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QUANTUM MEASUREMENT AND DOCUMENTATION OF RAINFALL FOR ENGINEERING METEOROLOGY IN RELATION TO FLOODING INCIDENCE IN OZORO NIGERIA

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Abstract: Rain is a fragment, particle, or, any matter moving or falling, basically through air, in the form of liquid or otherwise. The amount of rainfall of an area is a determinant to the rate of water available in the earth's lithosphere, influencing various variables relative to engineering meteorology. Prior site investigation, the area flood type were attributed to flash floods, and pluvial (surface) water flooding. Following appropriate engineering and meteorological processes, rainfall records were obtained from sets of standard rain gauges duly installed for data acquisition. Upon computations and analysis, documentable record were archived specifically for the area. It was found that the area had an annual total rainfall value of 14,791 ml or 44,824 mm of rainfall and monthly average rainfall of 3,735 mm, and daily average rainfall of 274 ml or 830 mm. Peak monthly rainfalls were 11,282 mm in October, 11, 252 mm in July, and 8,024 mm in June respectively. The area possessed bimodal rainfall distribution pattern, with rainfall impact notably more in months of June, July, and August, compared to other months observed in 2024. Rainfall potential impact of 0.23 m flood water depth, and 7.5 % damage impact of rainfall through flood were also attained. Based on the obtained results, it was therefore concluded that, the area had high rainfall amount from the rain events. Flood potential impact prior water depth was categorized relatively low, with the flood percentage damage through floodwater also low. These information are vital in: understanding the impact of rainfall as a causal factor to flooding; calibration of models directly applicable to Ozoro Nigeria in precise; fostering benchmark for climatology, environmental, and engineering decisions, in solving flood problems; and, monitoring lapse in general documentation which primarily appraised this work worthwhile. Lastly, replication and enhancement of data acquisition for at least a decade was noted to be a forthput for future purposes.

Keywords: Documentation, Flooding, Measurement, Quantum, Rainfall

I. Introduction

Rain is the condensed water from a cloud. It is a fragment, or, any matter moving or falling, through air, in the form of liquid or otherwise. Rainwater in motion exist as raindrops. Liquid precipitate of water droplets are of diameters greater than 0.5 mm, but, if widely scattered, the drops may be smaller [7]. If the air in the cloud is below the freezing point (32 °F or 0 °C), ice crystals form. If the air all the way down to the ground is also freezing or below, snow may form. However, if the layers of atmosphere within the cloud, and, between the cloud and the ground, alternate between warmer than freezing and colder than freezing [2], other types of precipitation form. Rainfall is the main way water in the skies comes down to earth [19], for various purposes. Rain is the source of water for many cultures where rivers, lakes, or aquifers are not easily accessible. Rain provide water for industry, agriculture, hygiene, electrical energy (through dams), etc., hence makes modern life a reality for mankind. Governments, groups, and individuals collect rain for personal and public use [10]. This is because, the vitality of rainfall abound in various life endeavors. The intermittent nature of rainfall has great impacts on plant growth, soil biogeochemical cycle, as well as water resource management (16; 17; 12; 14; 9; 6], and beyond. There are three distinct types of rainfall;

i. Conventional Rainfall: This occurs when earth's surface within unstable atmosphere becomes heated more than its surroundings leading to significant evaporation. It falls as showers with rapidly changing intensity. Areas with intense solar heating warm the air above providing convectional currents. Areas located near oceans or large water bodies possess higher humidity levels, and thus provide moisture for cloud formation and subsequent rainfall. The warm air interaction with a cooler, denser layer, provide cloud formation and eventual rainfall. Convective rainfall undergoes four (4) basic process/stages before it occurs: Stage 1 (the sun heats the ground and warm air rises), stage 2 (as the air rises, it cools and water vapor condenses to form clouds), stage 3 (when the condensation point is reached, large cumulonimbus clouds are formed), stage 4 (heavy rain storms occur, usually including thunders and lightening due to electric charge created by unstable condition).

ii. Stratiform Rainfall: This is caused by frontal systems surrounding extra tropical cyclones which form when warm air often tropical air meets cooler air. Stratiform precipitation falls out of nimbostratus clouds. When mass of air with different moisture and temperature characteristics meet, warmer air override colder air and the warmer air is forced to rise and if conditions are right, it becomes saturated causing precipitation. In turn, precipitation can enhance temperature and moisture content along a frontal boundary. Fronts cause sudden changes in general temperature, humidity and pressure of air. Warm front occurs where the warm air scours out a previously lodged cold air mass. The warm air overrides the cooler air and moves upward. Warm fronts are followed by extended periods of light rain and drizzle because after the warm air rises above the cooler air (which sinks to the ground), it gradually cools due to the air's expansion while being lifted, thus, it forms clouds and leads to precipitation. Cold fronts occur when mass of cooler air dislodges a mass of warm air. Normally, the cold air is denser than warm air and hence this type of transition is sharper. Stratiform rainfall undergoes four (4) basic process/stages before it occurs: stage1 (an area of warm air meets an area of cold air), stage 2 (the warm air is forced over the cold air), stage 3 (where the air meets the warm air is cooled, and water vapor condenses), stage 4 (clouds form and precipitation occurs).

iii. Orographic Rainfall: This is otherwise called relief rainfall, which results when near saturated mass of warm air is forced to rise by wind, when confronted by a coastal mountain barrier formations. The lift up of air at mountain sides results in adiabatic cooling, ultimate condensation and precipitation as a result of dynamic

expansion of air due to decrease in air pressure (when cloud get too heavy to be suspended, heavy rain falls). Orographic rainfall undergoes four (4) basic process/stages before it occurs: Stage 1 (warm wet air is forced to rise over highland), stage 2 (the drier air descends and warms), stage 3 (any moisture in the air for example cloud, evaporates), stage 4 (as the air rises, it cools and condenses, i.e., cloud forms and precipitation occurs).
Rain otherwise precipitation is an important state in the water cycle. This can be seen in figure one (1) presented below;

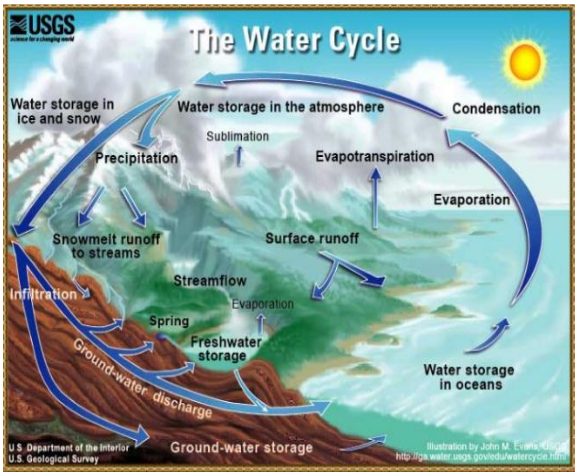

Figure 1: Water Cycle [19; 2]

In this cycle, water evaporates from the ocean and other water surfaces mostly through evapotranspiration in the form of water vapor to the atmosphere and eventually returns to land and sea in the form of precipitation which through infiltration and ground water storage and movement, returns to the ocean until another cycle uptake of the water. Water travels through the cycle in various ways. [13] noted that certain amounts of precipitated rain are lost to the atmosphere a few hours upon reaching the soil through evaporation. The sun radiation facilitates the evaporation process. The rate of availability of rainfall varies from region to region. One of the driest spots on earth is Iquique, Chile, where no rain fell for 14 years [19]. Mawsynram in northeastern India have been reported as one of the world wettest area with up to 494 inches at mean report. This is attributive to the area climate, traceable to the rainfall pattern (bimodal or unimodal distribution).

Measurement Of Rainfall: Rainfall measurement basically point to the rainfall amount. Amount of rainfall is the quantity of rain that falls in any given rainfall event [20]. The use of the rain gauge is the officially accepted method of obtaining rainfall data. These measurements help farmers make decisions about planting, crop irrigation and harvesting, they also aid engineers to design effective bridges, storm drains, and other structures [18], it also helps in achieving climate resilient goals and other useful purposes. Water measurement and documentation have faced various issues in the past leading to underutilization of these data. Scientists, engineers, policy makers, and stake holders require an interdisciplinary effort to effectively address these issues [11]. However, its vitality is not negligible.

Flood: Flood is the overflow of water over a land surface. According to [4], they are often caused by heavy rainfall, rapid snowmelt or a storm surge from a tropical cyclone or tsunami in coastal areas. Though some animals thrive in waterlogged areas, flood have negative impact on wildlife, causing disease proliferation, drowning and habitat destruction. Generally, it is regarded as an environmental problem. Also, according to [4], between 80-90% of all documented disasters from natural hazards during the past 10 years have resulted from floods, droughts, tropical cyclones, heat waves and severe storms. Flood disasters can generate tons of debris, including building rubble, green waste (e.g., trees and shrubs), soil and sediments, personal property, ash, and charred wood [8]. [1] penprinted that "floods are the leading cause of weather - related infectious disease outbreaks; Receding floodwater can create stagnant pools of water, which provide the perfect breeding ground for mosquitoes, which can transmit malaria and other diseases". Flood is a potential water medium for the spread of waterborne diseases like cholera and hepatitis A. Upon contact with pollutants of industrial chemicals, agricultural pesticides, sewage, debris, other hazardous or toxic substances, the water becomes contagious.

Types of flooding by source include; Pluvial or surface water flooding (surface water flooding happens when there is heavy rainfall on ground that is already saturated, or on surfaces where drainage is poor), groundwater flooding (occurs when rainfall causes the water that is naturally stored underground to rise to the surface, flooding low-lying areas), coastal flooding (occurs when weather and tidal conditions cause increase in sea levels, leading to coastal overtopping and flooding from high tides and storm surges, the frequency and severity of this type of flooding rises), river flooding, or fluvial flooding (occurs when a river's flow exceeds its capacity and floods the area around it), sewer flooding (occur when sewer system lack capacity to take water entering the system as a result of heavy rainfall or river or highway flooding), etc.

Flash floods account for approximately 85% of flooding cases, have the highest mortality rate and are among the world's deadliest disasters with more than 5,000 lives lost annually [5], in most areas. [15] reported that the United Nation's number of people affected by the flooding in Nigeria has risen to over 3.2 million, while over 1.4 million have been displaced in the 34 out of the 36 states of Nigeria. [3] explained that "flash floods occur when heavy rainfall exceeds the ability of the ground to absorb it and are the most dangerous kind of floods, because they combine the destructive power of a flood with incredible speed". They are essential to the functioning of many ecosystems, as well as, help to drive biodiversity [1].

II. MATERIALS

The main material used in this work is the study area "Delta State University Of Science And Technology, Ozoro". Ozoro is located within the rainforest vegetation region of Nigeria. It is geographically situated at latitude 5.544 north and longitude 6.232 east, with 14 meters (45.93 feet) altitude above sea level. It is situated in Isoko North local government area of Delta State. It forms part of Delta North senatorial district of Delta State. The location of the study area is presented in the figure two (2) below;

Figure 2: Location Of The Study Area (DSUST - Ozoro).

Other materials include: Rain gauge, site note, rain suite, measuring tape, site camera, etc.

III. METHODS

Following appropriate engineering and meteorological processes, rainfall records were obtained from set standard rain gauges duly installed for data acquisition. The daily rainfall data were obtained every 24 hour intervals at 9 am. The rainfall values were analyzed and further documented for meteorological and other usage. Rain water collection from the standard rain gauge (positioned rain gauge on a raingage stand for rain water harnessing in part a, and harnessing rain water measurement in part b) is presented in figure three (3) below;

(a) (b)

Figure 3: Rainfall Collection From A Standard Rain Gauge (site Photography)

Rainfall amount computation was obtained using the formula by [13], as below;

$$Ar = \frac{Vc\,(\lambda)}{Ac} \quad (1)$$

Where: Ar = Amount of rainfall (mm), Vc = volume of water collected by the gauge (ml), Ac = Area of rain catcher of gauge (cm), λ = constant variable for conversion. For example, on 25/3/2024, 83 ml was recorded from the gauge. Gauge internal cylinder was 3.3 cm. Conversion variable was 10.

Thus, Ar = (83/3.3) x (10/1)

Hence, Ar = 251.52 mm

This was replicated in every daily rainfall, leading to monthly and annual data.

Also, using site analysis, the flood potential were measured based on the amount of damage observed in percent (%) and the flood water depth in metres (m). These were achieved using stochastic approach. Twelve grid points were deployed in acquisition of flood depth and damage values. Flood correspondence to rainfall was deduced from the two flood variables (damage and water depth).

IV. RESULTS

The results obtained in the course of this experimental work are presented in tables one (1) and two (2), and figures four (4) to seven (7) below. The results of the rainfall data obtained are presented in table one (1) below;

Table 1: Rainfall data

S/N	**Date**	**Daily Rainfall Amount**		**Monthly Rainfall Amount, mm**
		(ml)	**mm**	
1	0-31/01	0.0	0.0	0.0
2	0-28/02	0.0	0.0	0.0
3	25/03	83	252	391
4	26/03	46	139	
5	04/04	267	809	3,152
6	18/04	480	1455	
7	29/04	293	888	
8	30/05	643	1,949	3,898
9	31/05	643	1,949	
10	10/06	960	2,909	8,024
11	21/06	828	2,509	
12	24/06	448	1,358	
13	25/06	58	176	
14	27/06	112	339	
15	28/06	242	733	
16	03/07	570	1,727	11,252
17	05/07	159	482	
18	08/07	149	452	
19	10/07	844	2,558	
20	11/07	368	1,115	
21	15/07	692	2,097	
22	16/07	59	179	
23	17/07	11	33	
24	18/07	3	9	
25	19/07	4	12	
26	22/07	355	1,076	
27	26/07	122	370	
28	29/07	368	1,115	
29	30/07	9	27	
30	02/08	124	376	3,413
31	12/08	64	194	
32	13/08	89	270	
33	15/08	07	21	
34	19/08	14	42	

35	20/08	368	1,115	
36	21/08	86	261	
37	26/08	252	764	
38	27/08	54	164	
39	31/08	68	206	
40	02/09	224	679	3,357
41	06/09	06	18	
42	09/09	214	648	
43	10/09	164	497	
44	11/09	289	876	
45	19/09	38	115	
46	23/09	109	330	
47	27/09	64	194	
48	02/10	437	1,324	11,282
49	04/10	07	21	
50	7/10	468	1,418	
51	09/10	57	173	
52	11/10	694	2,103	
53	14/10	1316	3,988	
54	22/10	628	1,903	
55	30/10	116	352	
56	29/11	18	55	55
57	0-31/12	0.0	0.0	0.0
Total	54	14,791	44,824	44,824
Average	-	274	830	3,735

The rainfall monthly curve is presented in figure four (4) below;

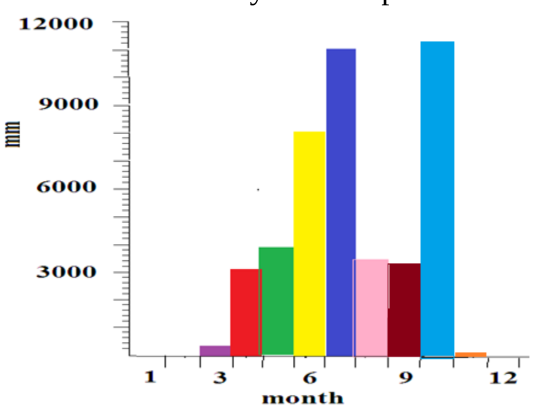

Figure 4: Monthly rainfall curve

The peak months daily rainfall curve are presented in figure five (5) to seven (7) below. The peak month (October) daily rainfall curve is presented in figure five (5) below;

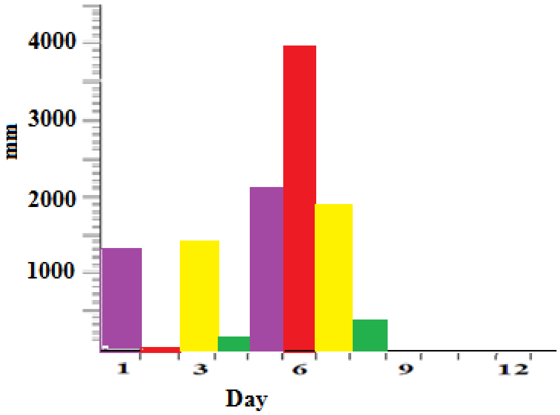

Figure 5: Peak Month (October) Daily Rainfall Curve

The second peak rainfall month (July) daily curve is presented in figure six (6) below;

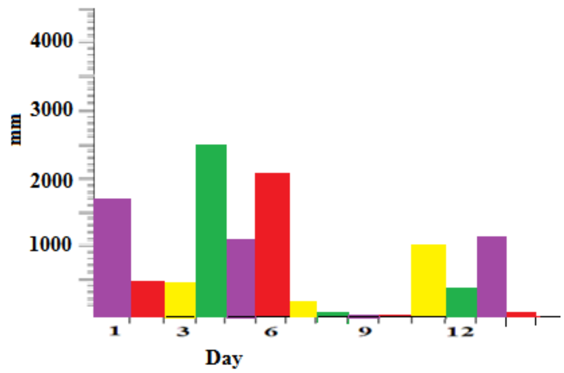

Figure 6: July Daily Rainfall Curve

The third peak rainfall month (June) daily curve is presented in figure seven (7) below;

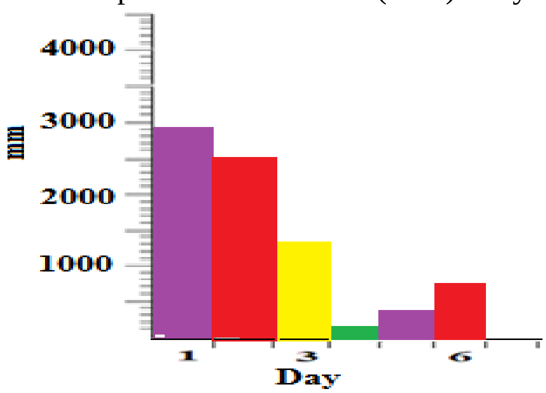

Figure 7: June Daily Rainfall Curve

The results of flood depth and damage impact are presented in table two (2) below;

Table 2: Results Of Rainfall Flood Depth And Damage

SN	Month	Depth (m)	Damage (%)
1	May	0.08	6
2	June	0.16	10
3	July	0.17	11
4	August	0.7	6

5	September	0.07	2
6	October	0.17	10
Average	Anum	0.23	7.5

V. DISCUSSIONS

From results obtained, a total of 44,824 mm of annual rainfall was recorded with monthly average of 3,735 mm, and daily average of 830 mm of rainfall were measured and documented for the area. This indicates that the area had high rainfall amount from the rain events. Peak monthly rainfalls were 11,282 mm in October, 11, 252 mm in July, and 8,024 mm in June respectively. From available data above, October was the peak rainfall month in 2024, exceeding July with 30 mm. Generally, July notably represent the peak rainfall month in the state and national climate reports. This is followed by the month of June. However, the exceedence of 30 mm was relatively too low to justify any change in climate, but posses a great mark in weather analysis. December and January experienced total dry spell. February had showers too little to quantify. The rainfall distribution pattern of the area from 2024 rainfall events was described as bimodal. This is because it stops towards the end of the year and begins again in the first quarter of the next year.

In the stochastic examination of flood potential impact, water depth of 0.23 m was obtained and categorized relatively low, pointing that rainfall impact on flooding with regards to the depth was not high in the year 2024. Thus, the area did not experience intense flooding in 2024 compared to problematic flooding periods which last took place in 2022. The 7.5 % damage relates to the negative impact of rainfall on and through flood. This percentage was notably not high for the said year. Generally, the potential damage ranges from 0% (no damage) to 100% (totally destroyed), describing the relationship between damage and flood characteristics such as water depth. This is a product of amount of damage observed in percent (%) to the flood water depth in metres (m). The rainfall impact occurrence were more in months of June, July, and August, compared to other months observed. These stated months above are attributed to peak rainfall months in the area, featured with high saturation of the soil environment. In these periods, soil voids and pores become already filled up with infiltrated water mass. Such infitration cause water logging and depending on the area soil properties like slope inclination, plasticity of soil, soil drainage, etc., the logged water otherwise flood may find it difficult to travel to a nature designed location like places with lower water table features, open and closed water bodies like streams, lakes, oceans, seas, and undeground aquifers.

More rainfall data including other variables should be documented on annual bases for at least a decade for proper future predictions and modeling of rainfall negative effects and mitigations for the study area. These include development of numerical methods for the area weather and climate, soil loss equations, ground water models, environmental hazard predictions, etc. Climate and other environmental concerns in relation to engineering meteorology can be uncovered and tackle. These climate and environmental data are useful for engineering meteorology. Engineering meteorology points to the application of meteorological knowledge in engineering, specifically in environmental engineering, soil and water engineering, civil engineering, aerospace engineering, etc. Data measurement and documentations are vital for various future embarkation. Long term data collection provides detailed information of desired variables. For example, plant cover data (%) collected by [17] over a 65-year period (1953–2018) on multiple same-size transects in nine pastures. Thus, more data acquisition and documentation will aid resolve myraids of climate and environmental issues.

Moreover, from site investigation, the area flood type are flash floods, and pluvial (surface) water flooding, though groundwater flooding have been perceived to contribute to the peak flood years like the 2022 or 2012. Also, soil properties, rainfall levels, groundwater and sea level rise are the suspected natural contributors to flood attributes of the study area. Also, on a threshold of occurrence, when rainfall impacts negatively or positively on flood, resultantly, the flood water will tend to relatively impact on structures like buildings, soil structures, etc. Such impacts as obtained from sites measurements aid in various decision making.

VI. CONCLUSION

Summarily, from the rain events, the area had an annual total rainfall of 44,824 mm of rainfall, average monthly rainfall of 3,735 mm, and average daily rainfall amount of 830 mm. Peak monthly rainfalls were 11,282 mm in October, 11, 252 mm in July, and 8,024 mm in June respectively. It had a bimodal distribution of rainfall. It possessed a flooding water depth of 0.23 m on average, signifying that the area rainfall had little impact on flooding occurrence. It also had rainfall flood water damage impact of 7.5 % at average value representing low percentage impact of rainfall flood water.

Rainfall naturally aid the earth water cycle balance, as well as the ecosystem. Flood on the other hand is a natural disaster whose presence in an area calls for solution. Thus, measurements and documentation of these data are useful. The obtained data are vital in understanding the impact of rainfall as a causal factor of the area flooding; calibration of rainfall models with variables directly applicable to Ozoro areas in precise; fostering benchmark for climatology, environmental, and engineering decisions, in solving the flood problem of the area.

This work " Quantum measurement and documentation of rainfall for engineering meteorology in relation to flooding incidence in ozoro nigeria" provides sectional documentation of the widely reportable rainfall which in addition to its provision of available data at spatial range, will aid in monitoring lapse in general documentation, as well in decision making.

This research recommendably forthput future experimental work on: Replication of rainfall data for a minimal of one decade for data availability in Ozoro area. This will facilitate future calibration of numerical methods as well as various environmental models.

Authors Contribution

Okolotu G.I (Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing). Oghenejabor O.D (Investigation; Resources; & Visualization). Olaye M (Investigation; Resources; Visualization). Udom E.A (Funding acquisition; Writing - review & editing).

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