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Stratigraphic Data and Groundwater Resources in the Coastal Sedimentary Basin of the Pointe-Noire Region (Republic of Congo)

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Abstract

The synthesis of geological and petroleum research undertaken in the coastal Sedimentary Basin of the Pointe-Noire region enabled the establishment of a lithostratigraphic scale. It has been observed that the order in which the series observed in outcrop and those encountered by deep wells succeed each other has allowed a value to be given to this relative scale. The study area corresponds to a longitudinal tectonic accident, fault or flexure. It belongs to the Cretaceous and Tertiary coastal sedimentary basin covered by the Plio- Pleistocene age formations (series of circuses), formed of highly permeable sands comprising multiple resistant horizons that store large bodies of water whose reserves are considered very important. Hydrographic network is composed of four main basins with a mediocre size. The quality of this groundwater is considered to be satisfactory for household consumption, but the sustainable management of these reserves requires constant checks on their quality as well as on the level of the reserves. All these resources put the agglomeration of Pointe-Noire close to large exploitable water reserves that meet the need for drinking water, even if, on the whole, the agglomeration is still experiencing many difficulties in terms of its drinking water supply.

Keywords

Geological, Stratigraphic Scale, Groundwater Resources, Coastal Aquifers, Sedimentary Basin, Pointe-Noire

1. Introduction

For more than two decades, harnessing the potential of water resources has been one of the priorities in the economic and social development plans of Pointe Noire/Republic of the Congo region. A number of research studies [1] [2] [3] [4] [5], and monitoring projects [6] [7] [8] [9] have been carried out since the 1980s to assess the hydraulic potential of these reservoirs. However, the results obtained on knowledge of water resources are still insufficient compared to the challenges of this region: 1) the ever-increasing population of the region, which is increasing the demand for water and the need for hydraulic structures that have not yet been fully met; 2) growing demand for water for agriculture and industry needs; 3) climatic variability that can lead to a decrease in groundwater recharge and groundwater supplies; 4) the risks of actual pollution of the water tables by salt intrusion on the one hand and by domestic and industrial discharges (hydrocarbons, various effluents) and by land use (eucalyptus forests) on the other. Hence there are still uncertainties about 1) the configuration of the aquifer system in the area; 2) the relationships between the aquifers; 3) the hydrodynamic functioning; 4) also the chemical quality of the waters and its evolution over time.

It is particularly important to stress the uncertainties concerning the nature and extent (vertical and horizontal) of the different geological layers or hydrostratigraphic units (aquifers, aquitards) due to a lack of proper evaluation of hydraulic drilling logs and boreholes. The Descriptions provided in very brief logs may lead to misinterpretation in the layout of geological formations.

In this context, the management of the basin's water resources requires a better knowledge of the characteristics of the different hydro systems and also an analysis of the different facies of the geological scale that establish the contact between the sedimentary deposits and the Precambrian basement of the Pointe-Noire region. This knowledge is indeed essential in order to better orient the exploitation and to take into account the necessary protective measures for the preservation of this important resource. The objectives of this study are 1) to establish a lithostratigraphic scale based on geological and petroleum research conducted in the coastal sedimentary basin of the Pointe-Noire region, 2) to describe the potential water resources of this region.

2. Materials and Methods

2.1. Presentation of the Study Area

The region of Pointe-Noire, which includes the city of Pointe-Noire, is located on the Atlantic coast of Central Africa, at the southwestern end of the Congo. It covers an area of about 6000 Km^2 and is bounded on the South West by The Atlantic Ocean, on the North West by the border of the Republic of Gabon, on the South East by the Angolan enclave of Cabinda and on the North East by the Mayombe mountain range (**Figure 1**).

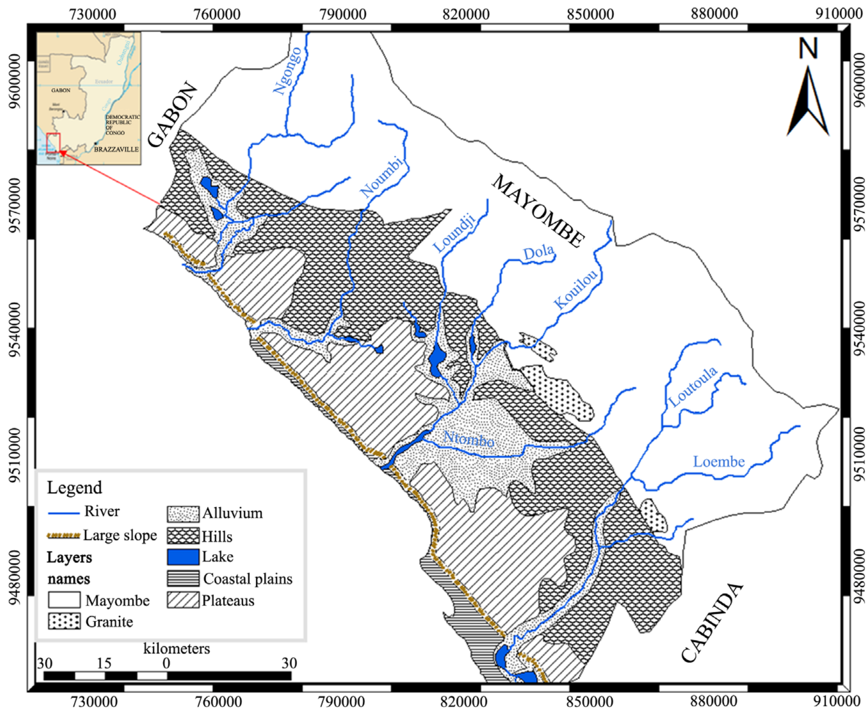

Figure 1. Geographical and geomorphological location of the study area.

Due to its geographical position and its most characteristic features, the study area is an ideal zone of ocean-continent contact where the effects of marine currents and the Atlantic maritime air mass have been reported by Leroux (1975) [10] and Samba-Kimbata (1978) [11]: atmospheric instability due to friction of the wet ocean flow saturated with moisture, greater thickness of the wet layer at the edge of the coast than at the interior of the continent, constant influence of the swells of the Southwest, annual precipitation relatively low on average 1200 mm compared to the whole country. Despite these effects, it is also the zone that facilitates the penetration of the ocean flow into the continent, attracted by the lower zones [12].

Average daily temperatures vary between 22.2˚C and 28˚C with small thermal deviations. The Pointe-Noire region belonging to the Cretaceous and tertiary coastal sedimentary basin is covered by formations of plio-Pleistocene ages other than the series of circuses (**Figure 2**), formed by highly permeable sands with multiple resistant horizons. The FAO classification (1998) classifies the soils of the Pointe-Noire region as belonging to the Ferralic Arenosols group, with a sandy texture (80% - 90%) over 1 meter [13].

2.2. Methods

In order to characterize the water potential of the Pointe-Noire region, it was proposed to analyse all existing geological and hydrogeological data and to synthesize the previous work [1] [14] [15] [16] [17] [18]. The geological synthesis of this earlier work allowed the establishment of a lithostratigraphic scale (**Figure 3**).

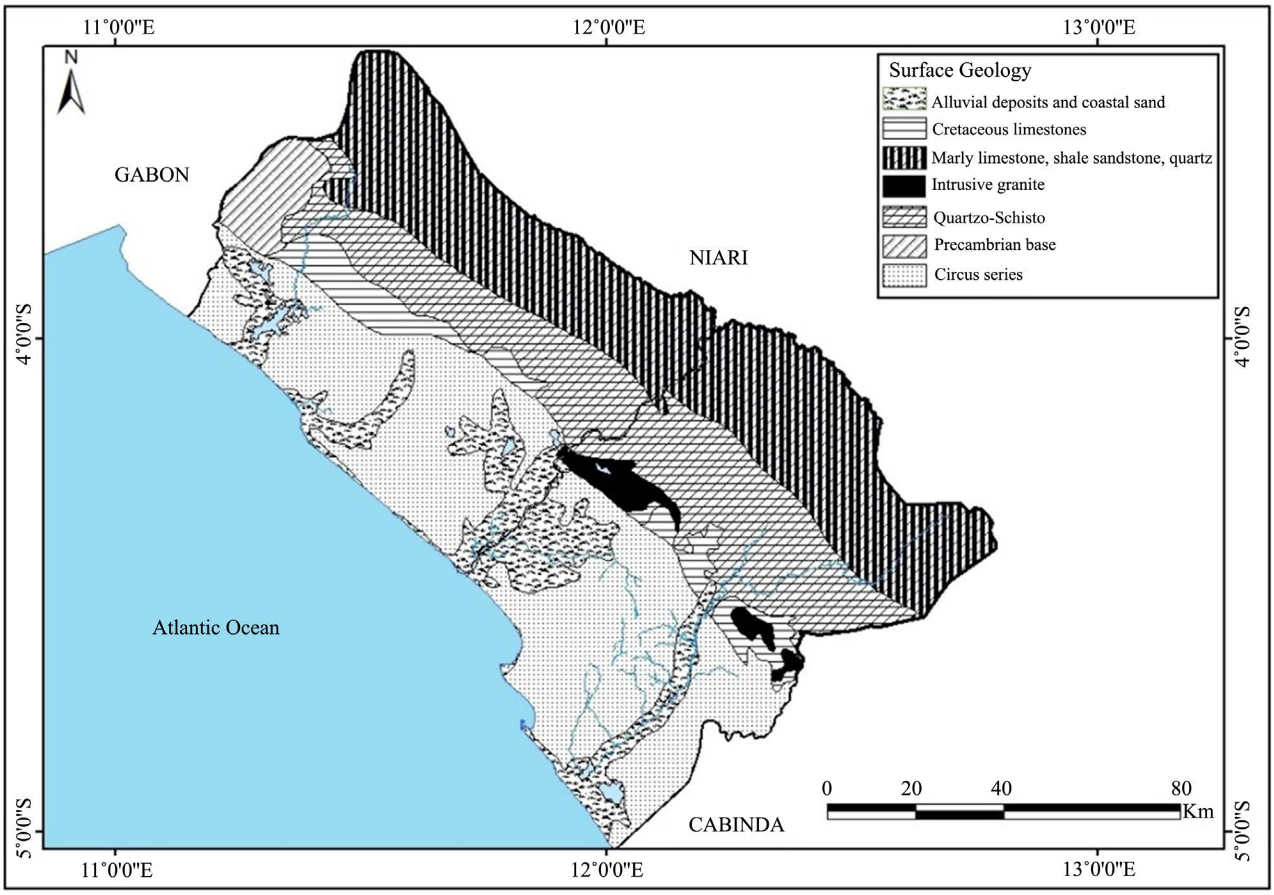

Figure 2. Surface geology.

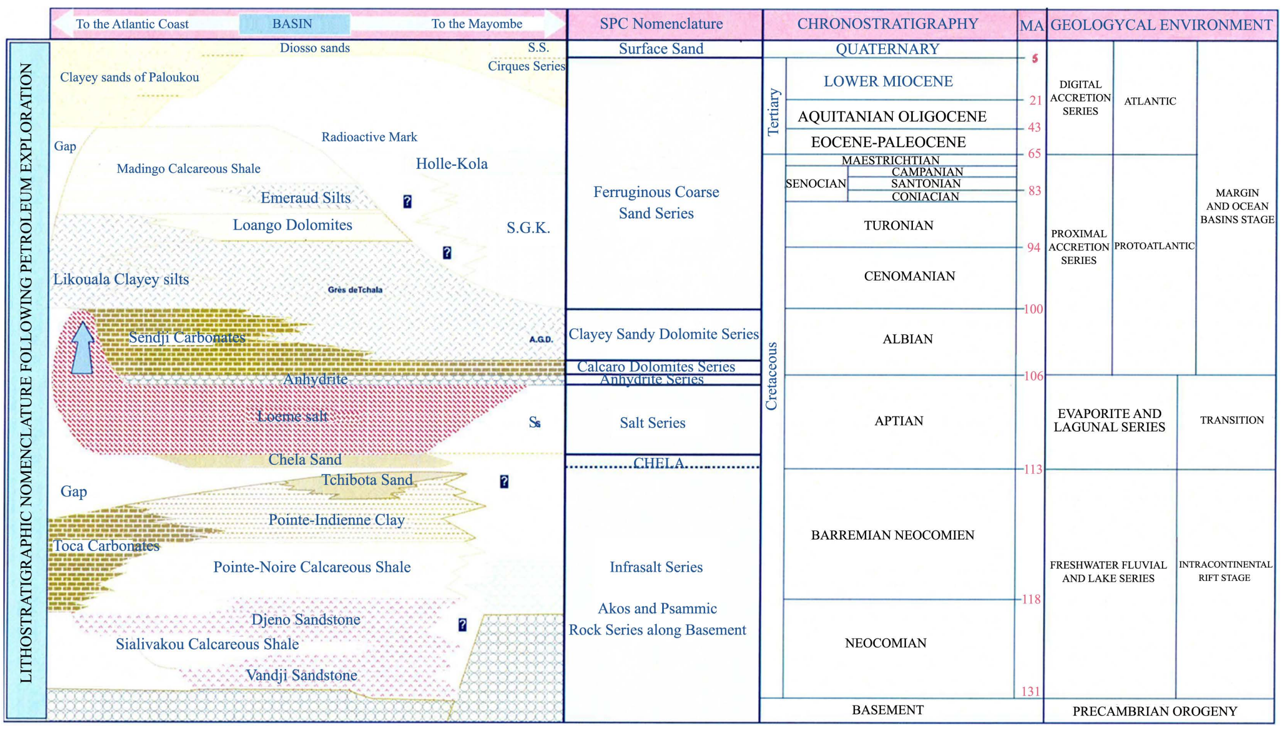

Figure 3. Lithostratigraphic section of the coastal Pointe-Noire sedimentary basin.

It was found that the order in which the series observed in outcrop and those encountered by deep boreholes followed each other allowed a value to be given to this relative scale.

From the synthesis of hydrogeological studies done in the region of Pointe-Noire [1] [18]-[23], it was a question of defining in detail the structure of the different aquifer horizons.

Field observations also provided information on recent water-related practices in the region, as well as on the alternatives put in place by various consumers in the Congolese coastal region.

3. Results

Based on the synthesis of existing work and field observations, The Pointe-Noire region can be said to belong to the coastal Sedimentary Basin of Cretaceous and tertiary age, covered by formations of Plio-Pleistocene ages other than the cirques series, formed by very permeable sands with multiple resistant horizons. The Cretaceous outcrops only along the edge of the Mayombe and in a few windows on the Atlantic Coast. Rare alluvium along the edges of a few rivers completes the cover of this basin.

3.1. Stratigraphic Elements

Our study area corresponds to a longitudinal, fault or flexural tectonic accident. However, the contact between the sedimentary deposits and the underlying Precambrian basement is discordant and indicates a long period of erosion. Lateral discontinuities are observed from downstream to upstream of the coastal Sedimentary Basin. Thus, we observe the following formations from bottom to top (**Figure 3**).

Precambrian: It is formed by a crystallophyllian basement which is outcropping the Mayombe, but in the sedimentary basin it is very deep. This deepening would be due to a longitudinal tectonic accident, fault or flexure. However, the contact between the sedimentary deposits and the underlying Precambrian basement is discordant and indicates a long period of erosion.

Cretaceous: The Cretaceous facies are represented under several stages: Neocomian, Barremian, Aptian, Albian, Cenomanian, Turonian and Maastrichtian.

Neocomian: characterized by sandstone formations ranging in thickness from 50 to 800 m, consisting of alternating feldspar sandstones, sometimes conglomerate, silty grey clays, and a few rare carbon levels; the sialivakou marls, which rest in continuity on the sandstone formations of Vandji, vary in thickness between 130 and 800 m. These formations consist of bituminous marls with intercalations of sandy or silty levels. They are covered by the Djeno sandstone formations with a thickness of between 800 and 1400 m, and consist of alternating clay-carbonate micaceous sandstones, siltstones and organic-rich grey clays.

Neocomian-Barremian: these are Pointe-Noire's marl formations of thickness varying between 300 and 700 m, consisting of bituminous and pyritous marls with intercalations of silty clays and very fine micaceous sandstones.

Barremian: the Indian-Point clays, which are about 1500 m thick, are plastic, sometimes silty and micaceous in colour. They contain intercalations of thin levels of sandstone, siltstones and carbonates. These clays are laterally equivalent to Toca carbonates, Mengo sandstones, and Tchibota sands.

Aptian: the sands of Chela, rest unconformably on all underlying formations. They are made up at the base of polygenic conglomerates surmounted by medium fine sand and sandstones with dolomitic cement and small beds of green clays. At the top are tarry marls rich in pyrite and with traces of anhydrite. Its thickness is between 15 and 60 m.

The Saliferous Loémé formation, an Aptian formation, has a cyclic sedimentation up to 650 to 1000 m thick. Each sequence is formed at the base of bituminous black clays rich in wood debris with rare intercalations of dolomitic banks less than 2 m thick and surmounted by a very thick saliferous level (alternance d'halite, sylvinite et carnallite). The whole cycle is crowned by a Bank of anhydrite about 50 m thick.

Albian: The carbonates of Sendji rise above the Saliferous Loémé series. Its thickness varies between 50 and 1700 m. This stage consists of alternating limestone dolomites, dolomitic limestones interspersed at the top with sandstones, silstones, silty clays and rare anhydrite levels.

Upper Albian, Cenomanian, Turonian: these series are marked by the Likouala silto-Clay formation, which is in continuous sedimentation on the Sendji carbonates. Its average thickness is 300 m. The formation consists of fine and very fine sandstones, clay-carbonate silstones, thin levels of bioclastic limestones, and greenish-grey silty clays.

Cenomanian: characterized by the Tchala sandstone lateral Likouala silt equivalent. With a thickness of up to 500 m, this formation consists of very little consolidated sand mixed with fine to coarse heterometric siliceous cement sandstones interspersed with clays, anhydrites, bariolate clays and clay limestones. It is much more common in the eastern part of the basin.

Turonian: Characterized by the Loango dolomitic formation composed of top to bottom layers of silty clay, siltstones with clay-carbonate cement sometimes passing to fine sandstone, from Grey to beige sandstone, microcrystalline, vacuolar. Its thickness is usually constant of about 100 m.

Maastrichtian: Characterized by the Holle series essentially phosphated. It is based either on sandstones or clays of the Middle Cretaceous Age. On the coast, the current marine erosion dissects and strikes in a pointed form the rock outcrops of the non-phosphated lower part of the Holle series of Senonian Age.

Tertiary: This facies is represented by the different stages from Senonian to Eocene, then Miocene.

Senonian to Eocene: The Madingo marls can reach a thickness of 600 m. This formation is composed of siliceous or Sandy marls interspersed with clay and chalky limestones, silty fossiliferous clays rich in organic substances.

Miocene: It is characterized by Paloukou clay-sand of the ferruginous coarse sand series, which rests in Unconformity on all the post-saliferous formations. This discordance is emphasized by the presence of shreds of an ancient lateritic breastplate. This formation ranges from 100 m on the continental shelf to more than 1000 m in the Slope zone. It is a powerful clay series interspersed with Sands and limestones. It is of particular hydrogeological interest.

Quaternary: it is characterized by the clay-Sandy formations of the Miocene, surmounted by 150 to 200 m of gravelo-sandy deposits mapped under the term "series of circuses" because of the enormous excavations that have crept in. These formations cover about 99% of the coastal Basin area. This series is interesting from a hydrogeological point of view. It consists of a hydrogeological complex including an aquifer system consisting of several overlying aquifers with hydraulic continuity.

3.2. Water Resources Potential

The study area consists of a large depression filled by a complex of plio-quaternary, tertiary, and secondary deposits containing five Water horizons or aquifers.

These aquifers are characterized geologically by their lithology or rock type, which can be established successively as follows (Figure 4).

The shallow aquifer, AQ-1 (unconfined), contains underground water, corresponding to the saturated environment of the most permeable and draining layers of surface Sands. This uncontained free water is a discontinuous unit with an average thickness of about 15 m observed at Pointe-Noire. It is notched in places by ravines and ravines even valleys, where it corresponds to the sands observed in the areas of the plateaus. It consists mainly of fine sands with a variable proportion of silt and clay, dry on the surface and saturated below the level of the underground water, which is generally free. According to the conceptual scheme shown in Figure 4, the thickness of the permeable to impermeable layer of clay separating the AQ-1 and AQ-2 aquifers gradually decreases from the coast inwards until a direct hydraulic link is established by bevelling the impermeable layer around the Mongo plateau.

This aquifer contributes in some places to the supply of water to the rivers via a quasi-continuous transfer, and also from the springs by Resurgence where the local populations are supplied. The recharge of this underground water is carried

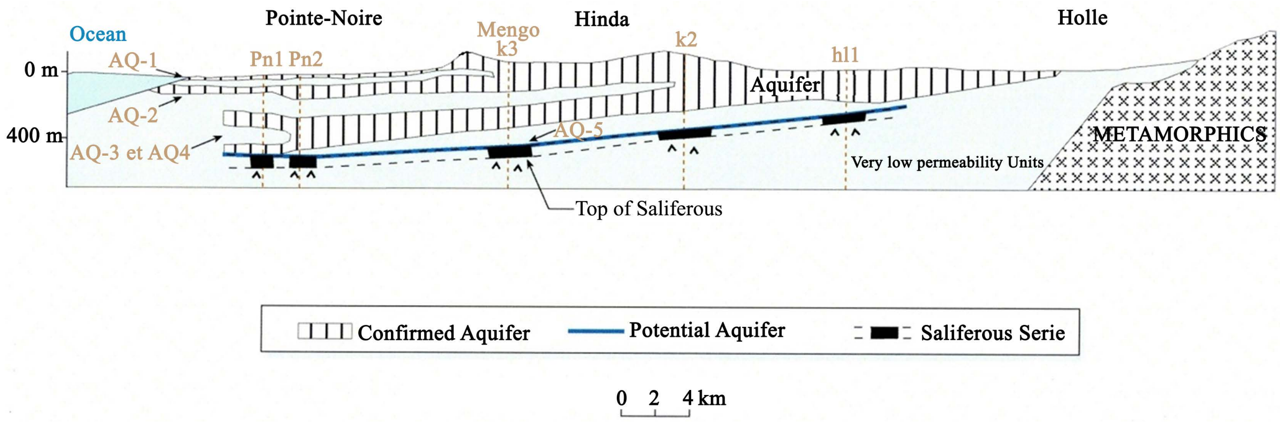

Figure 4. Schematic hydrogeological section.

out by infiltration of rainwater estimated at 350 mm·year^{-1} [24] and discharge is carried out via rivers and springs, by flow to the ocean but also by exploitation from traditional wells (about 3 m^3·h^{-1}) and shallow boreholes. This aquifer is vulnerable to surface contamination from various sources but also to salt intrusion on the coast.

The deep aquifer AQ-2 (confined), contains a deep confined artesian aquifer sometimes spurt in some places, corresponding to the most permeable layers of the series of circuses (quaternary). Its superstratum is 80 - 180 m deep. It consists of an alternation of fine and very fine sands with interlocks of fine silty sands and sometimes of cemented Sands. Drilling data are highly variable and appear to be contradictory, which explains the heterogeneity of this aquifer horizon. The thickness of the larger beds varies laterally and their relative depths to sea level differ significantly from site to site. The thickness of this aquifer varies between 20 and 30 m. The aquifer is confined and even Artesian in some places. The general regional flow likely extends from Mongo to the Northwest, West, and Southeast.

Data on hydrodynamic parameters (transmissivity and storage coefficient) are limited (**Table 1**) and are based on long-term pumping tests conducted in the SAFEGE study [7]. The transmissivity values (T) of the underground water in the city of Pointe Noire range from 10^{-3} to 10^{-2} m^2·s^{-1} and those of the storage coefficient (S) from 10^{-4} to 10^{-5}. The values T of T reported at the average thickness of 20 to 30 m of aquifer AQ2 give hydraulic conductivity values (K) of the order of 10^{-4} to 10^{-5} m·s^{-1}, characteristic values of medium fine sands.

Moukolo (1984) [24], using an analytical solution based on Darcy's law, considers that the average transmissivity value is underestimated and should be greater than 4×10^{-3} m^2·s^{-1}.

Table 1. T and S values obtained by long-term pumping test [7].

	Discharge m^3·h^{-1}	Transmissivity T (m^2·s^{-1})				Piezometer Storage Coefficient S	
		At the well		with a piezometer			
		Descent	Up	descente			
F1	107.4	7.5×10^{-3}	6.4×10^{-3}				
F2	50	9.7×10^{-3}	2.2×10^{-3}				
F5	81.8	6.8×10^{-3}	2.4×10^{-3}	F4	9.9×10^{-3}	F4	5.1×10^{-4}
				F6	1.9×10^{-2}	F6	4.5×10^{-4}
F7	131.6	7.8×10^{-3}	7.9×10^{-3}				
F8	145	4.9×10^{-3}	3.0×10^{-3}	F10	8.0×10^{-3}	F10	1.5×10^{-4}
F9	185	3.9×10^{-3}		F8	8.6×10^{-3}	F8	4.2×10^{-5}
				F10	6.7×10^{-3}	F10	8.7×10^{-5}
F11	132	2.8×10^{-3}		F12	7.7×10^{-3}	F12	1.5×10^{-4}
				F13	1.1×10^{-2}		1.7×10^{-4}
F14	76.9	1.2×10^{-3}	1.1×10^{-3}				

The AQ-2 aquifer is heavily mined in the Pointe Noire region; flows vary from less than 5 $m^3 \cdot h^{-1}$ to more than 100 $m^3 \cdot h^{-1}$ depending on use and depth of structures. The highest flows are from the deepest boreholes and particularly those managed by the Water Distribution Company which is the most exploited. Total discharges operated by this Company from 23 boreholes located in the Pointe Noire region range from an average of 42,000 to 50,000 $m \cdot d^{-1}$ during the 2009-2010 period [8].

The deep confined aquifer AQ-3 is the coarser portion of ferruginous Sands found between 250 and 275 m in the coastal plain and the Hinda plateaux at 100 and 125 m elevation. The series of coarse ferruginous Sands, 100 - 200 m thick depending on the location, is made up of white sands and clayey sands of beige or yellow colour, with variable granulometry and including past conglomerates of white quartz and ferruginous concretions [17] [18]. The potential and quality of the water in this aquifer is unknown.

The lithological descriptions of the water supply boreholes developed within the city limit of Pointe-Noire do not differentiate between the AQ-2 aquifers, either The Sands of the series of circuses and AQ-3, or the ferruginous Sands. The catchment depths suggest that several boreholes are capturing the confined and artesian aquifer AQ-2, while some deeper boreholes could capture the confined aquifer AQ-3. However, it has been tested by hydrogeological exploration drilling conducted by Magminerals Inc. [18], on the western flank of the highlands Hinda.

Given that data in the deepest horizons in the Pointe-Noire area appear to be inadequate, we can consider that the largest beds in the greso-dolomitic series could be an aquifer, *i.e.*, confined aquifer AQ-4. But this statement is random given the insufficiency of the data. The AQ-3 and AQ-4 aquifers identified on the basis of stratigraphic descriptions of deep drilling for mining and oil exploration have not been reached by any water drilling. These two aquifers, together with the AQ-1 and AQ-2 aquifers constitute a single aquifer unit per impermeable level bevelling in the northern sector beyond borehole K2 located south of Saint Paul (**Figure 4**).

As with unit AQ-3, the potential and chemical quality of the slick are unknown, but Lemaire (1965) [25] speculates that the slick could be loaded with salt because the salinity of the drilling mud had increased during drilling operations.

The AQ-5 deep confined aquifer of the calcaro-dolomitic series with a superstratum 400 - 465 m in the coastal plain and in the Hinda plateaus between elevations of 40,250 and 315 m.

This unit is considered to be an aquifer containing a groundwater table by a large loss of drilling mud between 400 and 415 m deep in the plateau zone, suggesting a locally permeable formation, probably Karst. It does not appear to be in contact with other aquifers in the sedimentary aquifer system. It may be part of the karstic aquifer that may have originated from the Mayombe metamorphic series.

The various strata that form the subsoil of the Pointe-Noire region are part of a series of depressions that delimit the western edge of the African continent from Côte d'Ivoire to Angola. The main formations present here are from the upper Quaternary and then the tertiary.

Since 1961, the main source of drinking water in the city has been the Pointe-Noire AQ-2 deep aquifer. There has been a considerable increase in abstraction from these aquifers, as shown in the figures below:

- 1974: 5300 $m^3 \cdot d^{-1}$ or 1.9 million $m^3 \cdot year^{-1}$ for three drillings in service.
- In 1989: 9450 $m^3 \cdot d^{-1}$ or 3.4 million $m^3 \cdot year^{-1}$ for 14 drillings in service.
- In 1990: 12 150 $m^3 \cdot d^{-1}$ or 4.4 million $m^3 \cdot year^{-1}$ for 14 drillings in service.
- In 2010: 88 848 $m^3 \cdot d^{-1}$ or 32.4 million $m^3 \cdot year^{-1}$ for 76 boreholes in service

At relatively short intervals, studies must be regularly conducted to estimate the quantity of reserves in the subsoil.

As part of sustainable resource management, these studies would not only make it possible to think now about the needs of future generations, but also to preserve the quality of water by protecting it from any pollution that could prove dangerous for urban users. However, it is important to point out the vulnerability of these aquifers, which could be linked to several factors, including:

- The existence of a salt front that could cause brackish water intrusions into aquifers;
- The diversity of activities within the city resulting in several uncontrolled discharges whose effects on Water Resources, in the short, medium or long term could endanger the quality of the current reserves;
- Finally, these resources may experience increased exploitation in the coming years because, currently in Pointe-Noire, several companies use underground water for daily business operations.

Increased exploitation of QA-2 can lead to a decrease in the quantity of resources and possibly their total disappearance if not monitored. Thus, in spite of the growing demand over the years, it is necessary to consider a regular monitoring of the behaviour of the groundwater at the level of the city.

The current piezometry shows depressions areas marking an over-exploitation of the AQ-2 aquifer layer (**Figure 5**).

In addition to groundwater several rivers for the city of Pointe-Noire. They gather around four watersheds (**Figure 6**): Gambouissi, Songolo, Kimpanzou and Tchikoumbi.

These different basins bring together a number of rivers, streams or lagoons of varying importance. These are the Loya, the Tchinouka, the Tchikondo, and the Labendé. It remains, however, established that the Songolo is the river that has the most importance in the city because not only does it actually flow within the city, but also its waters have long been used in various ways within urban households. On the other hand, the banks of the Songolo River are of tenused as a dumping ground, and its waters are responsible for carrying these various wastes downstream. Several years the Songolo marked the natural boundary of the city in its northern part. Today, the waters of this river are polluted by urban

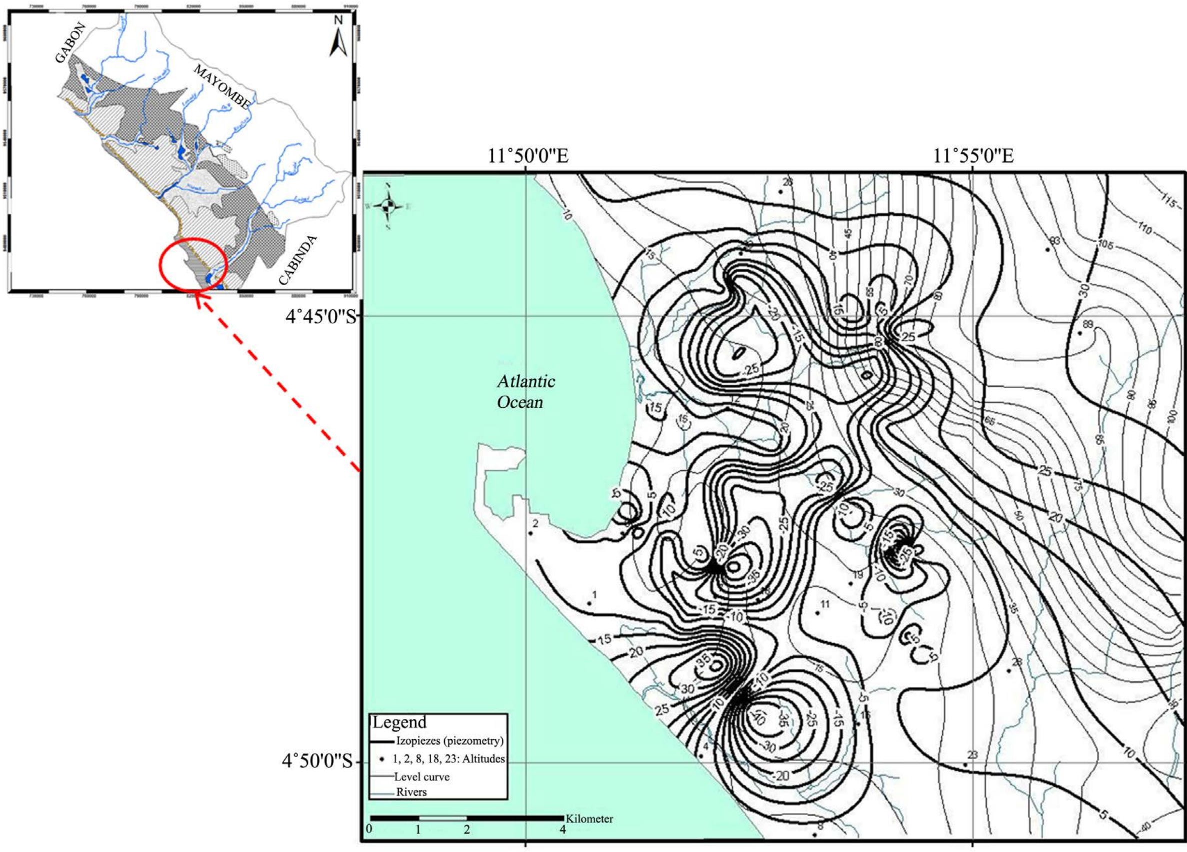

Figure 5. Piezometric surface morphology of QA-2 in 2010 [3].

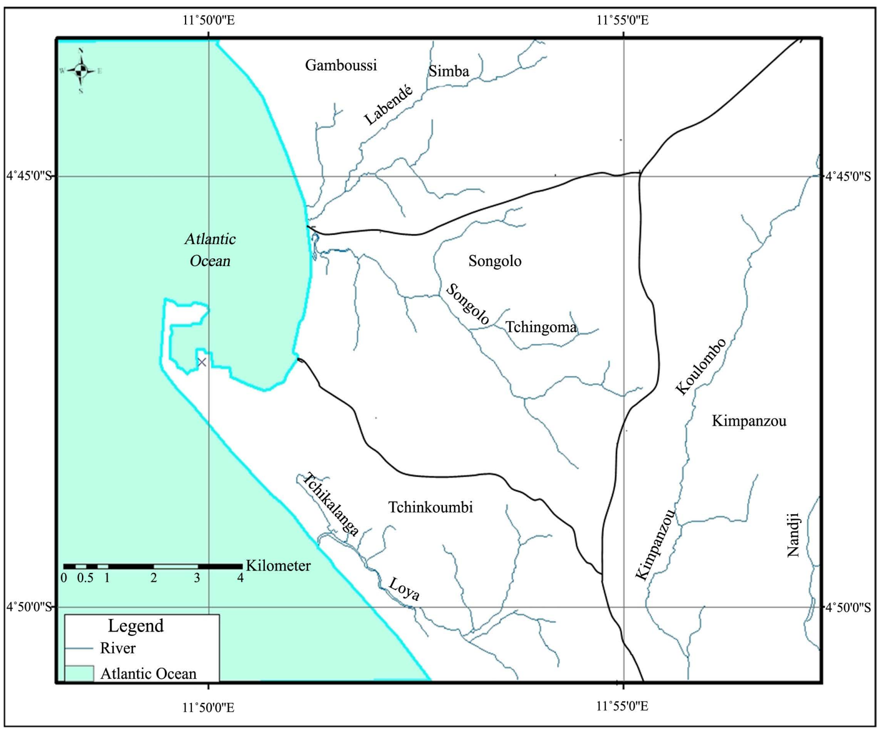

Figure 6. Hydrography and hydrology of the city of Pointe-noire [4].

populations and this situation is very worrisome given the different demands placed on these waters in various parts of the city.

However, all the watercourses are lined with swamps and lagoons that accentuate the unhealthy character of the urban site. These swamps isolate the neighborhoods from each other with the help of the many waterways that criss-cross the urban space. These areas were conquered thanks to the filling of certain lands, especially in the city centre. But in several places, these swamps could be filled up and valued by populations who then erected dwellings. Flood risks are often very high, but people generally care very little about them, their main concern being, above all, to obtain a plot of land to build a house.

Apart from these major basins, which are limited to the more or less immediate environment of Pointe-Noire, it must be remembered that the development of the Kouilou Department—which houses the city we are studying—also benefits from an important drainage network. There is notably the Kouilou River and then the basin of the Loémé which takes its source in the District of Mvouti, crosses the forest massif of the Mayombe and the District of Hinda before emptying into the sea at the border between the Congo and Angola.

There are also a large number of creeks which criss-cross the department and whose waters are used, depending on the locality, to feed the population or to irrigate vegetable crops grown in alluvial alleys and lowlands. Finally, there are a number of lakes including Noumbi, Tchisseka, and Youbi in the Madingo-Kayes district, then lakes Nanga, Loufoualéba and Cayo in the Hinda district.

Regardless of the greater or lesser distances between these different bodies of water and the city of Pointe-Noire, it must be recognized that surface water resources are a real guarantee for the supply of water under pressure to the city of Pointe-Noire in the years to come. Cayo Lake, 15 km from Pointe-Noire, has an area of 16.5 km^2 for a volume of water in a period of low water that was equal to 3×10^7 m^3 in August 1981. Lake Loufoualéba, which is also a few kilometers from Pointe-Noire, has an area of nearly 2.7 km^2. The volume of the waters of this lake reached, during high-water periods, nearly 2×10^7 m^3 in April 1982 where as during periods of low water this volume was close to 10^7 m^3 (August 1981). For the moment, all of these surface waters around the city of Pointe-Noire have not yet been used to supply the city. Only the waters of the Gambouissi (tributary of the Songolo) had been exploited for several years to satisfy the needs of urban consumers. The bulk of supplies are now supplied by groundwater exploitation through drilling throughout much of the city.

This being so, the importance of the superficial hydrographic scalp should not obscure the wealth of deep water resources in the urban subsoil.

In Pointe-Noire, many bodies of water are located a short distance from the surface of the ground and this position thus provides infiltration facilities for polluting agents in view of the many human activities that are developing on this urban space. In view of this situation, monitoring the quality of these groundwater should not be sacrificed solely for the purpose of monitoring the quantity of the reserves.

But how should we ensure the quality of these reserves when we know that very little, if any, scientific analysis of the quality of the waters of these aquifer layers is done on an ongoing basis in Pointe-Noire. In reality, it is not a question of limiting ourselves to the fact that groundwater is naturally pure to ban scientific analyzes of the quality of these deep waters.

Rom the point of view of its quality, it is true that the water in the surface water (AQ-1) of Pointe-Noire is little mineralized and that it reveals in its composition several chemical variations without gravity according to the seasons. The water in the deep water body QA-2, on the other hand, is heavier but does not require treatment for consumption [13].

4. Conclusion and Discussion

The Pointe-Noire region is located in the large hydrogeological complex of the coastal Sedimentary Basin of the Congo Brazzaville, with an area of 6000 km^2. It corresponds to a longitudinal tectonic accident, fault or flexure. However, the contact between the sedimentary deposits and the underlying Precambrian basement is discordant and indicates a long period of erosion. Lateral discontinuities are observed from downstream to upstream of the coastal Sedimentary Basin. Thus, we observe formations from the bottom to the top, from the Precambrian to the circus series in which the agree mains to be determined.

Paleontological investigations in this region assign approximate ages to the faun as found in the Eocene and Pleistocene regions. Several divergences can be noted in the determination of the age accuracy of the cirques series in this coastal region. Some studies [14] have reported did in the upper Senonian; others [26] mention that this discordant series on the Cretaceous, completely devoid of fossils, considered to be Plio-Pleistocene, is believed to have taken place on the occasion of subtle morphoclimatic periods…, higher horizons appear as simple levels of formation alteration, possibly related to the sub-present "Kibanguian" period. The work of Giresse and Kouyoumontzakis, 1990 [27] confirms the azoic character of the series of circuses and adds that one can admit this approximation for the most superficial layers, on the other hand, the boreholes of the oil exploration of the basin have been able to show that the deepest levels were the lateral continental equivalents of the Marine sedimentations Cenozoic, or even Mesozoic. Never the less, this series consists of a hydrogeological complex, including an aquifer system consisting of several overlying aquifers with hydraulic continuity.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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