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# Hydrologic analysis and hydraulics design of surface drainage for stormwater: A neglect of vital aspect

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## Abstract

*The importance of constructing drainage structures for the conveyance of direct runoff to suitable locations has long been identified by man. However, it has been observed that most constructed drainages did not serve the intended purpose during the design period despite being structurally sound with proper maintenance culture. This has been attributed to inadequate or lack of hydrologic analysis and hydraulics design before construction, as most design only consider the structural aspect. Hence, this work considered the hydrologic and hydraulics design of the drainage system of a proposed paved/tarred road, in line with engineering standards. This was achieved by incorporating environmental parameters such as digital elevation model (DEM) and land use-land cover map as well as hydrologic parameters such as composite runoff coefficient, rainfall intensity-duration-frequency (IDF) curves, concentration time and drainage area, in obtaining the expected surface runoff from the Rational Formula. Thereafter, the hydraulics design was done using the well-known Manning's Equation in accordance with most or best economic section. It was revealed that the catchment area capable of draining direct runoff into the drainage channels is 0.0874km$^2$ while the composite runoff coefficient and concentration time were 0.57 and approximately 120minutes respectively. It was also revealed that the 2.9km drainage on either side of the road will have a channel width of 510mm, flow depth of 255mm in addition to a freeboard space of 51mm and a bed slope of 0.01. The hydraulics designs were checked and it was observed that the design permits a flow velocity of 1.69m/s, which is sufficient for self-cleansing velocity without scouring of the bed and side walls. The engineering drawings of the designed channels were also provided and necessary recommendations were made.*

### Nomenclature and units

| | | |
|---|---|---|
| $Q$ | Expected surface runoff within catchment | $m^3$ |
| $Q_d$ | Design discharge in each drainage channel | $m^3$ |
| $R$ | Hydraulic radius | $m$ |
| $t_c$ | Time of concentration | $minute$ |
| $C$ | Runoff coefficient | dimensionless |
| $n$ | Manning's roughness coefficient | dimensionless) |
| $r$ | Overland flow roughness coefficient | dimensionless |

## 1.0 Introduction

It is a well-known fact that rainfall is very essential to human. However, improper management of excess rainfall which appear as direct or surface runoff could lead to flooding with its numerous associated consequences including destruction of paved roads, farmlands, homes, industries and institutions. Hence, it has been the practice of Civil and Water Resources Engineers to construct surface drainages (open channels) that could channelize the excess rainfall (surface runoff) to appropriate destinations. Notwithstanding, records have shown that most drainages especially in the developing countries did not serve the intended purpose. This is because most of these drainages were constructed by mere digging of gutters and then blinding of the floor beds and casting of the side walls with concrete, without adequate engineering design. In fact, in most cases the design only consider the structural (reinforcement) aspect, not caring the hydrologic and hydraulics design which are very vital. This could be due to lack of relevant hydrologic models of the concerned or nearby catchment, caused by inadequate long-term hydrologic data, or not involvement of Hydrology/Hydraulics experts during the design stage. Thus, such drainages in most cases usually leads to over flow of runoff thus, causing flooding with its associated effects.

Several researches including Tariku (2022), George *et al.* (2021), Ogbozige (2021), Dagne and Bortola (2020), Basnet *et al*. (2020) as well as Ezugwu and Eze (2019) have earlier identified failure of surface drainages (open channels) linked to negligence of hydrologic and hydraulics analysis or design. Hence, this research considered a detailed hydrologic and hydraulics design of the drainage system of a proposed road linking Otuoke and Ewoi communities in Ogbia Local Government Area (LGA) of Bayelsa State, Nigeria. This is because there has been reports of flooding along the road during rainy season therefore, it is important to consider the hydrologic and hydraulics design of the drainage system of the road (which is mostly neglected) so that prospective contractors, engineers, technologists, technicians, etc. could lay hands upon when constructing the proposed road and the associated drainage system.

## 2.0 Materials and Methods

### 2.1 Description of Study Area

The study area being Otuoke-Ewoi Road links the Otuoke and Ewoi communities, both in Ogbia LGA, Bayelsa State, Nigeria as could be seen in Figure 1. Its starting point is at Latitude 4° 47' 2.43" North and Longitude 6° 18' 10.29" East, were it intersects with the Onuebum-Otuoke Road at Otuoke town and terminates at Ewoi community (for the part being considered in this research) at Latitude 4° 45' 48.16" North and Longitude 6° 17' 17.20" East. However, at the moment, the road extend to Otuabula II community, also in Ogbia LGA.

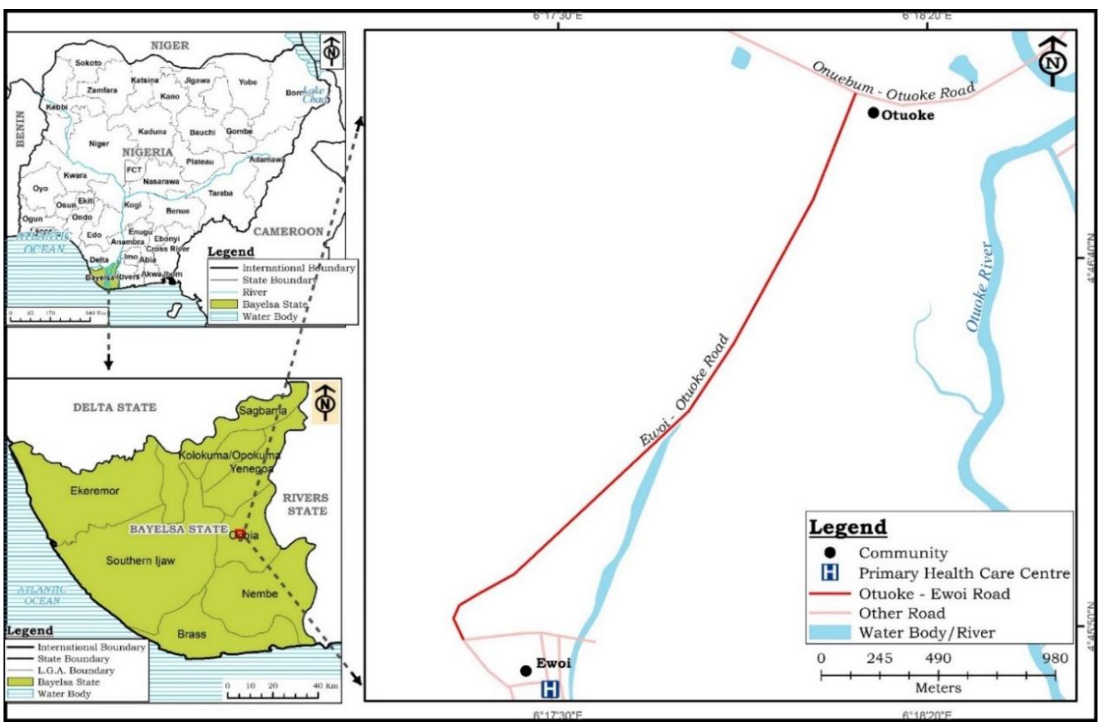


**Figure 1:** Study area map

The 2.9km road has a surface elevation range of 31.03m to 46.22m above mean sea level (MSL) with a surrounding vegetation that comprises of grasses, ferns and rain forest. The study area usually experience two meteorological seasons; rainy season and dry season. The monthly rainfall ranged from 61mm to 434mm with the wettest month fluctuating between July, September and October while the driest month fluctuates between December, January and February. Similarly, the daily mean temperature ranged from 26ºC to 28ºC with the warmest month fluctuating between February, March and April while the coldest month fluctuates between July, August and September (NIMET, 2024). The fluctuations in weather could be attributed to the effect of climate change.

## 2.2 Basic Environmental and Hydrologic Parameters

The basic environmental parameters considered necessary for the hydrologic analysis were Digital Elevation Model (DEM) as well as land use-land cover while the main hydrologic parameter considered was peak surface runoff. However, in the course of determining the considered main hydrologic parameter being runoff, other hydrologic parameters such as runoff coefficient, rainfall Intensity-Duration-Frequency (IDF) curves or model, watershed or drainage basin area, time of concentration, channel/catchment slope, etc. were also determined.

The digital elevation model (DEM) shown in Figure 2 was obtained in order to identify the portion of land that will drain surface runoff into the proposed drainage channels as well as the range of the surface elevation above mean sea level (MSL) which was useful in determining the channel slope. It was achieved by downloading advanced Land Observing Satellite (ALOS) elevation data (12.5m resolution) through https://search.asf.alaska.edu/. Digital Elevation Model data with a spatial resolution 12.5m was used to develop the digital elevation model (DEM). The study area boundary was used to clip out the elevation data, resulting to a DEM covering the study area. The clip elevation data was reprojected to a projected coordinate system (UTM Zone 32 Minna). This was done using the Reproject Raster Tool in ArcGIS 10.8 software. The create Hillshade tool in ArcGIS 10.8 software was used to create a Hillshade. The processed DEM was symbolized and placed on top of the Hillshade and its transparency set to 50%.

The land use-land cover (Figure 3) was generated through Landsat Enhanced Thematic Mapper Plus (ETM+) imagery of 24th December, 2024 with 30m resolution, sourced from global land cover facility (online portal) by means of maximum likelihood classification method based on its high accuracy (Ogbozige and Alfa, 2019). The image was classified into land use themes as Built-up Area (areas developed by human. i.e. buildings, graded roads and paved roads), Agricultural and Forested Area (cultivated lands and lands that are not yet cultivated such as grassland and forest), Bare Surface (lands without vegetation) as well as Water Body (all water surfaces such as river, stream and pond). In order to assess the agreement between the classified raster (result from a supervised classification) and the reference data (ground truth points with known class labels), an accuracy assessment was carried out. A total of 120 ground truth points were taken using a hand-held GPS. The "Create Accuracy Assessment Points" tool in ArcGIS 10.8 software (Tools > Image Classification toolbox) was used for the assessment. A total of 120 random points were generated from the classified raster (land use raster). This generated Confusion Matrix (Error Matrix) which compares the classified values to reference values. An Overall Accuracy of 95.0% and a Kappa Coefficient of 0.933 was obtained, indicating a very high degree of accuracy in the land use-land cover classification.


**Figure 2:** Digital elevation model (DEM) of study area

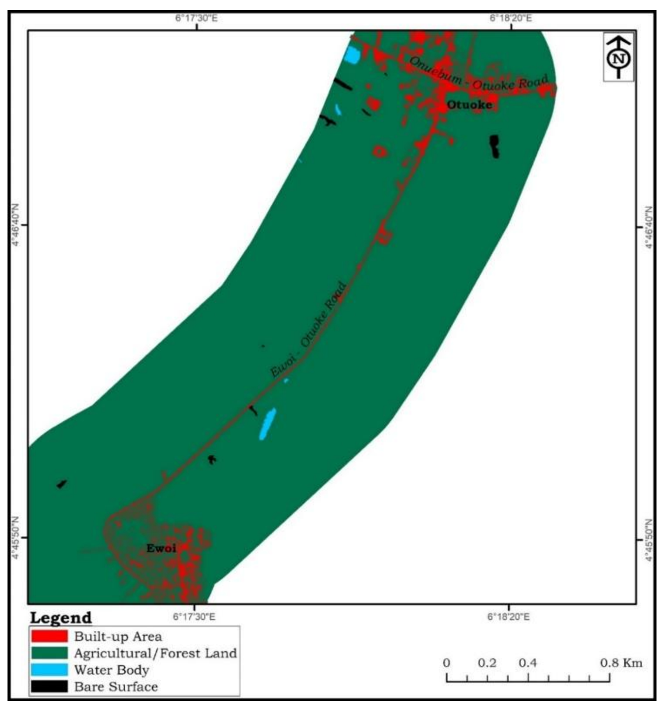


**Figure 3:** Land us - land cover map of study area

### 2.3 Determination of Peak Surface Runoff

The maximum expected quantity of surface runoff ($Q$) from the drainage area was determined through the Rational Formula for runoff, shown in Equation (1). The choice for adopting the Rational Formula over other methods such as the detailed HEC-HMS (calibrated with remote-sensed rainfall) was mainly due to the limited available data for the concerned catchment unlike the HEC-HMS method which requires more data. Beside, the concerned catchment is very small which makes it suitable for the Rational Formula.

$$Q = \left(\frac{1}{3.6}\right) CiA \qquad (1)$$

Where: $Q$ is the expected peak rate of runoff in m$^3$/s, $C$ is the coefficient of runoff which depends on the land use or land cover, $i$ is the maximum monthly rainfall intensity in mm/hour and $A$ is the area of drainage basin in km$^2$.

The catchment area consist of different land uses hence Equation (2) was used in obtaining the composite or weighted runoff coefficient ($C$) in line with runoff coefficients shown in Table 1. However, in determining the rainfall intensity (*i*), a nearby catchment at an aerial distance of 17.7km that has an existing rainfall Intensity-Duration-Frequency (IDF) curves was identified since the considered catchment (study area) had no developed IDF curves as at the time the research was conducted. Thereafter, the time of concentration ($t_c$) for the considered catchment was determined through the famous Kerby model shown in Equation (3) as recommended in the Nigerian Drainage Design Manual (2013). The determined time of concentration was taken as the storm duration in the considered IDF curves while the storm frequency was selected based on a recommended value in the Nigerian Drainage Design Manual (2013). Thus, the required rainfall intensity (*i*) was obtained from the IDF curves based on the selected storm duration and frequency.

$$C = \frac{C_1A_1 + C_2A_2 + C_3A_3 + \cdots + C_nA_n}{A} \qquad (2)$$

$$t_c = 0.604\left(\frac{rL}{\sqrt{S}}\right)^{0.467} \qquad (3)$$

In Equation (2), $C_1$, $C_2$, $C_3$,…., $C_n$ are the runoff coefficients in the sub-areas while $A_1$, $A_2$, $A_3$,…., $A_n$ are the corresponding sub-areas in km$^2$. However, in Equation (3), $t_c$ is the time of concentration in hours, *r* is the roughness coefficient (shown in Table 2), *L* is the hydraulic length of catchment measured along the flow path in km while *S* is the slope of the catchment expressed as the ratio of the elevation difference to length of flow path.

**Table 1:** Runoff coefficients for different land uses

| Type of land use | Runoff coefficient (*C*) |
|---|---|
| Concrete or asphalt pavement | 0.8 – 0.9 |
| Commercial and industrial | 0.7 – 0.9 |
| Gravel roadways and shoulders | 0.5 – 0.7 |
| Residential – urban | 0.5 – 0.7 |
| Residential – suburban | 0.3 – 0.5 |
| Agricultural – cultivated fields | 0.15 – 0.4 |
| Agricultural – pastures | 0.1 – 0.4 |
| Agricultural – forested areas | 0.1 – 0.4 |

Source: MDOT (2006)

**Table 2:** Recommended values for overland flow roughness

| Surface description | Roughness coefficient (*r*) |
|---|---|
| Paved areas | 0.02 |
| Clean compacted soil, no stone | 0.1 |
| Sparse grass over fairly rough surface | 0.3 |
| Medium grass cover | 0.4 |
| Thick grass cover | 0.8 |

Source: Nigerian Drainage Design Manual (2013)

### 2.4 Hydraulics Parameters

#### 2.4.1 Design discharge in drainage channel

The drainage system is proposed to be on both sides of the road (i.e. two equal drainage channels at the left and right sides of the road). Hence, the determined quantity of surface runoff ($Q$) was divided by two to get the expected or design discharge ($Q_d$) in each of the drainage channel as shown in Equation (4). i.e;

$$Q_d = \frac{Q}{2} \qquad (4)$$

Where $Q_d$ and $Q$ represent the discharge in each drainage channel and the expected surface runoff within the catchment respectively, both measured in m$^3$/s.

#### 2.4.2 Cross-sectional dimensions of channel

A rectangular drainage channel with cement concrete lining was adopted. The design of the channel's dimensions was done using the well-known Manning's Formula shown in Equation (5) in accordance with the principles of *most or best economic section*. Thereafter, the determined sectional dimensions were used in checking if the flow velocity lies within the acceptable range that permits self-cleansing velocity and prevent scouring of surfaces.

$$Q_d = \frac{A_c R^{2/3}\sqrt{S}}{n} \qquad (5)$$

Where $Q_d$ remains the designed discharge in each of the drainage channel in m$^3$/s, $A_c$ is the channel's cross-sectional area in m$^2$, *R* is the hydraulic radius (the ratio of cross-sectional area to wetted perimeter) measured in metres (m), *S* is the channel slope (the ratio of elevation difference to channel length) while *n* is the Manning's roughness coefficient.

### 2.5 Engineering Drawings

The designed dimensions obtained were used in producing the engineering drawings (orthographic and isometric views) by means of 2023 AutoCAD software. This was done with the intention to ease construction by masons or technicians which are to be supervised by a professional engineer.

## 3.0 Design Calculations and Drawings

### 3.1 Hydrologic Analysis

The hydrologic data used for the analysis of the designed drainage channel include runoff coefficient (*C*), catchment slope (*S*), time of concentration ($t_c$) and design storm duration, design rainfall frequency and intensity as well as expected surface runoff within the catchment (*Q*).

#### 3.1.1 Runoff coefficient

The catchment area has 0.055km$^2$ of agricultural and forest forested land, 0.0034km$^2$ of built-up area (i.e. sub-urban residential) and 0.029km$^2$ of the proposed paved road. Thus, the total catchment area (*A*) is 0.0874km$^2$. Based on the information in Table 1, the runoff coefficients for these land uses are 0.1 – 0.4, 0.3 – 0.5 and 0.8 – 0.9 respectively. However, the upper limits of the said range of runoff coefficients were selected for the sake of designing to prevent worst condition. Hence, Equation (2) was employed to determine the composite runoff coefficient (*C*) as follows.

$$C = \frac{C_1A_1+C_2A_2+C_3A_3+\cdots+C_nA_n}{A}$$

$$\therefore Runoff\ coefficient\ (C) = \frac{0.4(0.055)+0.5(0.0034)+0.9(0.029)}{0.0874} = 0.57$$

#### 3.1.2 Catchment slope (*S*)

The catchment elevation ranged from 31.03m – 46.22m above mean sea level (MSL) for a length of 2.9km (i.e. 2900m) as already shown in Figure 2. Since slope is the ratio of elevation difference to length, the catchment slope (*S*) was therefore calculated as;

$$catchment\ slope\ (S) = \frac{(46.22-31.03)m}{2900m}$$

$$=> \ Catchment\ slope\ (S) = 0.005 \cong 0.01$$

#### 3.1.3 Time of concentration and design rainfall duration

The catchment is dominated by medium grass cover hence the corresponding roughness coefficient (*r*) shown in Table 2 together with the other identified parameters were substituted in Equation (3) to determine the concentration time ($t_c$) as follows;

$$t_c = 0.604\left(\frac{rL}{\sqrt{S}}\right)^{0.467} = 0.604\left(\frac{0.4\times2.9}{\sqrt{0.01}}\right)^{0.467}$$

$$\therefore t_c = 1.897 \cong 2hours\ (i.e \cong 120minutes)$$

Since the concentration time ($t_c$) of a catchment is taken as the design rainfall duration (*t*), it implies the design rainfall duration (*t*) is approximately 120minutes.

#### 3.1.4 Rainfall frequency and intensity

The Otuoke – Ewoi Road falls under *Class C* (secondary road) hence the design storm frequency or return period (*T*) for the associated drainage channel is taken as ten (10) years based on the information in the Nigerian Drainage Design Manual published 2013. The rainfall intensity (*i*) was obtained from the IDF curves (Figure 4) of the nearby Yenagoa catchment which is just 17.7km away from the study area, developed by Ogbozige (2023).

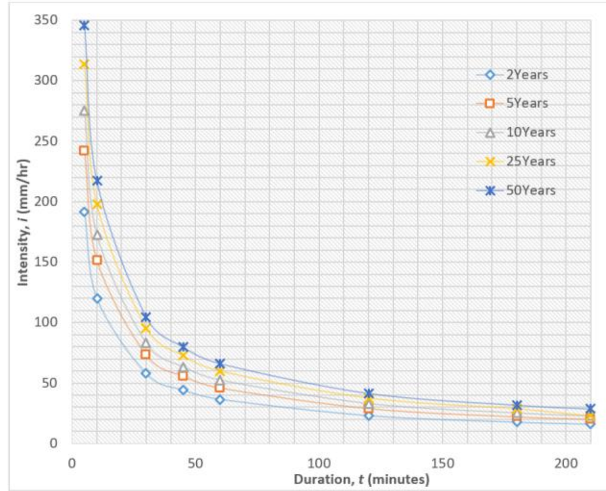


**Figure 4:** Rainfall IDF curves of nearby Yenagoa city

The mathematical model for the said IDV curves is given in Equation (6) where; *i*. *T* and *t* are the rainfall intensity in mm/hr, rainfall frequency or return period in years and rainfall duration in minutes respectively.

$$i = \frac{509.68T^{0.1863}}{t^{0.6693}} \quad (6)$$

Thus, the design rainfall intensity becomes:

$$i = \frac{509.68(10)^{0.1863}}{120^{0.6693}} = 31.77mm/hour$$

#### 3.1.5 Expected surface runoff within catchment

By employing Equation (1), the expected surface runoff in m$^3$/s was obtained as follows.

$$Q = \left(\frac{1}{3.6}\right)CiA = \left(\frac{1}{3.6}\right)\times 0.57\times 31.77\times 0.0874$$

$$\therefore Q = 0.44\,m^3/s$$

### 3.2 Hydraulics Design and Engineering Drawings

#### 3.2.1 Dimensions of drainage channel

The hydraulics design considered a most-economic rectangular section with cement concrete lining. Based on these considerations, the designed dimensions were simplified using Equation (7) to (11).

Since the cross-sectional area ($A_c$) of rectangular channel is expressed as the product of the channel's width (*b*) and depth of flow (*y*), it implies;

$$A_c = by \quad (7)$$

$$\therefore y = \frac{A_c}{b}$$

However, for a rectangular channel to have most-economic section, the depth of flow (*y*) must be half of the channel's width (*b*) while the hydraulic radius (*R*) must be half of the depth of flow (*y*). i.e.

$$y = \frac{b}{2} \quad (8)$$

$$R = \frac{y}{2} = \frac{b/2}{2} = \frac{b}{4} \quad (9)$$

$$\Rightarrow A_c = b\left(\frac{b}{2}\right) = \frac{b^2}{2} \qquad (10)$$

By substituting Equation (9) and (10) into Equation (5) which is the Manning's formula for continuity equation, it became;

$$Q_d = \frac{A_c R^{2/3}\sqrt{S}}{n} = \frac{(b^2/2)(b/4)^{2/3}\sqrt{S}}{n} = \frac{(b^{2+2/3})\sqrt{S}}{2(4)^{2/3}n} = \frac{b^{8/3}\sqrt{S}}{5.04n}$$

i.e. $Q_d = \frac{b^{8/3}\sqrt{S}}{5.04n}$

$$\Rightarrow b^{8/3} = \frac{5.04nQ_d}{\sqrt{S}}$$

$$\therefore Channel's\ width\ (b) = \left(\frac{5.04nQ_d}{\sqrt{S}}\right)^{3/8} \qquad (11)$$

As earlier stated, two equal parallel drainage channels are proposed hence, the design discharge $(Q_d)$ in each of the drainage channel was calculated by means of Equation (4) as;

$$Q_d = \frac{Q}{2} = \frac{0.44m^3/s}{2} = 0.22\,m^3/s$$

The channel or bed slope ($S$) being the ratio of elevation difference to channel length was calculated as 0.01. For cement concrete lining, the Manning's roughness coefficient ($n$) is 0.015 (Garg, 2010). Having known the values of $Q_d$, $n$, and $S$, the channel's width ($b$) was determined from Equation (11) as;

$$Channel's\ width\ (b) = \left(\frac{5.04 \times 0.015 \times 0.22}{\sqrt{0.01}}\right)^{3/8}$$

$$i.e.\ Channel's\ width\ (b) = 0.510m = 510mm$$

The depth of flow is calculated from Equation (8) as;

$$Depth\ of\ flow\ (y) = \frac{b}{2} = \frac{0.510}{2} = 0.255m = 255mm$$

One-fifth (1/5) of the flow depth was added as freeboard space ($F$) to manage unforeseen excessive storm thus;

$$Freeboard\ space\ (F) = \frac{1}{5} of\ (0.255m) = 0.051m = 51mm$$

Hence, the total depth of channel ($d$) becomes;

$$Total\ depth\ of\ channel\ (d) = y + F$$

$$i.e.\ d = 0.255m + 0.051m = 0.306m = 306mm$$

### 3.2.2 Checking for safe velocity of flow

The flow velocity $(v)$ for cement concrete lined channel is usually set at the range of 1.0 – 2.5m/s to prevent siltation and scouring of channel. In other words, a flow velocity less than 1.0m/s could lead to siltation of the channel, and a flow velocity above 2.5m/s could lead to scouring of the channel however, a flow velocity between the range of 1.0m/s – 2.5m/s will permit self-cleansing of the channel without scouring of the surfaces.

From Equation (7), cross-sectional area $(A_c)$ is:

$$A_c = by = 0.510m \times 0.255m = 0.130m^2$$

From continuity equation, discharge is the product of cross-sectional area of channel and flow velocity $(v)$. Thus;

$$Q_d = A_c \times v$$

$$i.e. Flow\ velocity\ (v) = \frac{Q_d}{A_c} = \frac{0.22m^3/s}{0.130m^2} = 1.69m/s$$

Since the flow velocity is 1.69m/s which is within the acceptable range, it implies the hydraulics design is satisfactory.

### 3.2.3 Engineering drawings

The technical drawings, specifically orthographic and isometric views of the designed surface drainage (open channel) are shown in Figure 5 and Figure 6 respectively, with all dimensions kept in mm.

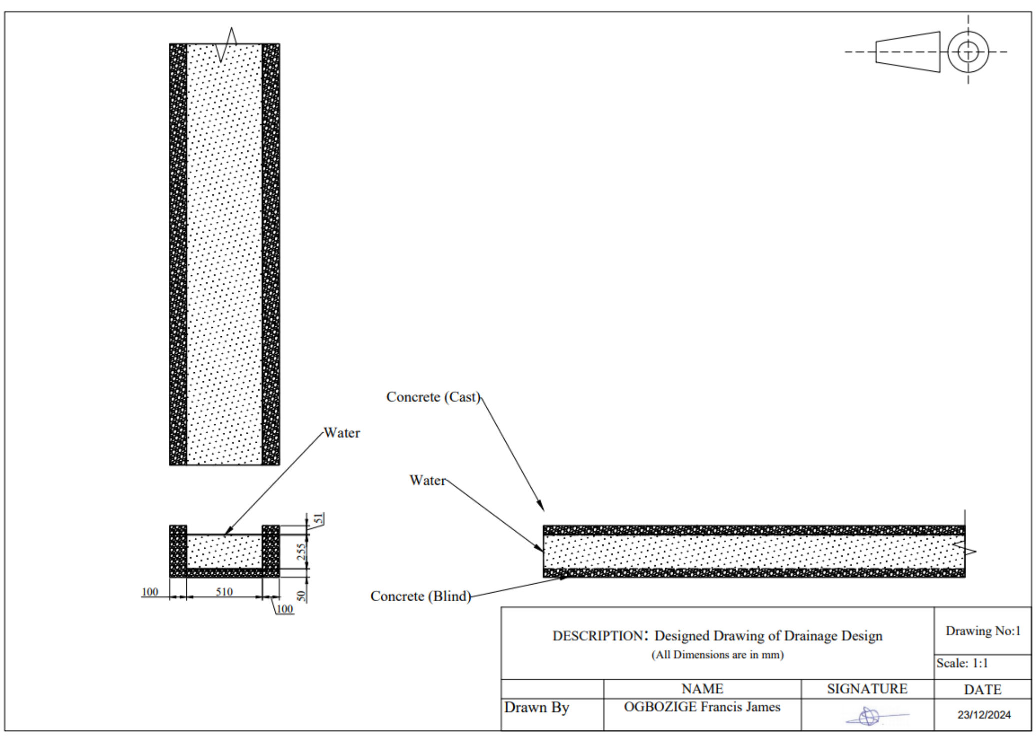


**Figure 5:** Orthographic projection (1st angle) of surface drainage channel

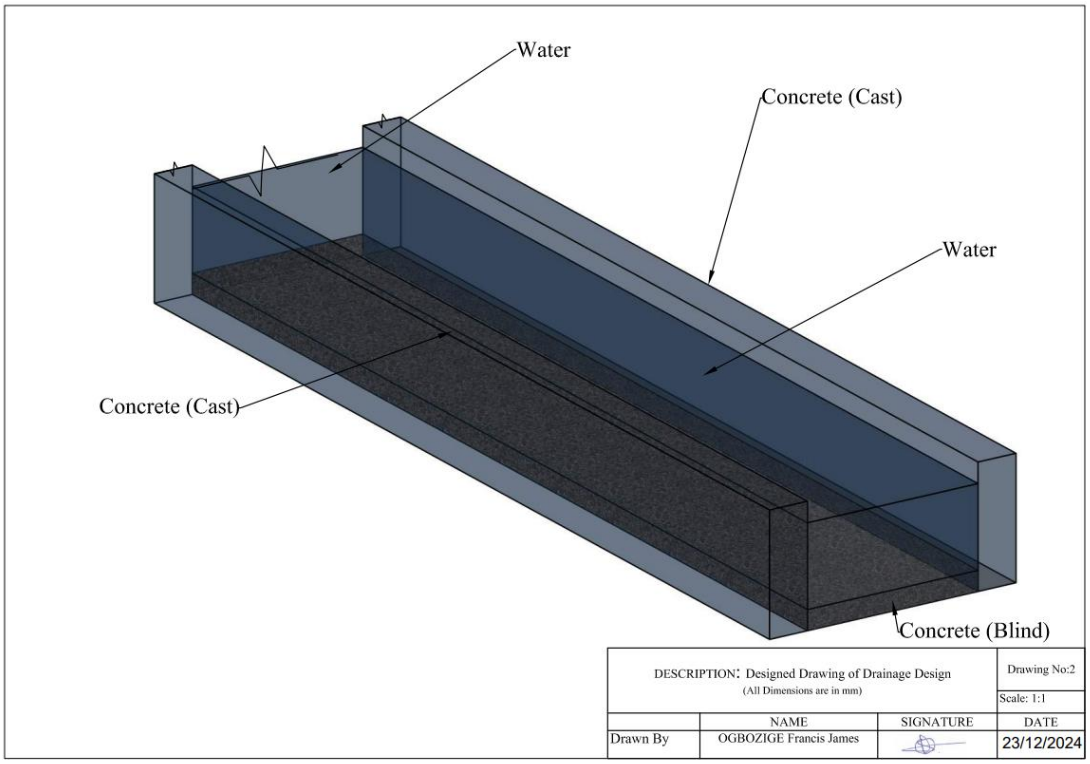


**Figure 6:** Isometric view of surface drainage channel

## 4.0 Conclusion and Recommendation

The work have applied the principles of Water Resources Engineering (Hydrology and Hydraulics) to design the optimal dimensions of a surface drainage channel that could successfully discharge excess rainwater (direct runoff), which is usually neglected in most cases despite its relevance. The design calculations were detailed and simplified to aid related prospective researchers, contractors, supervising engineers as well as students. Thus, the information made available in this work will not only help the proper design of the proposed drainage channel but will also serve as a guide during the design stage of other drainages (open channels) since most engineers complain of the lack of detail information of this kind apart from design standards. Hence, it is highly recommended for implementation during the design stage of the drainage channel in the study area as well as a guide to related designs by ensuring proper adjustments or moderations to suit the reality of the case being considered, in line with design standards.

## References

Basnet, K., Chettri, K., Parajuli, G. and Bhandari, A. (2020). Hydrological and Hydraulic Analyses of Urban Storm Water Drainage System of Major Area of Pokhara, Nepal. *Journal of Innovations in Engineering Education,* 3(1): 78 – 91.

Dagne, H.T. and Bortola, M.W. (2020). Assessment of Stormwater Drainage System for Small Urban Watershed: A Case of Shambu Town, Oromia Region, Ethiopia. *Jounal of Civil and Environmental Engineering,* 10(5): 1 – 7.

Ezugwu, M.O. and Eze, A.B. (2019). A Basic Design Approach of Drainage Facilities for Efficient Prevention and Control of Flooding. *Nigerian Journal of Engineering Science Research,* 2(1): 1 – 12.

Garg, S.K. (2010). Sewage Disposal and Air Pollution Engineering (Environmental Engineering Vol. II). Khanna Publishers, New Delhi, India.

George, A.G., Shaju, A., Rafeek, A., Binu, N. and Amadil, S.M. (2021). Storm Water Drainage Design Based on Hydrological Analysis at Shanmugham Road Area, Cochin, Kerala. *International Research Journal of Engineering and Technology,* 8(7): 543 – 548.

MDOT (2006). Design Guidance and Procedure in Hydrology. A publication of Michigan Department of Transportation (MDOT), Lansing, USA.

Nigerian Drainage Design Manual (2013). A Publication of the Federal Ministry of Works, Abuja, Nigeria.

NIMET (2024). Rainfall and Temperature in Ogbia, Nigeria. An Online Information Released by the Directorate of Weather Forecasting Service of the Nigerian Meteorological Agency. https://nomadseason.com/climate/nigeria/bayelsa/ogbia.html

Ogbozige, F.J. (2021). Development of Intensity-Duration-Frequency (IDF) Models for Manually Operated

Rain Gauge Catchment: A Case Study of Port Harcourt Metropolis Using 50 Years Rainfall Data. *Tanzania Journal of Engineering and Technology,* 40(2): 33 – 44. https://doi.org/10.52339/tjet.v40i2.731

Ogbozige, F.J. (2023). Application of GIS Techniques in Generating Rainfall-IDF Maps for Ungauged Catchment: A Case of Yenagoa City, Nigeria. *Journal of Engineering and Engineering Technology,* 17(2): 32 – 41. https://futajeet.ng/home/paperdetails/47

Ogbozige, F.J. and Alfa, M.I. (2019). Land Use-Land Cover Effects on Surface Flowing Water Quality: A Statistical Approach. *Nigerian Journal of Technological Development,* 16(1): 25 – 35. http://dx.doi.org/10.4314/njtd.v16i1.4

Tariku, M. (2022). Assessment of the Hydraulic Performance of the Drainage System in Dire Dawa Town. Journal of Civil and Environmental Engineering, 12(1): 1 – 6.