2. DESCRIPTION OF THE STUDY AREA

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2.1 General

The purpose of this chapter is to present the features of the Orinoco River Basin, especially of the Study Area and its importance in the Republic of Venezuela.

2.2 Natural Conditions

2.2.1 Overview of the River

The Orinoco River rises in the Parima mountains at the Brazilian and Venezuelan border at approximately 2°20′ north latitude and 63°20′ west longitude. From its source, it forms a great arc, first flowing northwest to its confluence with the Guaviare River, from there north to the Apure River, and then generally east to discharge into Atlantic Ocean.

The total catchment area of the Orinoco River Basin is 1,015,000 km^2 of which the territory of Columbia accounts for 305,000 km^2 (Table 2.2.1 and Fig. 2-2-1).

Table 2.2.1 Characteristics of the Orinoco River Basin

Reach	Main Station	Tributary		Distributary	Catchment Area (km^2)		Distance from Boca Grande	Slope	Main Discharge (m^3/s)		Suspended Sediment (Mg/year)	
		Left Side	Right Side		Main Station	Tributary	(km)	(cm/km)	Main Station	Tributary	Main Station	Tributary
Upper		Río Guaviare				140,000				8,200		25-30
			Río Ventuari							2,000		1
			Río Orinoco									
	Puerto Ayacucho				343,500		1176		15,000			
Middle		Río Meta				113,000				4,600		80
		Río Apure				150,000				2,000		20-25
			Río Caura			42,000				4,000		2
	Musinacio				870,000		652		30,100		150	
	Ciudad Bolivar						446	4.5				
			Río Caroni							5,000		2
Lower (Delta)	Ciudad Guayana				900,000		335		36,000		200	
				Canal Macareo						3,600		
				Canal Manamo						100-200		
				Canal Rio Grande						33,000		
	Boca Grande				1,015,000		0		*40,000*		*200*	

Source: C.F.Nordin, Abel Mejia, Carmen Delgado,Sediment Studies of the Orinoco River Venezuela, 1994

The total length of the river is 2,063 km, and from its headwaters, it drops 1,100 m to the ocean. Downstream of Puerto Ayacucho, the river has a fairly uniform profile with a mean slope of about 4.5 cm/km (Fig. 2-2-2).

The main tributaries of the Orinoco River along its right bank are the Ventuari, Caura, and Caroni Rivers. These streams drain the Guyana Shield; they are dilute in their chemical constituents and suspended sediments, but they transport as bed load substantial quantities of coarse sands and fine gravel to the Orinoco River.

The main left bank tributaries, the Guaviare, Meta, Arauca and Apure Rivers originate in the high Andes and flow east across the Llanos to the Orinoco River. These tributaries transport heavy sediment loads from the Andes to form the alluvial fans and great plains of the Llanos and to push the Orinoco River against the Guyana Shield along most of its course.

The Casiquare River actively captures the headwaters of the Orinoco, diverting up to 25 % of the flow into the Negro-Amazon drainage, mainly at high stage.

The Orinoco River drains to the ocean an average flow in excess of 36,000 m^3/s and an average sediment load of about 150 million ton per year (Fig. 2-2-3).

The Orinoco Delta in the Orinoco River basin can be defined as an area downstream of Ciudad Guayana along its main course. The southern boundary of the Delta is the northern part of the Guyana Shield and the northwestern boundary is the alluvial plain of Monagas State, considering tributary basins entering Manamo Channel and Rio Grande. (Fig. 2-2-4)

The total area of the Delta is approximately 66,000 km^2 including the tributary basin entering Manamo Channel. The area of the delta surrounded by Rio Grande and Manamo Channel in itself is 22,000 km^2.

Fig. 2-2-4 shows spot elevations above MSL (Mean Sea Level) in the Delta based on topographical maps of Cartografia Nacional. The elevation in the delta surrounded by Rio Grande and Manamo Channel is mostly less than 20 m, except the Pedernales area.

The river system in the Orinoco Delta can be divided into three (3) as follows (Table 2.2.2 and Fig.2-2-5),

Table 2.2.2 River System in the Orinoco Delta

Code Number	Name	Main River and Channel
6-1	Morichal Largo-Uracoa	Rio Tigre, Rio Morichal Largo, Rio Uracoa, Rio Yabo
6-2	Casacoima-Cano Basama	Rio Grande, Rio Cayubini, Rio Amacuro, Rio Barima
6-3	Delta	Manamo Channel, Macareo Channel, Pedernales Channel, Rio Grande, Mariusa Channel, Amaguro Channel

Source: Ministerio de Energia y Minas

2.2.2 Meteorology and Climate

The Orinoco River basin is located entirely in the Northern Hemisphere, so it enjoys a tropical wet-dry climate, determined mostly by the seasonal variation of the Equatorial Trough and its interaction with northern trade winds.

The wet season extends over most of the basin from May to October. Rainfall varies from about 3,000 mm per year in the southern part of the basin to approximately 800 mm per year in the eastern Llanos.

The dry season is pronounced everywhere except in the Amazon region in the extreme southern part of the basin where rainfall is uniformly 3,000 mm throughout the year.

The Study Area is located below 100 meters above mean sea level, resulting in an annual average temperatures higher than 26 C and annual average rainfall that varies between 2,012 mm in Curiapo and 1,095 mm in Barrancas. The annual pattern of rainfall is bimodal, having its maximum from June to August; decreasing in September and increasing again from October to December. The dry period extends from February to April, May being the transitional month. The annual evaporation in the Study Area is around 1,800 mm. (Fig. 2-2-6 and Fig. 2-2-7)

2.2.3 Geology

The Orinoco River basin contains a broad range of geologic environments. The major features are:

- An active orogenic belt of the Andes and Coastal ranges that forms the western and northern boundaries of the drainage

- Sedimentary basins of the Sub-Andean trough or foredeep in the central lowland of the basin, which constitute the great alluvial fans and plains of the Llanos to the west of the river

- Stable Guyana Shield to the south and east of the river

  The Study Area occupies the eastern part of the tectonic depression (elongated E-W direction) between Guyana plateau and Caribe mountain range.

  Guyana plateau is geologically called Guyana shield, which is made up mainly of granulite and gneiss along with amphibolite. These rocks are quite old and date back to Precambrian age. This area has also been stable since the end of Precambrian age (some 600 million years ago).

On the other hand, the northern uplift of Caribe mountain range is made up of younger and more complex geological formation. Banded arrangement of mainly Paleozoic and Mesozoic metamorphic rocks and meta-sedimentary rocks are observed in this area.

These two geological units in the north and south form a basement for a sedimentary basin where thick secession of sediments from Cretaceous age to the recent age lies. The thickness of the sediment at the eastern edge of the study area (where it is deepest) amounts to over 10,000 m.

The main lithologies observed in the area are unconsolidated Pleistocene sediments in the west and recent river deposit in Orinoco delta. The former may be an old delta deposit formed as the delta migrated seaward. These sediments are probably composed of layers of silt and clay with sandy lenses and they overlie older sediments and sedimentary rocks some of which are exposed to the west of the study area.

A large negative bouguer anomaly is characteristically indicated at the north western edge of Orinoco delta. This implies the existence of relatively less dense substance underground and may lead to gradual isostatic rising of the area. (Fig. 2-2-8)

2.2.4 Soil

In general, the type of the soil in the Study Area is a recently accumulated fluvial deposit (Holocene). During the last marine transgression (sea water invasion over the continent), the increase in the sea level caused a marine clays filling, locally mixed with peat and fluvial sediments especially in the superior delta, where the Orinoco river influence is greater.(Fig. 2-2-9)

The slopes of the ground elevation are very low, below 0.5 %. The periodic floods of the Orinoco River, the tide oscillation, the excessive rainfall and the plain topography, determine conditions of total or partial hydric saturation in almost all the plain.

The vegetation is a reflection of the environmental conditions. It is a very important parameter of the soil formation in this type of plain topographies; playing a role in the process of sedimentation, not only in the production of organic material but also as a mitigation to the fluvial and marine sedimentation.

According to the importance of the fluvial sedimentation in relation to the marine materials deposit and the development of organic materials (peat bed), different types of soils are developed with differences caused by the type of material present in the different environments that constitute this fluvial-marine plain.

The mineral soils represent approximately 75 % of the surface of the delta and according to the origin of the material, they can be classified into two principal types: the ones derived from the fluvial sedimentation and the ones developed over a marine sub-stratum. Organic soils represent the other 25 %.

The upper delta has better agricultural potential because fluvial sedimentation has been predominant, in this portion of the Delta although mineral soils prevail. The intermediate and lower delta plains generally have a substrate of marine origin with high contents of pyrite. This means that these soils are potentially sulfate acidic. The problem is aggravated as this strata reaches the surface and if the areas are drained in order to make a more intensive use of the soil, sulfate acidic soils may be formed. The lack of drainage and textures are two factors that also contribute to worsen the acidic problem.

The organic soils have low agricultural potential due to the low pH (acidic) of the peat, strong problems of drainage and/or high contents of pyrite

Fig. 2-2-10 shows a diagrammatic section of the Orinoco Delta. It can be found the apex, intermediate delta with its foundation in the Mesa formation, and the inferior delta with a subjacent material consistent of sulphurous marine clay where sulfate acid soils (cat clay) are present when the soil is drained. Peat is accumulated in the surface of this part of the delta.

2.2.5 Vegetation

In front of the outer edge of the Orinoco Delta, littoral vegetation, i.e., mangrove forest is distributed, which corresponds to the estuary formation (Fig. 2-2-11).

Most of the Orinoco Delta is covered with savanna (pasture), semi-deciduous forest and evergreen forest. Especially, the area around Tucupita is covered with savanna (pasture) since it is an agricultural area.

The tributary basins entering Manamo Channel have savanna (pasture), saxicolous vegetation and riparian forest.

2.2.6 River Water Quality

The river water quality in the Orinoco River is highly influenced by the erosion rates of different parts of the river basins. In the Guayana Shield erosion rates are among the slowest on earth: a meter per million years on the flat tops of mountains such as Roraima and Auyan Tepui. Consequently the rivers flowing out of these areas are free of sediment under natural conditions, being colored only by the humic acids dissolved from their soils. In the Andes the typical characteristics of regions of active tectonism give rise to erosion rates that are at least two orders of magnitude greater than those on the Shield.

The water quality measurement has been conducted by MARN in the Orinoco River. The overall characteristics of water quality at Ciudad Bolivar station are shown in Table 2.2.3. The dissolved solid concentration is around the order of 10 mg/l, which indicates that the river water is flowing from the alluvial terrain such as the Llanos.

Table 2.2.3 Water Quality of Orinoco River

Station	Measurment Date	Conductivity Electricity	Temperature	Color	pH	Alcalinity Total	Hardness Total	Hardness Calcium	Solid Total(Dissolved)
		ì S/cm[1]	℃	U. Pt- Co[2]	at 25 ℃	mg/l as $CaCO_3$[3]	mg/l as $CaCO_3$	mg/l as $CaCO_3$	mg/l at 105℃(180℃)
Ciudad Bolivar	1988/3/22	110.0	28.2	50.0	6.7	6.0	28.8	14.0	82.4
	1988/6/27	33.0	27.2	70.0	5.7	2.0	10.0	8.0	408.0
	1988/9/20	25.0	25.5	50.0	5.6	1.0	12.0	6.0	52.0(16.0)
	1989/3/14	46.0	27.6	50.0	6.0	8.0	14.0	10.0	76.0(29.0)
	1989/6/15	25.3	28.0	52.0	5.8	0.0	10.0	8.0	308.0(16.2)
	1989/11/27	24.9	28.0		6.0	10.0	10.0	8.0	160.0(15.9)
	1990/3/22	40.0	28.0		6.5	13.0	18.0	13.0	36.0(25.6)
	1990/6/27	30.0	28.0		6.7	12.0	14.0	12.0	184.0(19.0)
	1990/9/19	25.0	28.2		6.6	12.0	11.0	7.0	116.0(16.0)
	1990/12/10	33.4	29.0		6.8	13.0	15.0	12.0	116.0(21.4)
Centro del Río	1989/9/14	39.0	30.0		6.3	16.0	5.0	4.0	192.0(25.0)
	1988/11/22	20.0	27.9	70.0	5.2	3.0	6.0	4.0	64.0(13.0)
	1988/11/15	31.0	28.8	60.0	5.4	6.0	10.0	6.0	204.0(20.0)
Pta, Cuchillo	1996/9/30	22.0	23.0	5.0	4.5	10.0	4.0	4.0	11.0

Source: MARN

[1] Micro Siemens / cm
[2] Visual comparison method based on platinum-cobalt method
[3] 1 meq=50.05 mg $CaCO_3$