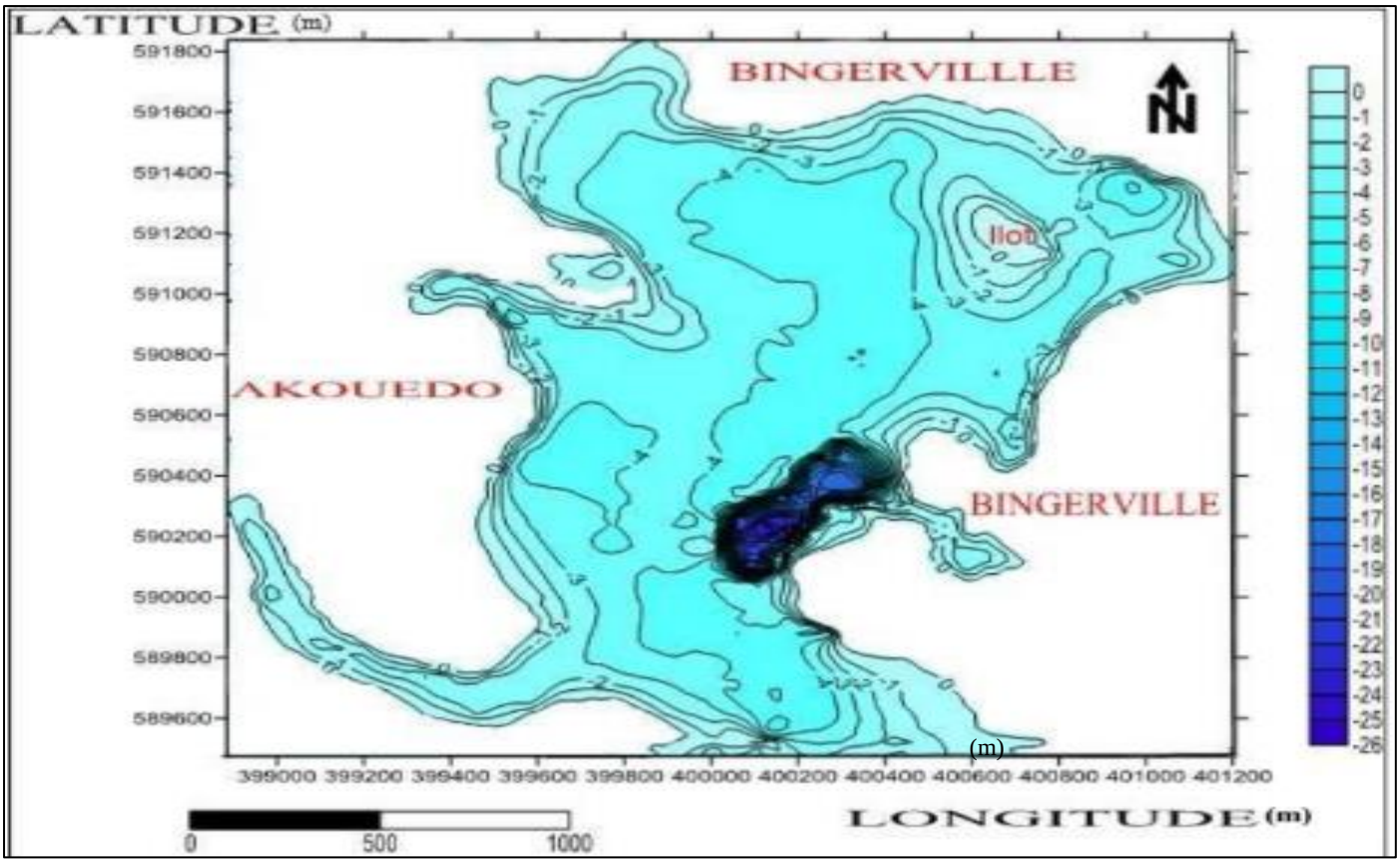

Fig 3: 2D Map of Bingerville Bay

➢ *Physiographic Map and Digital Model of Bingerville Bay*

The topographic background, thanks to the digital and physiographic model of Bingerville Bay, reveals two characteristic geomorphological aspects. These are the shoals and the depressions. The physiographic map (figure 4) is a sort of panchromatic photograph of the bay. It highlights a depression with a maximum depth of around 26m. It is located to the south of the islet and reflects very rough hydrodynamic conditions. This sudden and rapid variation in depth is due to the increased erosion caused by the phenomenon of sediment dredging (suction of huge quantities of sediment from the bottom of the bay). This sediment is used to build bridges, houses, etc.

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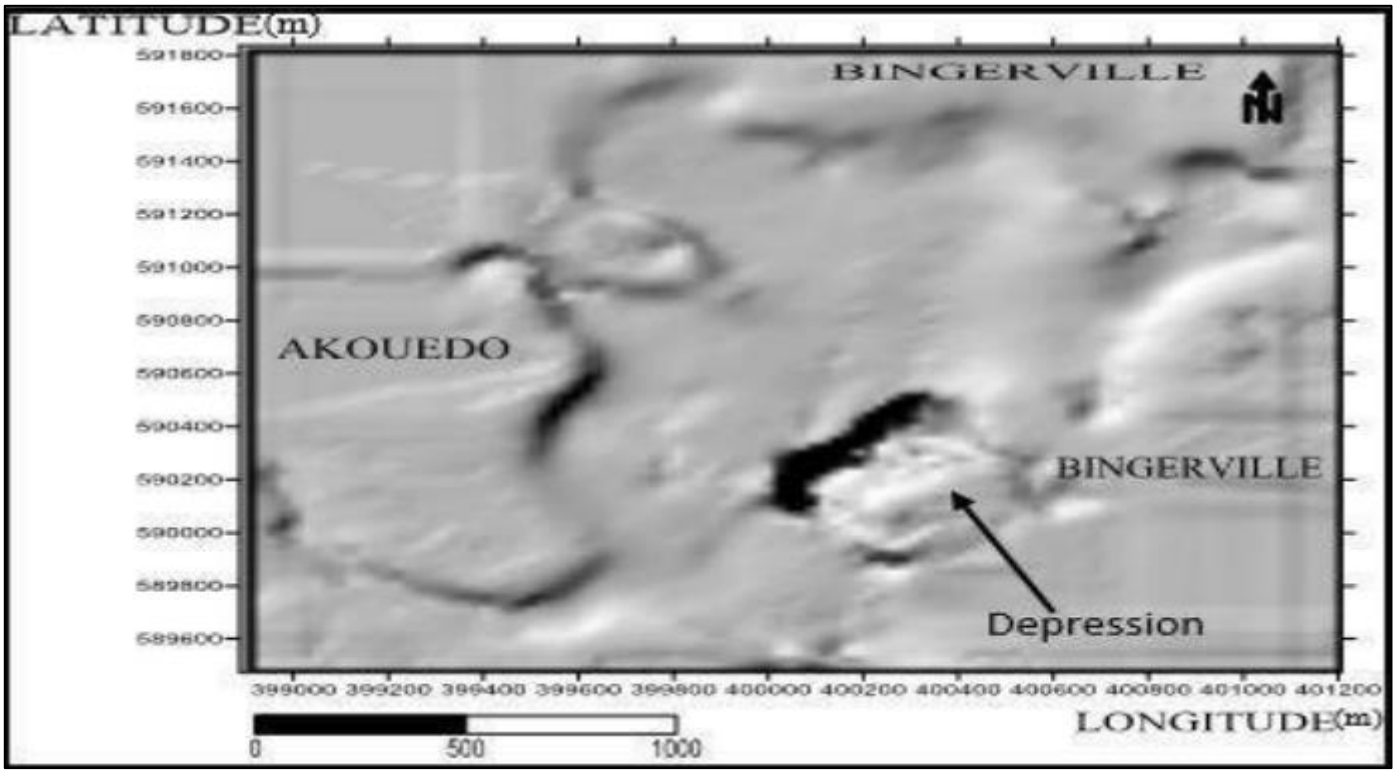

Fig 4 : Physiographic Map of Bingerville Bay

Figure 5 shows shoals at the young and terminal (mature) stages of evolution. They reflect fairly calm hydrodynamic conditions. The shoals at the terminal stage of evolution appear in one place as an island [10]. This islet is colonised by vegetation and is located to the north-east of the bay. Shoals at a young stage of evolution are located in the centre of the bay. These areas are calm environments that are not influenced by currents. Some of the sediment drained by the water is deposited and accumulates there, while the rest is carried away by the flow of water. They are formed by an accumulation of sediment.

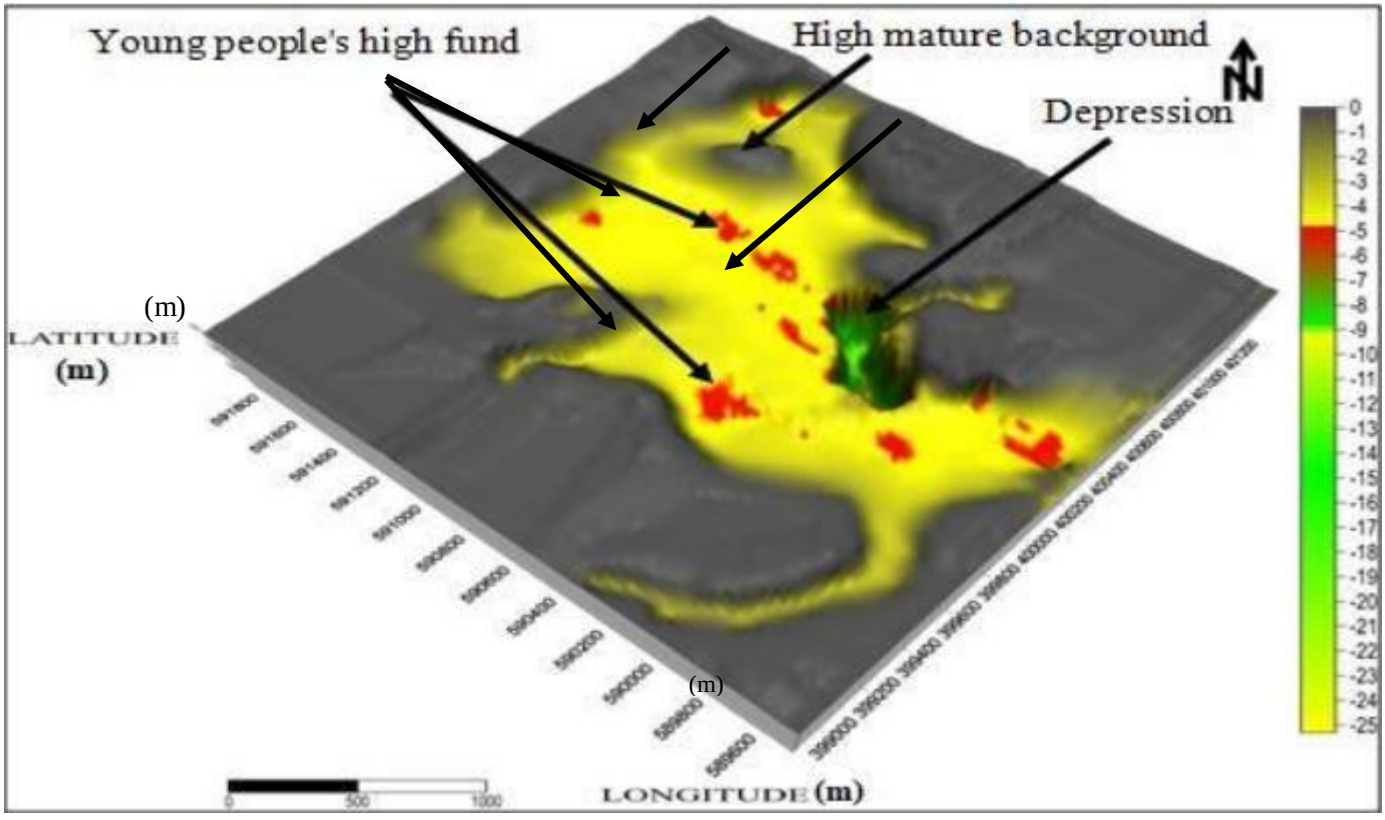

Fig 5: 3D Map of Bingerville Bay

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B. Slope Changes

The evolution of the slopes takes into account the direction of flow of the slope vectors and their hue (figure 6). These slope vectors show how the water flows into the bay (in black). Several values associated with the different shades are shown on the scale (figure 7). These range from blue (low slopes) to violet (medium slopes) to red (high slopes). However, there are three (3) types of slope vectors. Red slope vectors indicate strong water flow. They are found inside the depression. Violet slope vectors indicate medium water flow. They are found inside the central depression. Blue slope vectors indicate low water flow. They are found more along the banks and generally throughout the bay.

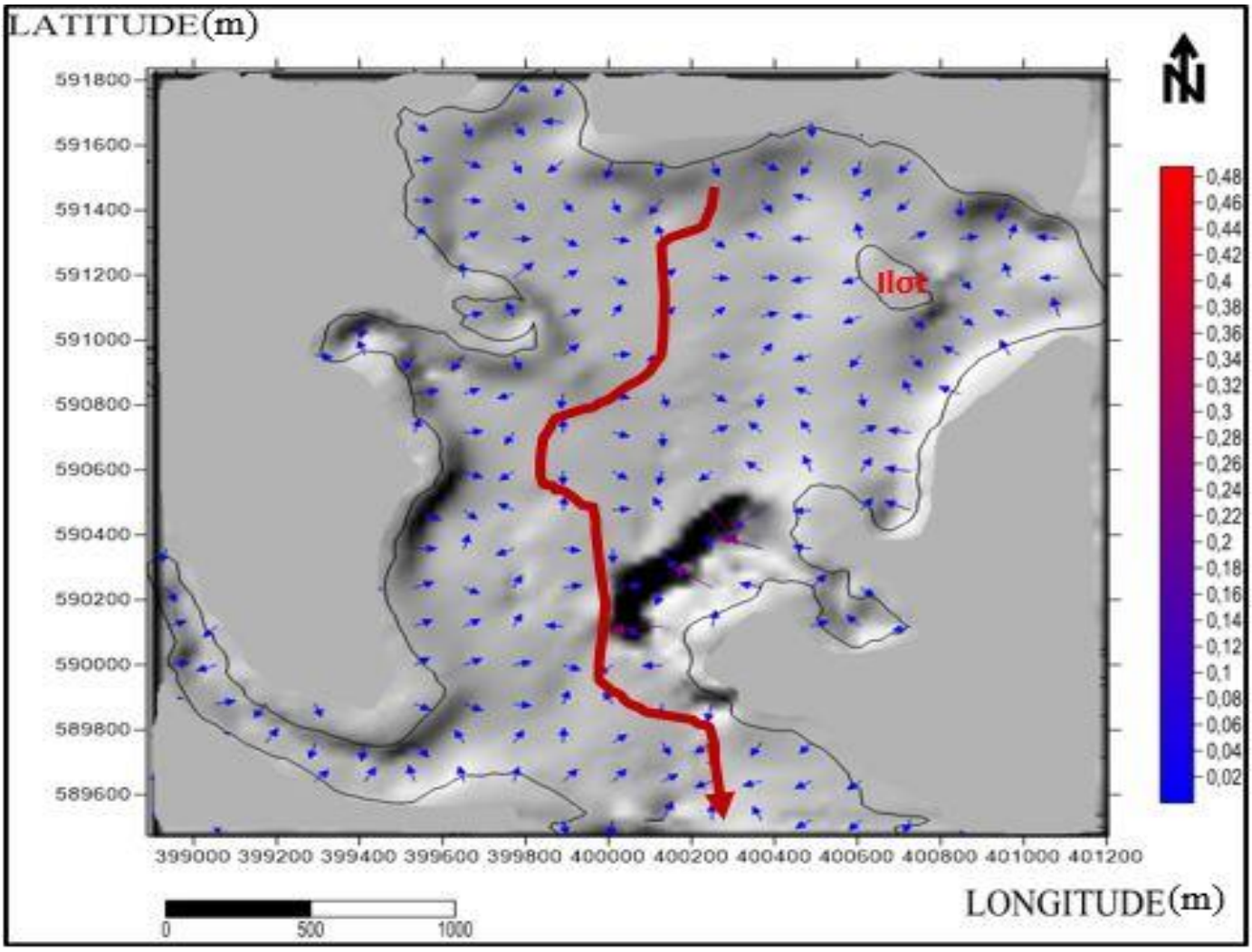

Fig 6 : Route of the Main Channel in Bingerville Bay

Figure 8 shows the values of the slopes in degrees, so that they can be better appreciated. These different values are recorded in Table I.

Table 1: Direction and Different Slope Values of Bingerville Bay

SLOPE	MEASURE (m)	DIRECTION	SLOPE VALUE(°)
AB	449	NW-SE	0.51
CD	82	NE-SW	2.79
EF	301	NW-SE	0.76
GF	121	NE-SW	1.42
IJ	126	NE-SW	1.81
KL	82	NE-SW	2.79
TN	132	E-W	1.73

The average slope is 1.68°, while the AB, EF, GH, IJ and TN slopes are shallow (less than 2°), justifying the filling phenomenon. Generally speaking, the steepest slopes are found near the banks. In ascending order we have : CD and KL.

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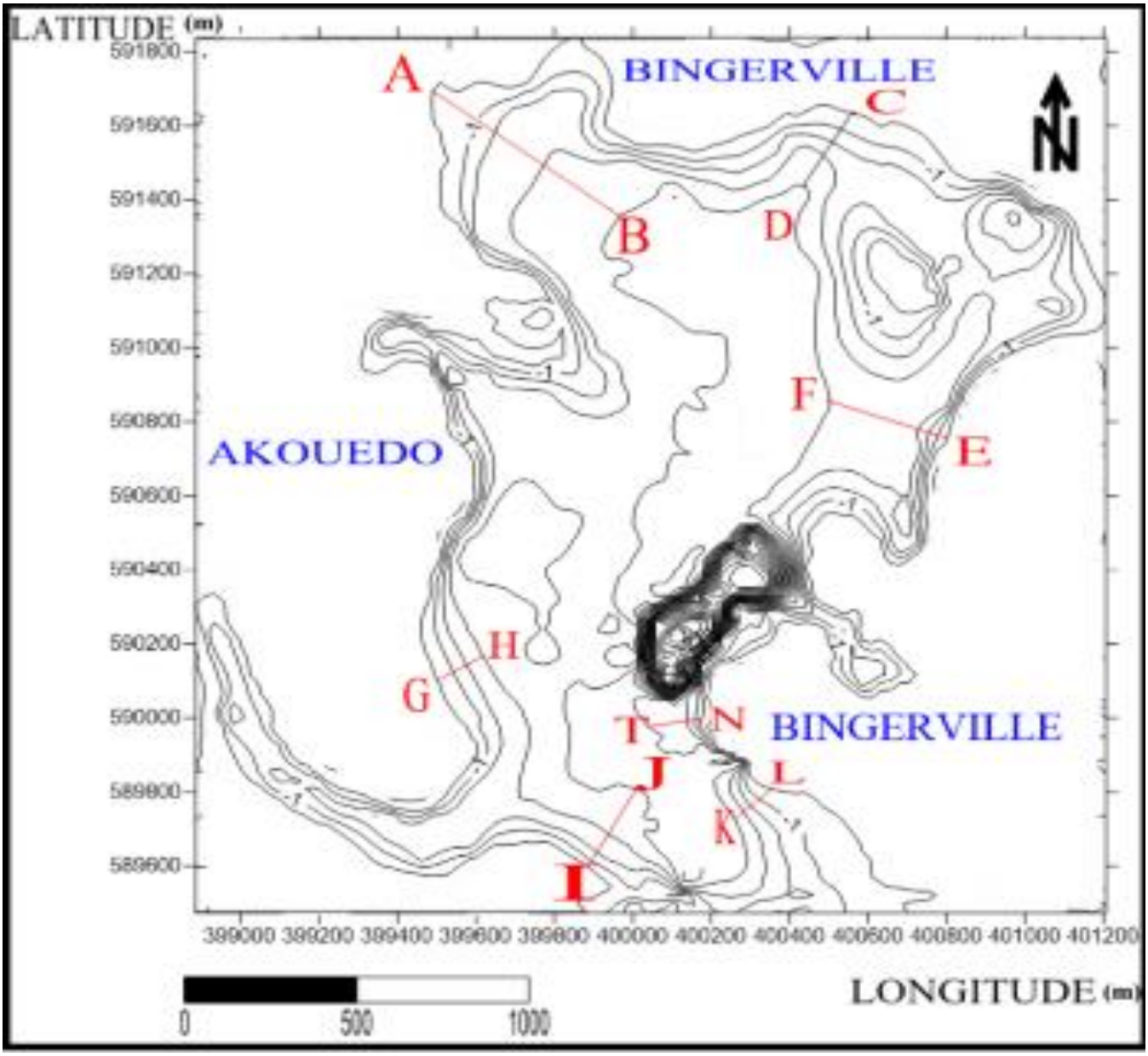

Fig 7: Slope Position Map

C. Channel Configuration

The characterisation of the channels in Bingerville Bay was studied on the basis of ten (10) radials radiating around the single island (figure 8) and perpendicular to the watercourse (to the main channel). They can be grouped into two (2) preferred directions. The NW-SE direction is oriented by radials R2, R3, R4, R5, R7 and R9. They have an average length of 172m ; 1267m ; 381m ; 647m ; 42m and 53m with slopes of 2.33° ; 0.40° ; 1.35° ; 0.79° ; 6.78° and 1.94° respectively. The NE-SW direction has radials R1 (140m long), R6 (397m), R10 (120m) and radial R8 with an average length of 483m. The slopes of the radials are 1.63°, 1.29°, 1.43° and 1.06° respectively.

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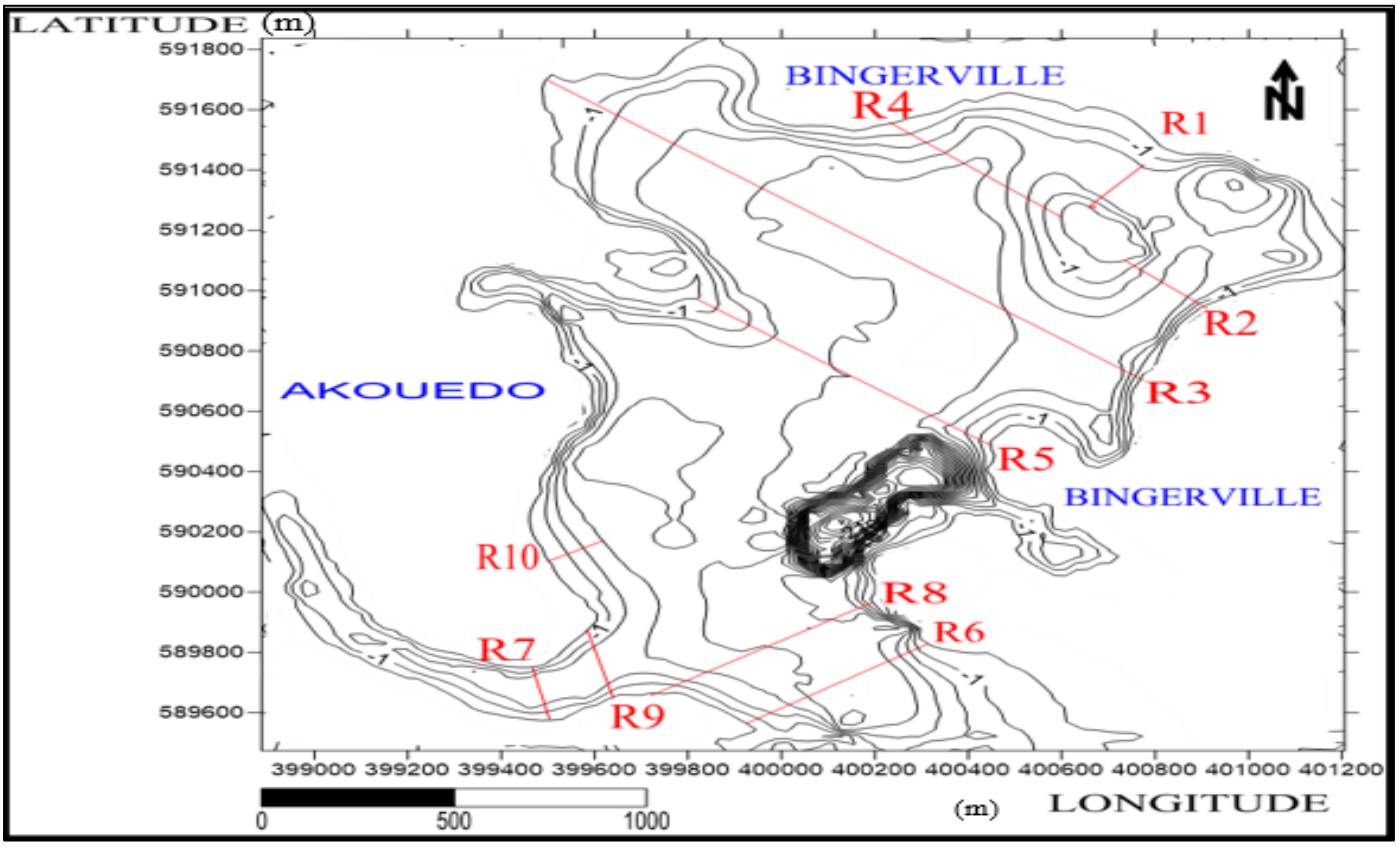

Fig 8: Radial Position Map

Examination of the profiles from the ten (10) radials revealed three (3) channel shape models. The 'U' channel, the 'V' channel and the intermediate type.

The U-shaped channels are represented by profiles 6, 7, 8, 9 and 10. From east to west on the bank, they have a monotonous or even flat morphology. The slope is average (1.63°) from the bank to the islet (figure 9). The 'U'-shaped channel is a profile of equilibrium of action between the agents of accumulation and the agents of erosion [11]. It reflects deposition and therefore stability between the agents of erosion and deposition.

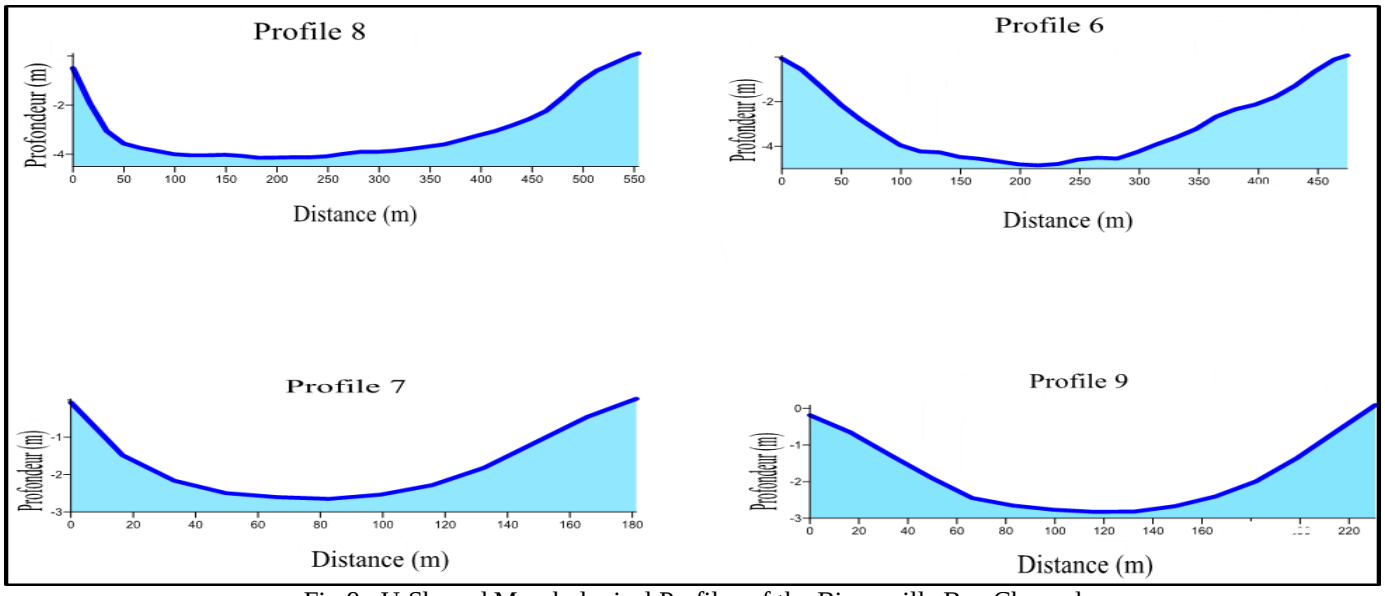

Fig 9 : U-Shaped Morphological Profiles of the Bingerville Bay Channel

Morphological profiles 1, 2 and 4 have angular cavity curves (figure 10). The channel has a 'V' type morphology. This profile is the result of the mechanism responsible for the formation of the erosion, which could reflect a deposit of sediment due to erosion and transport movements.

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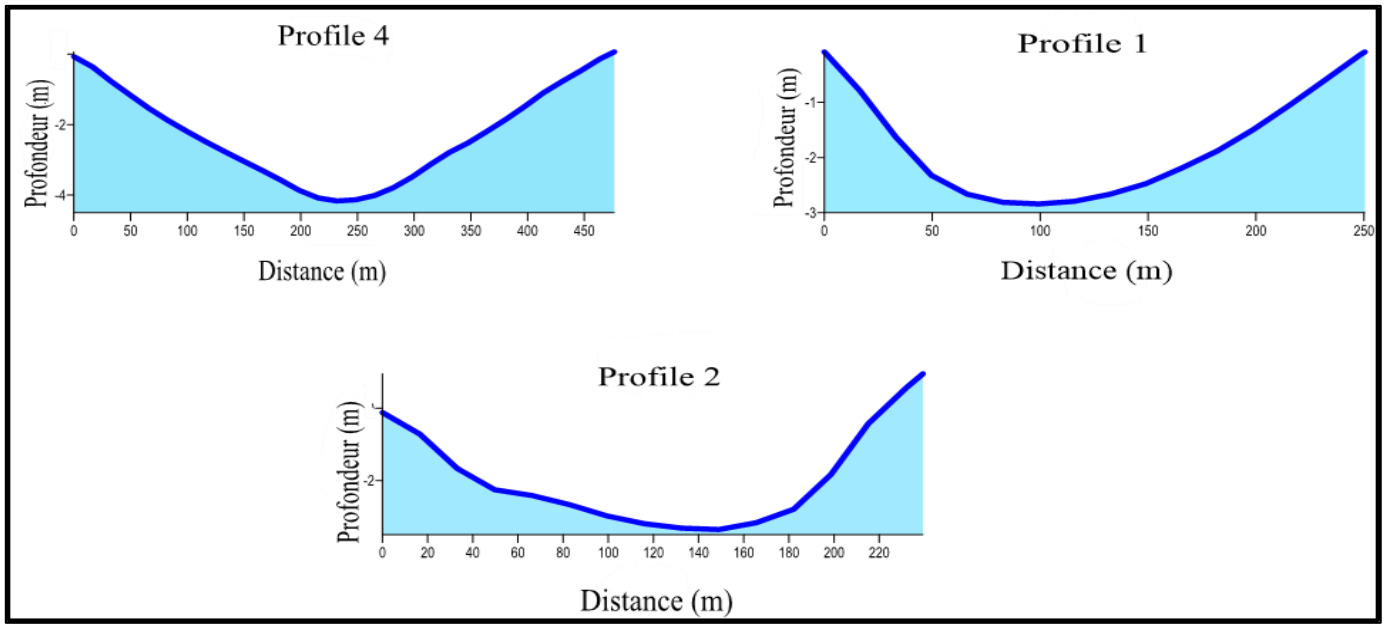

Fig 10 : V-Shaped Morphological Profiles of the Channel in Bingerville Bay

Profiles 3 and 5 have an intermediate morphology between the 'V' type and the 'U' type (figure 11). The intermediate channels also have an unstable shape between the V-shaped channel and the U-shaped channel. The action of the accumulation agents and that of the erosion agents do not balance each other out. Erosion agents have a more intense action than accumulation agents. They make it possible to monitor and understand the evolution of an erosion profile, which is characterised by the transition from a 'V' profile to a 'U' profile [11]. The variation in the relief of the lagoon floor can be due to several mechanical, chemical and physical phenomena [12].

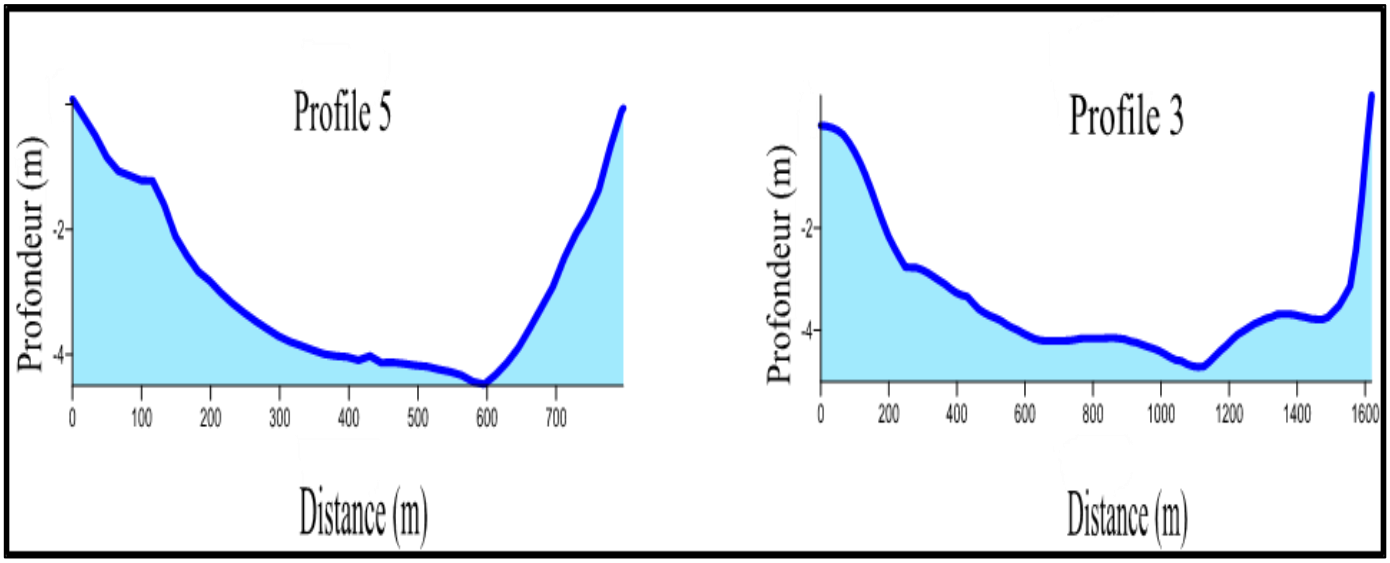

Fig 11 : Intermediate Morphological Profiles of the Bingerville Bay Channel

D. Characterisation of Hydrochemical Parameters in Bingerville Bay

Through the physico-chemical parameters, we will assess the potability properties of the water in Bingerville Bay, which is subject to high levels of anthropogenic activity. The various water samples were taken at a depth of 1 (one) metre at the 5 (five) water sampling stations.

Table 2: Concentrations of Hydrochemical Parameters

	S1	**S2**	**S3**	**S4**	**S5**
pH	7.2	6.8	7.2	7.3	6.9
Temperature (°C)	26.7	27.5	26.9	26.9	26
Conductivity (us/cm)	4540	3730	2360	3790	2380
Dissolved oxygen (mg/l)	5.97	5.61	6.77	6.87	6.63

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➢ *Changes in pH*

In Bingerville Bay, the pH measured varies between 6.8 and 7.3. These values are below 7 at station S5 and above 7 at stations S1, S2 and S4. These different levels of pH variation show that the water is acidic and neutral. They reflect levels that comply with WHO rules on water potability (figure 12).

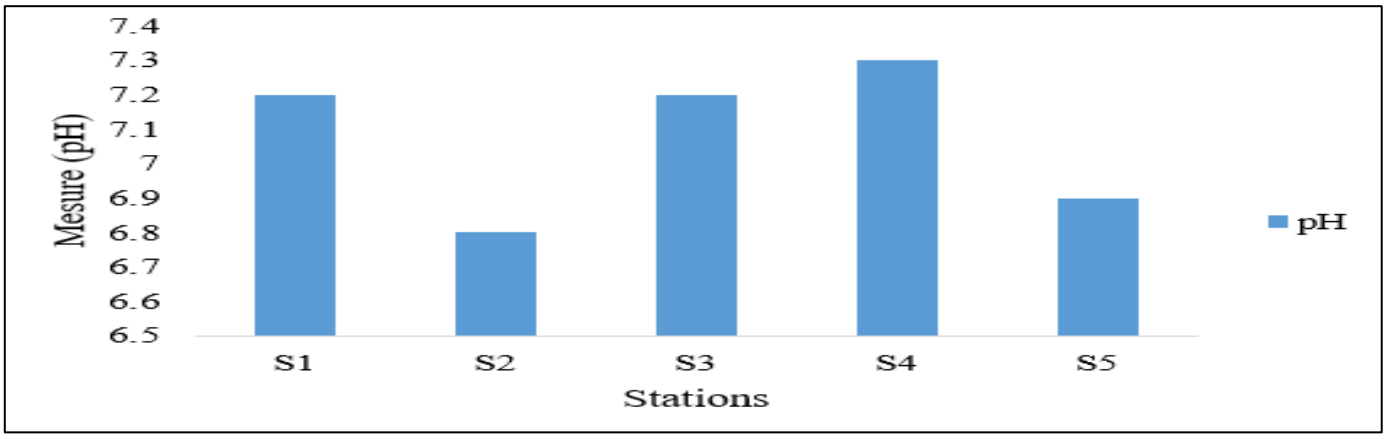

Fig 12 : Temporal Variation in pH

➢ *Temperature Trends*

The temperature between 26 and 27.5 shows a variation which respects the intervals of the WHO standards. It indicates temperatures between 25° and 30°c. Station S2 has the highest value, close to 30°C (figure 13).

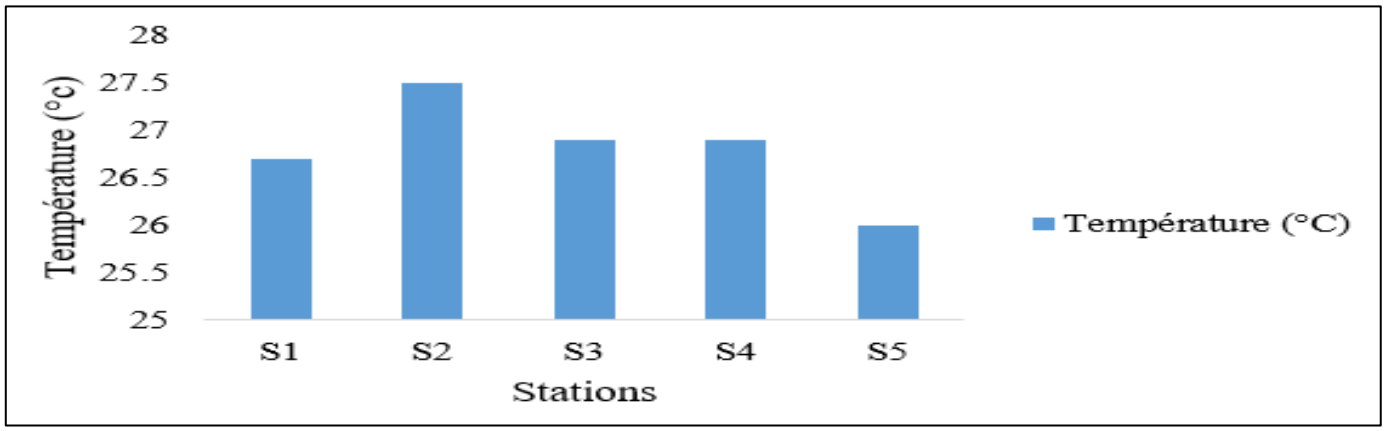

Fig 13: Temperature Variation Over Time

➢ *Changes in Conductivity*

Observation of conductivity concentrations at the various stations reveals values between 1000 and 3000 us/cm (S3 and S5). We also note levels above 3000 us/cm (S1, S2 and S4) (Figure 14).

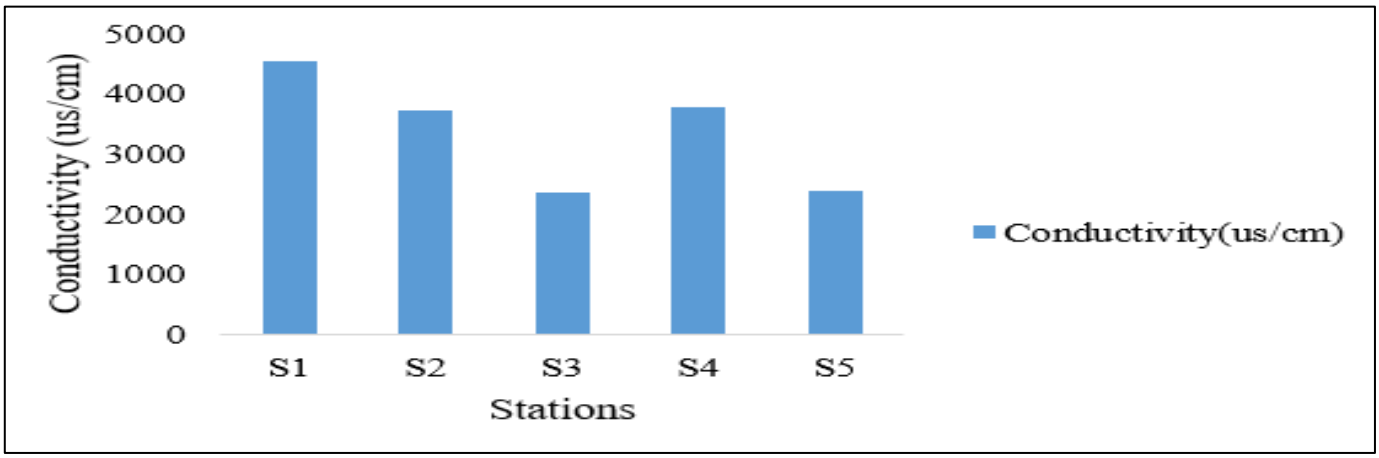

Fig 14: Temporal Variation in Conductivity

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➢ *Changes in Dissolved Oxygen*

Dissolved oxygen concentrations vary between 5.61 and 6.87 mg/l. Station S2 records a low concentration. However, the highest concentration was recorded at station S4. According to WHO standards, these values are between 5 and 7 (figure 15).

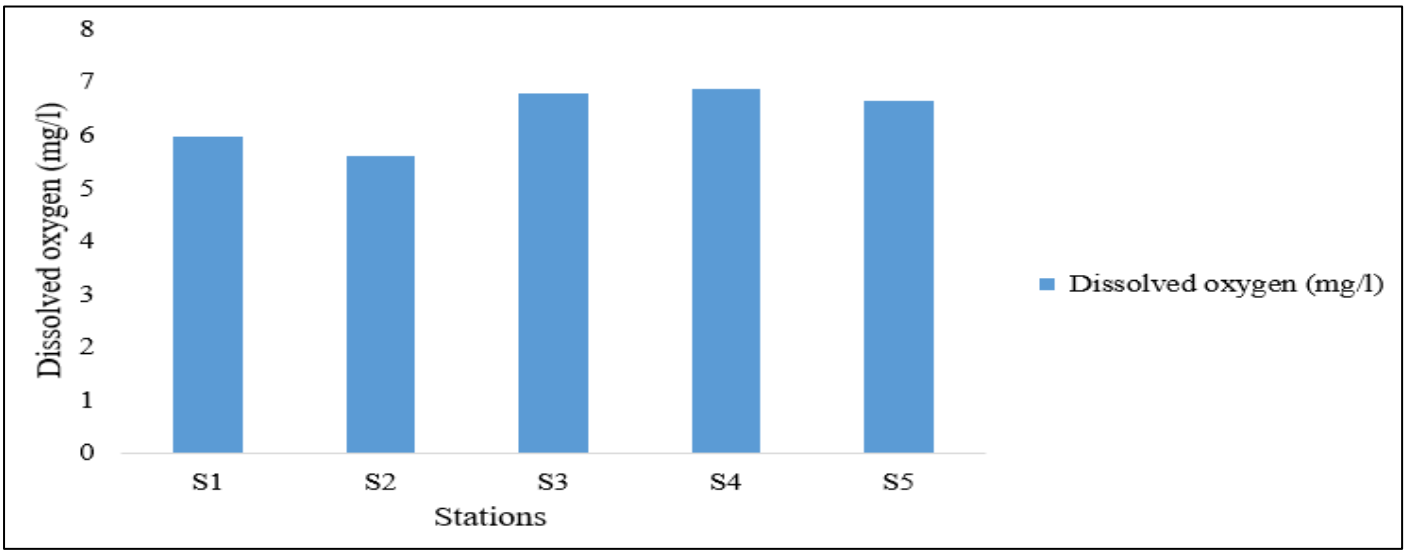

Fig 15: Temporal Variation in Dissolved Oxygen

IV. DISCUSSION

The results obtained from the morphological study reveal the existence of U-shaped channels in Bingerville Bay. They are the most abundant in the bay and reflect a balance between the agents of accumulation and erosion [13]. These channels are characteristic of glacial environments [14]. In Côte d'Ivoire, in fluvial environments (bays, lagoons and rivers), most of the fluvial, lagoon and estuarine channels encountered are of the 'V' type [10, 15, 16]. The V-shaped channel reflects erosion due to factors such as currents and relief [17]. According to [18], U-shaped channels mark a glacial period. The last glaciation occurred in the interval (115000-10000 BP) and is known as the Würm glaciation. Given the origin of the formation of the lagoons, the Würm glaciation could have an effect on them [11]. Thus, there should only be 'U'-type channels if we consider the presence of an ice age in the Ebrié lagoon. V' type channels have been observed in certain areas of the Ebrié lagoon, including the bays it contains. If we accept the existence of natural 'U' type channels in the Adiopo-Doumé bay, this would mean that the bay was affected by glaciation. Similarly, if we accept the existence of artificial 'U'-shaped channels, this would mean that the 'V'-shaped channels have been modified into 'U'-shaped channels by dredging and the sediments brought in by run-off water [7]. These results are similar to our work in Bingerville Bay. This anthropogenic activity is characterised by the presence of depressions. These depressions are responsible for the various changes observed in the channels. These depressions reflect very agitated hydrodynamic conditions that modify the morphology of the channels.

Examination of the hydrochemical parameters revealed that the pH varies between 6.8 and 7.3. The water is more or less acidic and neutral. According to WHO guide values [19], pH values between 4.5 and 10 have no impact on water quality. These values are similar to those obtained in Adiopo-Doumé Bay (6.48 to 7.9) by [7] and [20] in Banco Bay (6.69 to 6.9). Temperatures ranged from 26° to 27.5°c. These values are between 25° and 30°c according to WHO standards [19]. In relation to WHO potability standards [19], this water is mediocre and confirms the work of [5] in the bays of Cocody, Banco and M'badon. Conductivity concentrations fluctuate between 1000 and 3000 us/cm and qualify the water in Bingerville Bay as saline or highly mineralised according to WHO standards [19]. The electrical conductivity concentrations of water from the Abouabou Bay borehole vary between 2920 us/cm and 3040 us/cm [21]. They are also within the range of WHO standards and are in line with the conductivity levels measured in the waters of Bingerville Bay.

V. CONCLUSION

The study carried out on Bingerville Bay provided an insight into its morphobathymetry and the consequences of its transformation on physico-chemical parameters. This study was carried out because of the morphological transformations that bays generally undergo. This transformation is due to run-off and human activities (domestic, industrial and other wastewater discharges). In addition, knowledge of the morphology of the bottom of Bingerville Bay during this study contributed to a good understanding of the different variations in water depth through the bathymetric maps produced. Bingerville Bay has an average depth of 13m and a maximum depth of 26m over a surface area of 2.59Km^2. Morphologically, it is characterised by depressions and shoals. The latter have reached maturity, forming a veritable island colonised by vegetation. Analysis of the 2D and 3D bathymetric maps has enabled us to better appreciate the morphology of the bay and the direction of water run-off. Analysis of the slope map reveals the existence of two types of bank : low-slope banks located (North-West) and (South-East), and steep-slope banks located (North-East) and (South-

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West). Analysis of the channels reveals three (3) morphological types. However, we note the presence of channels resulting from erosion processes (V shape) and channels with an intermediate profile indicating an evolution from (V) to (U) type.

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