HYDROGRAPHY OF THE OCEAN COAST OF THE BELGIAN CONGO.

(Extracts from a Paper presented to the Association for the Study of Civil Engineering and River Hydraulics of the University of Liege by J. TRIQUET, Hydrographer attached to the Colonial Ministry and Head of the Dredging Department of Lower Congo, Director of Inland Waterways, with introduction by Mr. R. SPRONCK, Mining Engineer, Professor at the Faculty of Sciences.)

The maritime reach of the Congo river is divided into three widely differentiated parts :

From Matadi, immediately below the rapids, over a stretch of about 50 kilometres, the river flows between narrow banks never more than 2 kilometres apart, and is very deep.

Opposite Boma the width of the river bed, including Princes-Island, is 4,5 kilometres.

Between Boma and Scotchman Head over a stretch of about 60 kilometres following the navigable channel, the river spreads out, and reaches a width when passing through the Congo Yella plains, of some 19 kilometres including Mateba island. Here the river is dotted with alluvial islands, is shallow and the sandy bottom is constantly shifted by the current. Between the two narrows of Fetish-Rock and Kisange, over a 35 kilometre stretch, is the "meandering area" within which navigational difficulties are found ; the depths in this region limit the draught of vessels calling at the ports of Boma and Matadi.

Finally, from Scotchman Head to the sea, over a 27 kilometre stretch the bed of the river consists of a deep trench surrounded by creeks and low-lying islands.

The maritime reach separates the Belgian Congo from Portuguese Angola. Between Banana point and Padron point the mouth of the river is about 10 km. wide (fig. 1). To the North of Banana, the Belgian Congo Coast is about 40 km. long, extending up to the Portuguese enclave of Cabinda. The Belgian post for the pilotage of vessels through the passes is at Banana. The mouth of the "Zaïre" (Portuguese name of the river) was discovered in 1482 by Diego Cao, who landed on the peninsula of the South of Banana and, to proclaim possession, erected a monolith or " padrao " there.

As is well known, the rate of discharge of the river in its maritime stretch varies comparatively little ; regular river conditions consist in a slight fall in February-March, a slight rise in May, a very appreciable fall in July-August, the waters reaching their highest level in December. In any average year the discharge volume varies between 30,000 and 60,000 m3/sec.

In addition to its tropical latitude, the whole of this area of the Congo estuary is characterised by low-lying shores and extensive marshland.

Even previous to the last war, the steps taken to improve this waterway had made the maritime stretch of the Congo the busiest centre of traffic along the western coast of Africa between Dakar and the Cape.

There is no doubt that the important improvements that have already been carried out in the region, over a period of many years, are in large part due to an increasingly complete knowledge of river conditions and the action of the water on the different types of river-bed. The usefulness of the hydrographic surveys in this connection is no longer questioned.

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Among the old charts of the lower part of the river, the most important as far as maritime soundings are concerned, is the chart published in London for the first time in 1901, plotted from a survey made in 1899 by the officers of the British vessel *Rambler.* The various British and American charts afterwards published are the result of adjustments made to this chart.

The source of the soundings plotted on the charts of the maritime reach published by the Inland-Waterways Department of the colony, is either the *Rambler* chart or the partial surveys made at different times by the Department.

In 1933 the Hydrographic, Navigational and Nautical Meteorology Departments of the Portuguese Naval Ministry published a chart of the rio Zaïre (Congo) which covers the mouth of the river and the North coast of Angola. This chart was plotted from a survey made in 1933 under the direction of Commander Dias.

It may also be noted that the 1938 edition of the General Bathymetric Chart of the Oceans plotted by the International Hydrographic Bureau, Monaco, figures approximately the depth contours off Banana.

The publication by the Geological Society of America in 1939 of the article by A.C. Veatch and P.A. Smith on Atlantic submarine valleys is accompanied by a separate chart to scale of 1 : 210 000 of the estuary and of the submarine valley of the Congo river which reproduces all available soundings west of the limits of the above-mentioned Portuguese chart of the river Zaïre (See : E.J. Devroey : *La Vallée sous-marine du fleuve Congo* (Congo River Submarine Valley)—*Bulletin des Sciences de l'Institut Royal Colonial* XVII-1946-3).

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With regard to tides, the two nearest ports to Banana are Pointe-Noire, in French Equatorial Africa, and Saint-Paul-de-Loanda, in Portuguese Angola (See : Fig. 1).

Tide Tables for Pointe-Noire are published by the Hydrographic Department (Tides and Geophysics Division) of the French Navy. They were formerly contained in a small volume covering the French Atlantic Colonies but are now given in the Tide Tables for French Overseas Territories.

These Tables are drawn up from short-period observations dating from 1912 and supplying only approximate values for the harmonic constants. It follows that the levels given for HW and LW (incidentally expressed in decimetres) are relatively lacking in accuracy.

The Tide Tables of the Portuguese Hydrographic Department give values of far greater accuracy for Saint-Paul-de-Loanda. They are based on the harmonic analysis of one year's tidal curve.

In both cases the tide presents a noticeable diurnal inequality, its largest range being ± 2 metres.

The first observations made at Banana appear to date from 1923/24 under the direction of the hydrographers Claeyssens and Mayaudon.

The expediton sent to the Congo in 1929 by the Association for the Study of the Lower Congo, commanded by *Ingénieur des Ponts et Chaussées* Garbe, France, made tidal observations in the Bay of Banana ; tidal observations were also made by the Inland Waterways Colonial Department on several occasions, but mainly in 1935, using a Gurley limnigraph transformed into a makeshift tide-gauge.

From a comparison of the results of these observations with the above-mentioned Tables it was possible to deduce that the heights of HW and LW differ only very slightly from those of the two neighbouring ports.

As a rule the tide increase lasts slightly longer than its decrease.

Corrections for the transference of hours predicted for Pointe-Noire and Saint-Paul-de-Loanda to the corresponding hours for Banana are irregular and show great uncertainties during neaps because of the slight range of the tide.

Moreover, approximate methods of prediction through reference to a neighbouring standard port are relatively untrustworthy in the case of any appreciable diurnal inequality.

The tide, although rather slight, can nevertheless make itself felt up as far as Matadi. It is not the intention to emphasise here the importance that an accurate knowledge of the tidal flow in the estuary may present in the future, although present-day practice guarantees a minimum anchorage in the channels, whatever may be the condition of the waters.

A few years ago the Portuguese Hydrographic Department began the publication of tidal prediction tables for " Ponta Padrao " (rio Zaïre) opposite Banana on the Portuguese side of the river (1).

The tables are derived from one year's (October 1931-September 1932) continuous tidal record. The harmonic analysis of these observations, worked out by the Doodson method, has shown no less than 60 component waves a large number of which, however, have amplitudes of a few millimetres. The only components the range of which exceeds 5 cm. are those

(1) Ministerio da Marinha, Lisboa, 1947.—Tabelas das Marés para a ano de 1948.

mentioned in Table I (except for wave O_1). For the predictions a 16-wave Kelvin machine is used.

The tide at Banana is practically identical. Neither the observations nor the necessary equipment permitting the resumption of the remarkable work done by the above-mentioned Department are at present available. The recent examination made leads to reconsideration of the question of constants relating to long-period constituents and possible corrections brought to these constants may lead to a slight revision of the whole question.

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CONSTRUCTION OF THE CHART OF THE BELGIAN CONGO COAST.

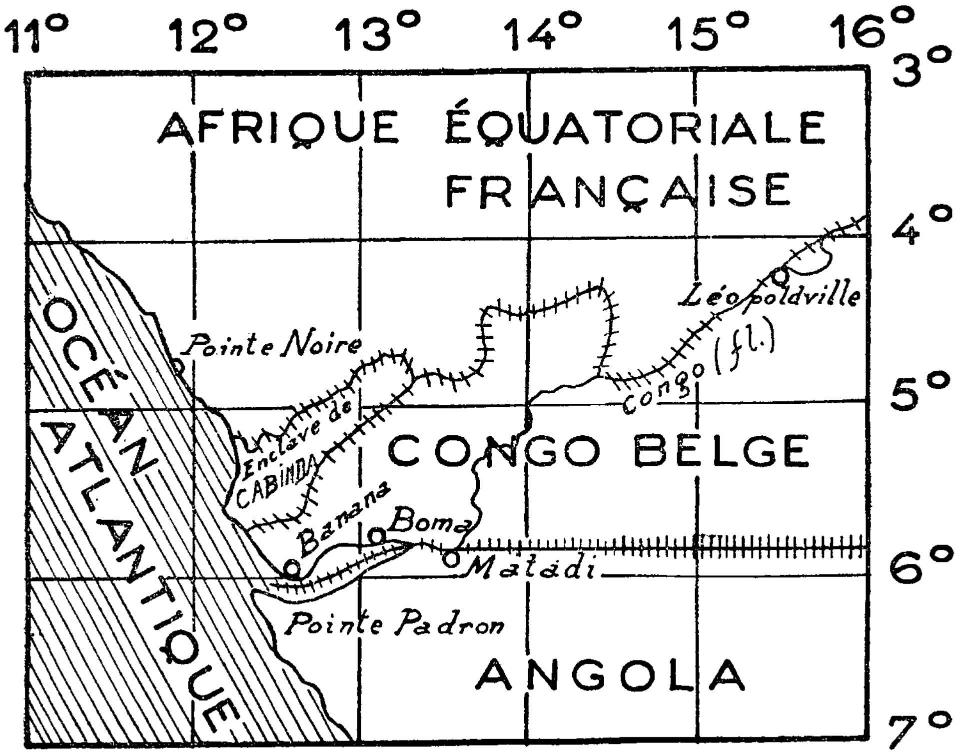
In 1934 the Inland-Waterways Colonial Department had begun the survey of the mouth of the Congo, but lack of technical equipment and the necessity for directing the operations of the surveying parties towards improvement of the meandering area of the lowest branch of the river, prevented its undertaking the coastal survey at that time.

Nevertheless the work remained on its programme.

In 1938, during an interview between the Head of the *Bas-Congo* Division and the Commander of the Belgian Training Ship, the possibility of participation by the "Mercator" in the hydrographic survey of the Congo coast was discussed, and this led to the Colonial Ministry's approaching the Belgian Naval Administration with a view to obtaining the co-operation of the Training Ship in the projected survey. An agreement in principle was arrived at and it was arranged that for this purpose the "Mercator" would proceed to the Lower Congo early in 1940.

The Inland Waterways Department, anxious to be ready in good time, had made all necessary preparations as early as 1939 and triangulation had been carried out along the coast with a view to the setting up of signals intended as markers for the determination of sounding points.

The preparatory work was pushed forward to completion and in December, 1939, the survey of a belt of land along the whole coast and extending about 10 kilometres inland was carried out. The invasion of Belgium in May, 1940, compelled the "Mercator" to interrupt her training cruise and to take refuge in the Belgian Congo.



It was decided that the Training Ship would be used as a base for a party sent out by the Inland Waterways Department and that, since she had an echo-sounding machine, she would be detached for sounding the lower depths while the motor-launch of the surveying party would be employed in shallow and medium depths.

The hydrographic staff of the Colony consisted of two European surveyors, a native assistant-surveyor, two leadsmen, two seamen and two mechanics. The assistant-surveyor, a native of the Lower Congo, was self-educated and had been taught to read and to use a sextant as well as to plot positions on a chart.

The party had a minimum amount of equipment : three sextants, two field-glasses, one station pointer and a Warluzel sounding-machine.

Operations began on 4th September, 1940, and were carried on until 17th December of the same year.

The signals set up for the purpose of the maritime survey (makeshifts contrived out of native materials including tree-trunks, varieties of bamboo and tropical creepers) were connected to the geodetic triangulation of the Mayumba. Their minimum height was 15 metres, which rendered them visible at nearly 20 kilometres' distance to observers on the bridge of the motor-launch.

Owing to the limited extent of the projection survey—30 kilometres' length by 20 kilometres' width—it was decided to use rectangular plane-projection which in equatorial regions differs very little from the Mercator projection.

The scale of 1 : 30 000 was chosen for the working sheet. This made it possible to plot a close survey on it and to determine readily by stigmograph the total of points taken during sounding operations.

As it was a question of work done for the first time by the Inland Waterways Department and as the character of the river-bed and its slow rate of variation encouraged the belief that it would not often be necessary to repeat it, it was decided that profiles should be parallel to, and only 350 metres distant from, one another in order that as faithful a representation as possible of actual conditions might be obtained.

The selection of the direction of the sounding profiles is of great importance in accurate charting. Care must be taken to keep them invariably almost perpendicular to those of the isobaths so that an accurate drawing of the depth contours can readily be obtained.

Swell and surf combined with the slight inclination of the coastal strand, prevented starting from points on shore. Large profiles were necessarily begun at a distance from the coast varying between one and two kilometres.

The launch went inshore as far as points 1.50 to 2 metres deep and anchored there. Having determined the anchorage position on the working sheet by the use of three subtended angles and having marked from it the lay of the direction assigned to the profile in relation to a known point on the coast, the operator could follow by means of the sextant and field-glasses the prolongation of this profile towards land and would fix it in his mind by means of one landmark in the foreground, i.e. on the shore, and another in the background, i.e. as far as possible inland.

Soundings were made by means of a 30 kg. fish-lead suspended from a special steel cable 1 millimetre in diameter, divided into 20 centimetre sections up to 20 metres and into 50 centimetre sections up to 50 metres. The equipment was operated by means of a patented windlass commonly known as the "*Warluzel* sounding machine".

In sounding with such equipment, however, the immersed part takes the shape of a curve which approaches the catenary enabling soundings to be corrected accordingly. At a speed of from three to four knots the correction may vary between 10 and 50 centimetres for a depth of 10 metres, for a depth of 20 metres it often exceeds 30 centimetres, occasionally reaching 1.30 metres, and for a depth of 50 metres, it is almost always greater than 1 metre.

The curve correction to soundings is made by the operator simultaneously with the depth reading. In this connection the recorder uses a correction table previously drawn up in terms of the announced depth and the estimated inclination of the cable. At regular intervals the leadsman announces a figure and the recorder enters the corrected figure.

The soundings off the Congo coast were made at intervals of 15 seconds, thus assuring a depth measurement approximately every 30 metres.

Their position on the chart was marked every two or three minutes by a sextant measurement of two adjacent angles between three topographical signals on the coast. The time of each position was carefully noted and as on the other hand the variations of the water-level were observed every 15 minutes according to the Banana tide-gauge, it was possible later on to reduce the soundings to chart datum. The datum, chosen as the origin of the soundings, passes through the zero of the Banana tide-gauge.

The tide-gauge zero is 2.34 m. under the upper surface of the R bench-mark at Banana ; it is slightly lower than the lowest low water observed.

During the survey of the Congo coast 1,900 kilometres of profiles were surveyed and 35,500 soundings made. The marking of the positions of these required fixing by sextant 4,296 positions. The nature of the upper layer of the sea-bottom was regularly observed after every 10 soundings and 68 bottom samples were taken for analysis. Meteorological observations were made by officers of the "Mercator" and measurements were made of speed and direction of the surface current, of wind and of swell.

Unfortunately the lack of personnel in the Inland-Waterways Department of the Colony since, has so far prevented the sorting and analysis of these observations. The only result so far possible has been the plotting of a chart to scale of 1 : 50 000, Plate I. The samples of the upper layer of sea-bottom were taken at each of the observed positions by an auxiliary sounder. This operation is carried out by means of an ordinary sounding lead, the cavity of which is filled with tallow which brings up a small amount of the material on the sea-bottom. Samples meant for analysis are taken by means of a small skip or any other type of bottom sample collector.

The extremity of the shoal bordering the Congo coast was sounded in the manner described up to the 50 metre curve. Beyond this depth contour and particularly in the deep trench at the river-mouth, soundings were made by the ultra-sonic echo-sounding machine belonging to the "Mercator".

In accordance with what has been said on the subject of the orientation of sounding profiles, when the distribution of the currents is not yet known it is logical to begin a hydrographic survey by observing the speed and direction of those currents.

On the Congo coast they were fairly well known, so that sounding operations and the drawing of depth contours could be proceeded with from the beginning. This allowed a better distribution of observations in relation to currents.

All along the Congo coastal line, it is the surface current that most affects a ship's track. This is due to the volume of discharge of the river, which is so great that the fresh water carried to sea flows above the salt water and mingles very little with it. At 15 kilometres from land and in fine weather the surface water is brackish. Its density (invariably under 1.010) and its dark brown colour are reliable indications for the navigator coming in from the open sea and seeking the mouth of the river. The speed of these surface currents is great over the entire Congo coast. Off the Belgian Congo frontier and the Cabinda Enclave, i.e. 35 kilometres from the mouth of the river, it still reaches 5 kilometres an hour.

It has been impossible to give any formal opinion as to the existence of two isolated shoals shown on the coastal chart published by the British Admiralty and indicated as being situated at the edge of Mona Mazea Bank. No trace of them was found during operations in spite of the numerous supplementary soundings made over their supposed positions.

However, an isolated shoal of 25 metres was discovered and its position noted, lying right within a deep trench and on a level with the "Ponta do Padrao". This small shoal had been detected and reported by a British corvette equipped with an ultra-sonic sounding instrument. Although the crest was nearly 500 metres long and 100 metres wide, it had nevertheless escaped the notice of the Portuguese Hydrographic expedition which had made a survey of the mouth of the Zaïre river in 1933.

It is hardly necessary to emphasize the usefulness of these maritime surveys. That of the Congo coast is extremely helpful to the navigator as it supplies him with additional information concerning the anchorages at the mouth of the Congo river and it makes landing easier for captains coming in from the North by providing data on the extent of the Mona Mazea bank, enabling them to keep a reasonable distance away from it while entering the mouth of the river.

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EXAMINATION OF THE TIDE AT BANANA.

Table II recapitulates the principal harmonic constants given by the French and Portuguese Hydrographic Services for the mouth of the Zaïre river and neighbouring ports.

In studying tidal harmonic constants in a port, a primary assumption is that the mean level is by definition constant, and in principle the result of the analysis includes all the waves (long-period waves included) which, starting at constant mean level, should allow reconstitution of the true tide.

HARMONIC CONSTANTS.

Components	Black Point (Pointe-Noire)				Rio Zaïre (Ponta do Padrao)		St-Paul-de-Loanda	
	Publication No. 12 of the International Hydrographic Bureau (1926)		Tide Tables of the French Atlantic Colonies 1937		Tabelas das Marés Lisbonne, 1948			
	Demi-ampl. (cm.)	Situation (°)	Demi-ampl. (cm.)	Situation (°)	Demi-ampl. (cm.)	Situation (°)	Demi-ampl. (cm.)	Situation (°)
M_2	(79)	(118)	50	105	48	109	47,5	105
S_2	(28)	(142)	21	142	16	136	15	132
K_2	(8)	(142)	6	142	5	128	4	124
N_2	—	—	—	—	10	105	10	97
O_1	(7)	(181)	2	297	—	—	1	266
K_1	(10)	(199)	12	1	9	15	8	19
P_1	(3)	(199)	4	1	3	11	2	11
S_a	—	—	—	—	8	277	10	322
S_{sa}	—	—	—	—	4	33	7,5	47

Two level-observation periods were selected : from 16th to 22nd September, 1935, and from 23rd to 29th August, 1937. An attempt was made to reconstitute the tide wave from the principal components given for the mouth of the Zaïre river. However, the two long-period waves (yearly and half-yearly) were not entered on the Table.

If the curve obtained by totalising the principal components is compared with the recorded tidal curve referred to a mean level provisionally fixed at 84 centimetres, a steadily progressive rate of change in the level is noted during the 6-day observation period.

The introduction of the previously mentioned long-period waves would have a uniform effect of a few centimetres addition to or subtraction from the component curves. No better result would therefore be obtained. This example leads to the belief that there must exist an influence causing more rapid variations than that of the long-period waves.

The question then arises as to what this additional influence should be attributed.

Anomalies of this kind have been noted over a long period at Banana and this is the significance of the statement that the mean level at Banana varies.

Contrary to what might be believed, the principal harmonic constants can, in the present case, be approximately determined fairly quickly. To compute them in 1st approximation, a method based on a 5-day continuous observation may be used, only the differences of level being taken into account.

In the case of Banana, only the following primary waves will be considered : M_2, N_2, S_2, K_2, K_I and P_I.

The components K_I and P_I on the one hand and S_2 and K_2 on the other hand having almost the same period, the computations are simplified by combining them two by two.

From the graphs obtained, the ranges and approximate situations of S_2, K_2, P_I and K_I are deduced and there is thus obtained :

Components	Ranges (cm.)			Situations (°)		
	1st computation	2nd computation	Means	1st computation	2nd computation	Means
M_2	55,27	55,32	55,3	132	96	114
N_2	11,07	16,83	14	348	50	19
S_2	—	—	22	—	—	105
K_2	—	—	23	—	—	185
K_1	—	—	6	—	—	8
P_1	—	—	2	—	—	3

It is understood, of course, that the same computations should be repeated for a larger number of similar series of observations. The above values are given, therefore, only as *first approximations.*

The causes to which the variation in mean level may be attributed remain to be examined.

The long-period waves given by the Portuguese Hydrographic Department are primarily the yearly and semi-yearly solar constituent tides.

It is generally admitted that the first, and the most important, of those waves results principally from the monsoons, which are regular winds, caused by unequal heating, reversed according to the seasons, of land and sea. In the warm season, the continent draws air and the wind from the sea blows in towards land while in the cold season the reverse is the case.

At Banana, it seems fairly evident that the yearly and semi-yearly waves which cause perturbation of the mean level cannot be attributed to these winds. Weather observations made by the Master Pilot from 1st April, 1941, to 31st March, 1942, show in fact that the direction of the wind towards land and that of the swell are relatively stable throughout the year.

One may ask whether the mean-level variations at Banana cannot be attributed to regular conditions on the Congo river and to the volume of its discharge. Examinations of a few simultaneous observations made at the Boma and Banana tide gauges leads to the belief that the risings of the river are felt as far as Banana Bay. Unfortunately the number of these observations is much too limited to permit any positive opinion. If it were a matter of a tideless sea, the question would be simple. In their work entitled : *Le Bas-Congo, artère vitale de la Colonie,* Messrs. Devroey and Vanderlinden have pointed out that the place is a few metres away from the Ocean and that, consequently, mean-level variations at Banana cannot be attributed to a variation in the slope of the river. They have sought for an explanation of these fluctuations in the difference of the densities of fresh and salt water and in the variations of mean volume of the superficial layer of fresh water flowing above the sea water. It remains to be seen whether this is sufficient to explain the fall in mean level of tides—a phenomenon of dynamics.

It might also be asked whether the fact of a sort of choking at the mouth might not explain a comparatively marked variation of mean level.

Finally, another cause of perturbation, which ought to be taken into consideration, resides in the variations of barometric pressure. At Banana, these rise from a mean of 757 millimetres in December to a mean of 763 millimetres in July and it seems as if they might better explain the abrupt and irregular changes in mean level than the variations of wind or rising of the river do.

To sum up, one important point is now settled : the existence of an additional change, which might very well not be harmonic, influencing the mean level, of the mouth of the Congo. The exact cause of it remains to be determined, but this does not hinder the fact that even now good tidal predictions are available.

Since this one point remains to be cleared up, no conclusion can be reached at present but only until careful and continuous observations have been made at Banana of the tide, the wind and barometric pressure, combined with observations of the rise of the river at Boma.

The results of such observations will be duly communicated to the International Hydrographic Bureau, Monaco, which, in conformity with the resolution adopted at the Fifth International Hydrographic Conference, is at present conducting global tidal investigations.

The U.S.A. Coast and Geodetic Survey has generously offered its services to the International Hydrographic Bureau in connection with the execution of this programme by proposing to carry out for any State concerned the harmonic analysis of observations supplied.