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PERFORMANCE ANALYSIS OF BOX AND CIRCULAR CULVERTS USING HY 8 SOFTWARE FOR ALUU CLAN, PORT HARCOURT

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ABSTRACT
This study is on culvert performance analysis carried out in Aluu clan comprising of nine communities. A total of ten culverts located across the roads within the communities were inspected and monitored during rainy season. It entails assessing the culverts to ascertain their functionalities. Amongst all the culverts, one location was observed to be problematic because of the extent and duration of flooding after an incidence of intense rainfall in the area. From field data obtained, the Rational method was employed to determine the peak design flow as 450 ft³/s (12.74 m³/s). The hydraulic analysis was carried out using HY-8 software (in imperial units) by US Federal Highway Administraion, a powerful tool for analyzing variety of culvert shapes and configurations. From field measurements it was discovered that the existing circular culvert comprising of three barrels of 3 ft (914 mm) diameter, each has a headwater elevation of 115.72 ft (35.27 m) as compared to the roadway elevation of 115 ft (35.05 m). The existing circular culvert was redesigned as box and circular options for comparison and selection. Comparing the two redesigned options, circular and box culverts having headwater elevations of 113.06 ft (34.46 m) and 109.58 ft (33.40 m) while tail-water elevations of both is 106.17 ft (32.36 m), with respect to roadway elevation of 115 ft (35.05 m). Both design options are capable of containing the design flow without any incidence of flooding. However, box culvert has an advantage of lower headwater elevation. Also, both circular and box culverts are outlet control as depicted by culvert performance curves. We stand to gain by redesigning existing culverts observed to experience flooding during heavy storms of short durations. There is need to monitor performance of existing culverts as some were designed with limited field data resulting in under- or over-design.

Keywords: *Circular and Box culverts, headwater elevation, HY-8 software, Design flow, Aluu Clan, Port Harcourt.*

1. INTRODUCTION

In recent times, flooding has become a menace in Rivers State. Hence the need to take pragmatic steps to stop or prevent its occurrence. A number of factors are responsible for urban flooding, namely: poorly constructed gutter inverts with flat and/or undulating slopes; inadequate drainage network system with larger drains discharging into smaller drains; and under sized culverts [1]. The issue of flooding due to culvert inadequacy arising from limited or lack of field data used in design has not been fully addressed ,hence this study.

According to ODOT [2] culvert can be defined as a structure used to convey surface runoff through embankments and as a structure, as distinguished from bridges, that is ordinarily concealed with embankment and is composed of structural material around the entire boundary, although some are supported on spread footings with the streambed serving as the bottom of the culvert. The term "culvert" covers virtually all closed conduits applied for allowing the passage of storm water through an embankment or obstruction along the roadway with the exception of drains. The designer should consider which structure amongst culvert,

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bridge and other storm water systems that will be hydraulically, aesthetically and economically feasible bearing safety in mind. Furthermore, culverts are distinguished from bridges due to span.

Culverts with span width exceeding 20 ft (6.1 m) are categorized as bridges generally following National Bridge Inspection Standards, NBIS [3]. Culverts are constructed in different standard shapes and sizes and are obtainable for most culverts materials. Concrete and steel amongst other materials are the two that are often used in constructing culverts. The most common culvert shapes are box (rectangular), elliptical, circular, and pipe-arch. Choosing a shape is dependent on the following factors such as; construction cost, the upstream water surface elevation control, embankment height of roadway, and hydraulic performance [3]. The aforementioned cross sectional shapes consist of the standard shapes obtainable in the computer program for culvert design developed by FHWA known as HY-8 which is used for running the analysis for this work.

Culvert design can be categorized into two distinctive areas, namely the structural analysis, with emphasis on static and dynamic load (moving vehicles, trains, etc.) on culvert design parameters such as effects on coefficient of earth pressure, angle of dispersion of live load, depth of cushion provided on top slab of say box culvert against structural deformation [4 - 12]. The second category is the hydrologic and hydraulic design analysis based on estimated peak flow rate using Rational formula or Geographic information system based software ArcGIS 10.4 edition, HY-8 software for sizing the culvert types [13 – 16].

For conventional box or circular culverts without any inlet modification, manual design approach can be adopted with the aid of design charts or Nomographs, procedures are found in standard hydraulic textbooks or reports [16].

Perrin and Jhaveri [17] carried out an economic exploration of culvert life cycles. They noted that most culverts are not replaced at the end of their life cycles, rather replacement occurs after failure and is costly. When these culverts fail, they are then replaced at emergency rates. Perrin and Jhaveri furthermore, stated that inspection and maintenance programs will lead to an overall savings when compared to emergency replacements. Perrin and Jhaveri concluded that it is important to consider whether a pipe with longer life is more cost effective simply based on the likelihood that the pipe may not be replaced at the end of its design life.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Aluu clan which comprises of nine (9) communities. It is located in Ikwerre Local Government Area of Rivers State Nigeria. Aluu is located in latitude 4^0 56′ 01.8″ N (4.9338400^0) and longitude 6^0 56′ 58.1″ E (6.9494600^0). The University of Port Harcourt is located close to it and most of the members of staff and students reside here. Though it is a rural area but it is rapidly developing into a semi urban. Figure 1 shows the map of Aluu with the area where the problematic culvert is located been circled.

Figure 1: Location Map of Aluu (Problematic circular culvert location circled in red.)

2.2 Data Collection

Data acquisition for this research was carried out in phases. Before embarking on data collection, it was pertinent to decide on what information to collect. This was necessary to allow for judicious use of time and resources. Some of the data obtained were by physical observation while others were obtained by direct measurements as presented in Table 3. Table 1 presents the culverts' details (location, type, size, length across the road and coordinates).

2.3 Data Analysis

2.3.1 Design Flow

Various methods are in use to calculate the design flow. For gaged sites, statistical analysis is employed while for ungagged sites, Rational formula is used. Given that the site is ungagged and the watershed is not vast, the Rational method is employed to estimate the design flow. The Rational formula is applied with some assumptions as follows [18].

i. The maximum rate of runoff for particular rainfall intensity occurs if the duration of rainfall is equal or greater than the time of concentration.
ii. The maximum rate of runoff from a specific rainfall intensity whose duration is equal to or greater than the time of concentration is directly proportional to the rainfall intensity.
iii. The frequency of occurrence of the peak discharge is the same as that of rainfall intensity from which it was calculated.
iv. The peak discharge per unit drainage area increases and the intensity of rainfall decreases as its duration increases
v. The coefficient of runoff remains constant for all storms on a given watershed.

The Rational formula is expressed as follows:

$$Q = 0.278CiA \tag{1}$$

Where: Q is the amount of runoff (m^3 /s); C is the coefficient of runoff (unitless); i is the rainfall intensity (mm/hr); and A is the area (km^2).
However, if "i" is expressed in m/s and "A" in m^2 then " Q" will be expressed as:

$$Q = CiA \tag{2}$$

2.3.2 Rainfall Intensity

The rainfall intensity is often read from an intensity duration curve if the duration and storm return periods are known [19]. However, the rainfall intensity is obtained from models developed by Nwaogazie and Duru [20] for Port Harcourt city. The return period adopted for this research is 5.5years. The models for the determination of rainfall intensity are as presented in Table 2

Table 1: Existing Culverts Locations & Other Details

S/No.	Location/ Community	Type	Size (mm)	Length across the Road (m)	Remark	Coordinates
1	Omuokiri	Circular	900	11.8	Silted	4.916538, 6.916795
2	Omuike	Circular	900	10.2	Silted with debris	4.943555, 6.928741
3	Omuigwe	Circular	750	13.9	Good	4.942638, 6.931590
4	Boundary	Box	(1000x1200)	7.15	Silted	4.932634, 6.942604
5	Boundary	Box	(1100 x 600)	12	Silted	4.934545, 6.942043
6	Omahunwo	Circular	900	15	Silted	4.931792, 6.938495
+7	Omuoko	Circular	900	20	Problematic	4.924677, 6.916675
8	Omuehuechi	Box	(1200 x 600)	10.1	Silted with debris	4.914864, 6.899903
9	Health centre Road	Box	(750 x 900)	9	Silted	4.910095, 6.907148

+ Problematic culvert, because it floods after heavy rainfall which lasts for weeks hence there is need for its redesign.

Table 2: Port Harcourt City Rainfall Intensity-Frequency Models for Specified Durations

Duration (Minutes)	Rainfall Models $i=aR^b$	Regression Parameters*
18	$i= 21.1471R^{0.48787}$	GF=0.8869, CC=0.9417
24	$i= 18.2569R^{0.52112}$	GF=0.9178, CC=0.9580
30	$i=16.8537R^{0.469207}$	GF=0.9516, CC=0.9655
48	$i=16.13534^{0.46904}$	GF=0.9353, CC=0.9671
60	$i=14.6422R^{0.47881}$	GF=0.9335, CC=0.9662
120	$i=13.2533R^{0.40953}$	GF=0.9307, CC=0.9647
180	$i=11.2667R^{0.42011}$	GF=0.9798, CC=0.9899
300	$i=10.1071R^{0.43356}$	GF=0.9744, CC=0.9871

**GF=Goodness of Fit; CC=Correlation Coefficient;* +Source: Nwaogazie and Duru (2002)

2.3.3 Catchment Area

The catchment area was obtained by carefully observing the watershed during rainfall to approximately ascertain the various areas contributing to the channel. These areas were measured and an approximate figure was obtained. The frequency periods for estimating the amount of runoff for different areas was very necessary.

2.4 HY-8 Software for Culvert Design

HY-8 computer software, also known as HYDRAIN (written in imperial units) by United States of America Federal Highway Administration [3] is used for design and analysis of culverts. HY-8 is a 32 –bit program, but it is fully compatible with 32 and 64 bit Windows – based operating systems (XP, Vista and Windows 7) and runs in 32 – bit mode on these operating systems. It automates culvert hydraulic computations and also enables the analysis of the following:

(a) Performance of the culvert;
(b) Multiple culvert barrels at a single crossing as well as multiple crossing;
(c) Roadway overtopping at the crossing; and
(d) Develop report documentation in the form of performance tables, graphs, and key information regarding the input variables.

HY-8 should be used if any of the following conditions apply:

(a) Crossing has only culverts and no nearby upstream or downstream structures;
(b) Crossing is to be designed;
(c) A tapered inlet alternative is been considered;
(d) An irregular shape culvert has to be considered for joint use;
(e) Embedded culvert is being considered for aquatic organism passage (AOP) design;
(f) A broken-back culvert is to be considered; and
(g) Energy dissipator design is expected.

The culvert design flow chart with respect to HY-8 software is as presented in Figure 2

The input data for the analysis of the culverts are presented in Table 3

3. RESULTS AND DISCUSSION

3.1 Results

The summary of flows for the existing circular culvert as obtained from HY-8 simulation is presented in Table 4. After the simulation, it was discovered that the existing culvert lacks the capacity to convey the design flow hence the need to redesign using box and circular culvers as options, respectively to ascertain which type will better convey the design flow of 450 ft^3/s (12.72 m^3/s).

Table 5 presents the summary of flows obtained from simulations done for the redesigned box culvert with respect to the design flow of 450 cfs.

Table 6 presents the summary of flows obtained from simulations done for the redesigned circular culvert with reference to the design flow of 450 cfs.

Table 7 presents the comprehensive result obtained from the simulation done on the redesigned box culvert.

Table 8 presents the comprehensive result obtained from the simulation done on the redesigned circular culvert

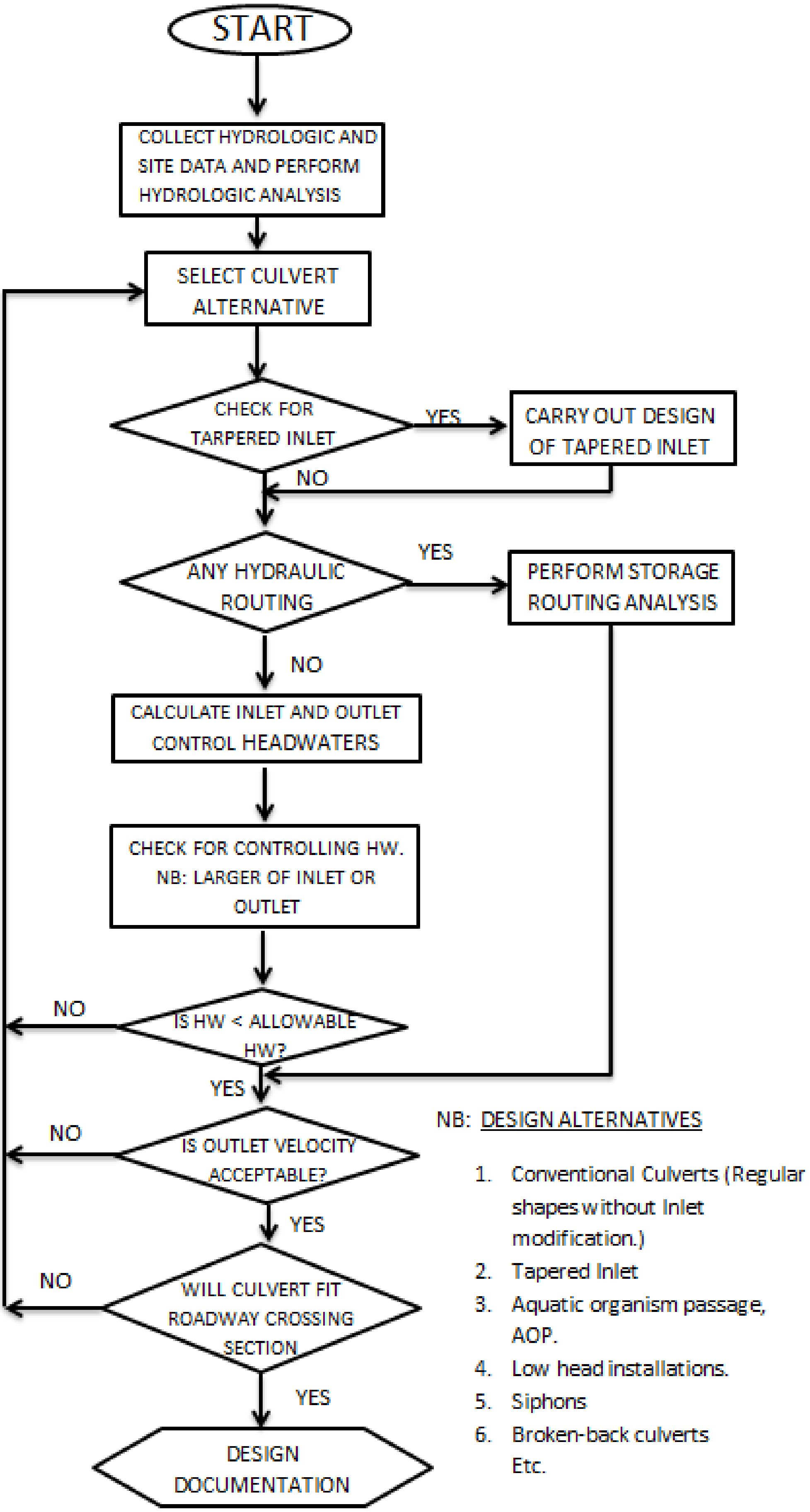

Figure 2: Flow Chart for HY-8 Software

Table 3: Input Data for Culvert Design Using HY-8 Software

S/N	Description	Value		Remark
		Metric	Imperial	
1	Design Flow	12.43m3/s	450 cfs	Calculated
2	Channel Type	Rectangular	Rectangular	Observation
3	Channel Slope	0.02	0.02	Measured
4	Channel Invert Elevation	30.23m	99.2 ft	Measured
5	Manning's Constant (Channel)	0.032	0.032	From Literature
6	Inlet Invert Elevation	30.33m	99.5 ft	Measured
7	Outlet invert elevation	29.87m	98.0 ft	Measured
8	Culvert Slope	-	-	To be calculated
9	Manning's Constant (Culvert)	0.012	0.012	Observation
10	Roadway Elevation	35.05m	115 ft	Measured
11	Roadway Surface	Paved	Paved	Observation
12	Shape	Circular/Box	Circular/Box	Observation
13	Material	Concrete	Concrete	Observation
14	Length of Culvert	20m	65 ft	Measured
15	Top width	20m	65 ft	Measured
16	Span (width)-Box	1.5m	5 ft	Measured
17	Rise (height)-Box	1.2m	4 ft	Measured
18	Diameter-Circular	0.9m	3 ft	Measured
19	Bottom width of Channel	1.8m	6 ft	Measured
20	Crest Length	9.14m	30 ft	Measured
21	Number of Barrels (Box)	2	2	Observation
22	Number of Barrels (Circular)	3	3	Observation
23	Inlet Configuration	1:1 bevel(45^{o}) E Wingwall	1:1 bevel(45^{o}) E Wingwall	Observation
24	Culvert Type	Straight	Straight	Observation

Table 4: Summary of Existing Circular Culvert Flows of Three Barrels at Crossing (D=3ft^{+}).

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
99.50	0.00	0.00	0.00	1
101.35	50.00	50.00	0.00	1
102.36	100.00	100.00	0.00	1
103.61	150.00	150.00	0.00	1
105.46	200.00	200.00	0.00	1
107.63	250.00	250.00	0.00	1
110.11	300.00	300.00	0.00	1
112.90	350.00	350.00	0.00	1
115.26	400.00	388.32	11.57	8
$^{++}$115.72	450.00	394.99	54.99	5
116.07	500.00	399.69	100.22	4
115.00	384.31	384.31	0.00	Overtopping

$^{+}$HY-8 output is usually in imperial units.

$^{++}$ This row depicts results obtained at the designed flow after simulation.

Table 5: Summary of Redesigned Box Culvert Flows of Two Barrels at Crossing, (5ft x 4ft).

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
99.50	0.00	0.00	0.00	1
101.04	50.00	50.00	0.00	1
101.94	100.00	100.00	0.00	1
102.78	150.00	150.00	0.00	1
103.62	200.00	200.00	0.00	1
104.58	250.00	250.00	0.00	1
105.72	300.00	300.00	0.00	1
106.93	350.00	350.00	0.00	1
108.22	400.00	400.00	0.00	1
+109.58	450.00	450.00	0.00	1
111.02	500.00	500.00	0.00	1
115.00	625.46	625.46	0.00	Overtopping

+ This row depicts results obtained at the designed flow after simulation.

Table 6 Summary of Redesigned Circular Culvert Flows of Three Barrels at Crossing, (D=3.5ft).

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
99.50	0.00	0.00	0.00	1
101.19	50.00	50.00	0.00	1
102.11	100.00	100.00	0.00	1
103.08	150.00	150.00	0.00	1
103.73	200.00	200.00	0.00	1
105.66	250.00	250.00	0.00	1
107.27	300.00	300.00	0.00	1
109.03	350.00	350.00	0.00	1
110.96	400.00	400.00	0.00	1
+113.06	450.00	450.00	0.00	1
115.13	500.00	495.97	3.93	8
115.00	493.27	493.27	0.00	Overtopping

+ This row depicts results obtained at the designed flow after simulation.

Table 7 Summary of Simulated Redesigned Box Culvert Details of Two Barrels

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	99.50	0.000	0.000	0-NF	0.000	0.000	1.200	0.000	0.000	0.000
50.00	50.00	101.04	1.542	1.079	1-JS1t	0.470	0.919	2.537	1.337	1.971	6.233
100.00	100.00	101.94	2.440	2.043	1-JS1t	0.740	1.459	3.375	2.175	2.963	7.664
150.00	150.00	102.78	3.190	3.284	1-S1f	0.971	1.912	4.000	2.929w	3.750	8.536
200.00	200.00	103.62	3.881	4.118	1-S1f	1.182	2.316	4.000	3.642	5.000	9.152
250.00	250.00	104.58	4.576	5.084	4-FFf	1.381	2.687	4.000	4.332	6.250	9.619
300.00	300.00	105.72	5.322	6.221	4-FFf	1.571	3.035	4.000	5.006	7.500	9.989
350.00	350.00	106.93	6.154	7.432	4-FFf	1.755	3.363	4.000	5.668	8.750	10.291
400.00	400.00	108.22	7.099	8.717	4-FFf	1.933	3.676	4.000	6.322	10.000	10.545
+ 450.00	450.00	109.58	8.171	10.081	4-FFf	2.107	3.977	4.000	6.970	11.250	10.760
500.00	500.00	111.02	9.381	11.524	4-FFf	2.278	4.000	4.000	7.613	12.500	10.946

+ This row depicts results obtained at the design flow after simulation

Figures 3 and 4 present plots of headwater elevation against discharge known as Rating curve for box culvert and circular culvert, respectively.

Figures 5 and 6 present the front view and roadway profile of the box and circular culverts respectively. Figures 7 and 8 present plots of headwater elevation against discharge for the box and circular culverts, respectively. These graphs are known as performance curves. They are used to know the section that is controlling the flow in the culvert. Table 9 presents summary of results for redesigned box & circular culverts.

Figures 9 and 10 present the plots of elevation against station (the position of the culvert along the roadway) for box and circular culverts respectively. This plot is known as water surface profile.

Table 8 Summary of Simulated Redesigned Circular Culvert Details of Three Barrels

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	99.50	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
50.00	50.00	101.19	1.691	1.122	1-JS1t	0.729	0.919	1.243	1.337	2.171	6.233
100.00	100.00	102.11	2.608	2.215	1-JS1t	1.036	1.459	1.787	2.175	3.475	7.664
150.00	150.00	103.08	3.384	3.579	1-S1f	1.283	1.912	2.206	2.929	5.197	8.536
200.00	200.00	103.73	4.229	3.342	5-S2n	1.504	2.316	2.556	3.642	12.996	9.152
250.00	250.00	105.66	5.269	6.157	4-FFf	1.710	2.687	2.844	4.332	8.661	9.619
300.00	300.00	107.27	6.565	7.766	4-FFf	1.909	3.035	3.068	5.006	10.394	9.989
350.00	350.00	109.03	8.125	9.533	4-FFf	2.109	3.363	3.224	5.668	12.126	10.291
400.00	400.00	110.96	9.934	11.463	4-FFf	2.315	3.676	3.321	6.322	13.858	10.545
+ 450.00	450.00	113.06	12.059	13.556	4-FFf	2.540	3.977	3.413	6.970	15.591	10.760
500.00	500.00	115.13	14.273	15.677	4-FFf	2.784	4.000	3.500	7.613	17.184	10.946

+ This row depicts results obtained at the design flow after simulation.

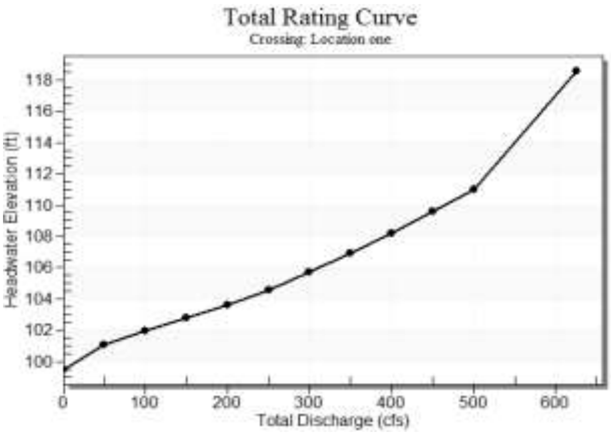

Figure 3: Rating Curve for Crossing: Box Culvert (5ft x 4ft)-Double Barrel -Redesigned

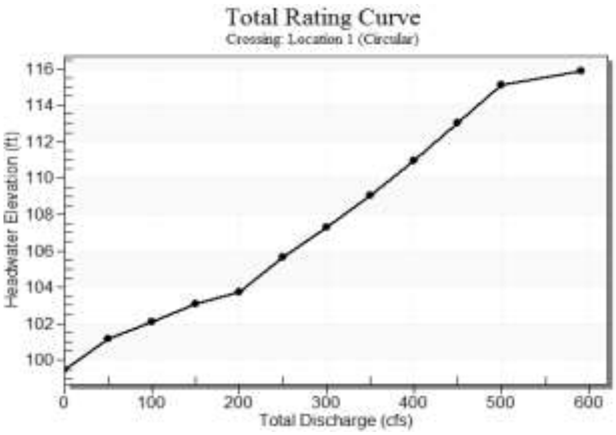

Figure. 4: Rating Curve for Crossing: Circular Culvert (3.5ft Diameter) – 3 Barrels Redesigned

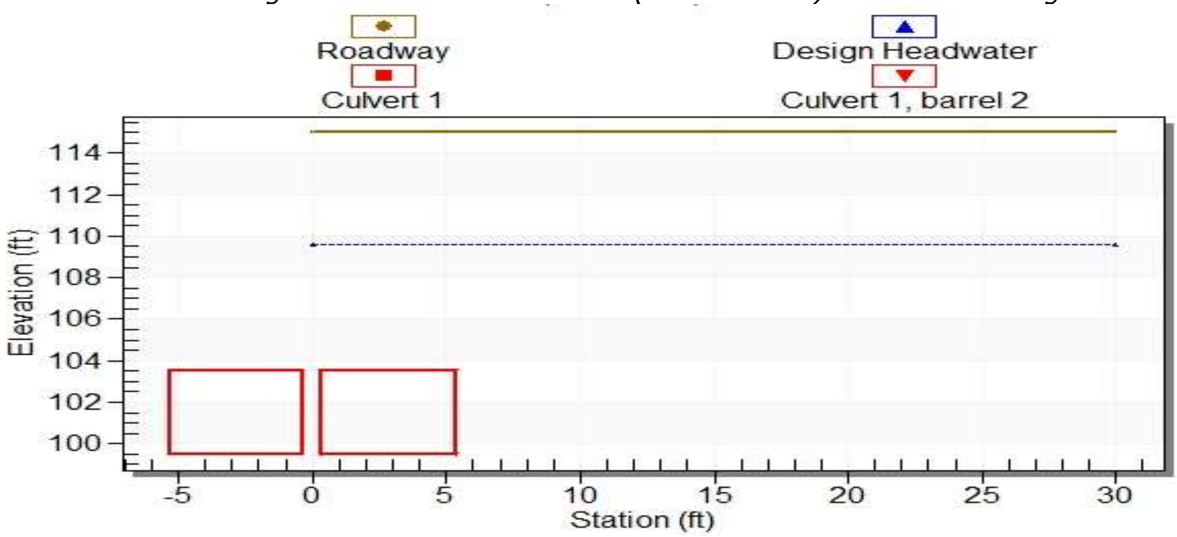

Figure 5 Crossing Front View (Roadway Profile): Box Culvert (5ft x 4ft) Two Barrels

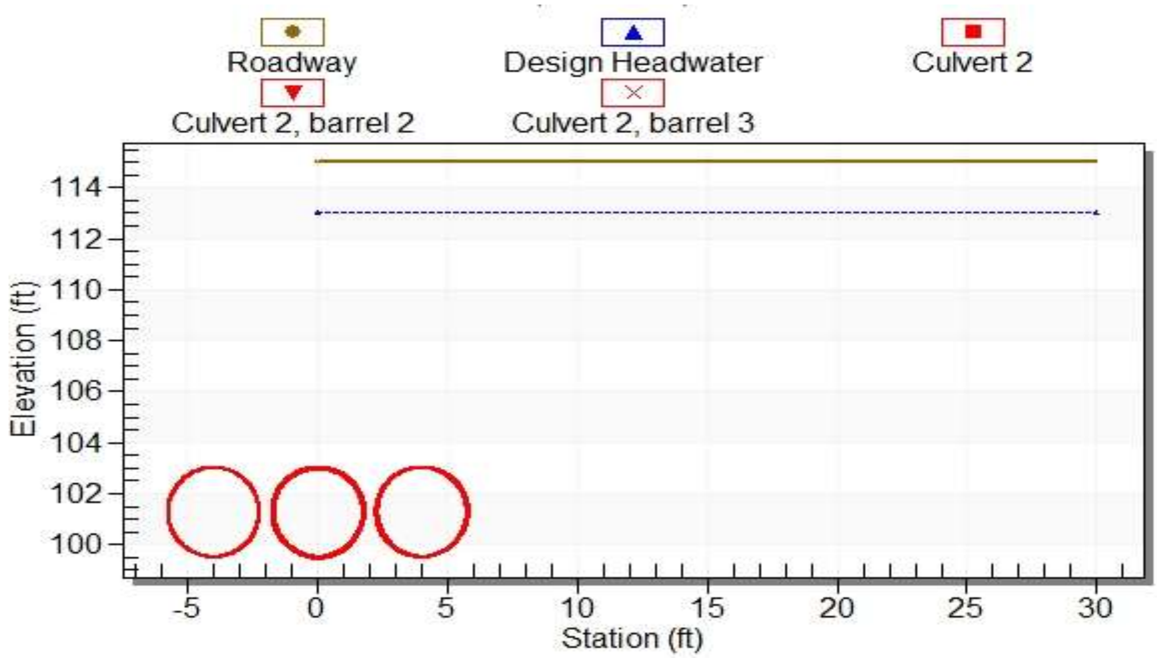

Figure 6 Crossing Front View (Roadway Profile): Circular Culvert (3.5ft Diameter)-3 Barrels

Table 9: Summary of results for redesigned Box & Circular Culverts.

Type	HW (ft)	CONTROL		Slope	TW (ft)	Q_{total} (ft^3/s)	VELOCITY		Froude No.	Barrel No.
		Inlet	Outlet				Outlet	TW		
Box	109.58		Yes	0.0231	106.17	450	11.250	10.760	0.72	2
Circular	113.06		Yes	0.0231	106.17	450	15.591	10.760	0.72	3

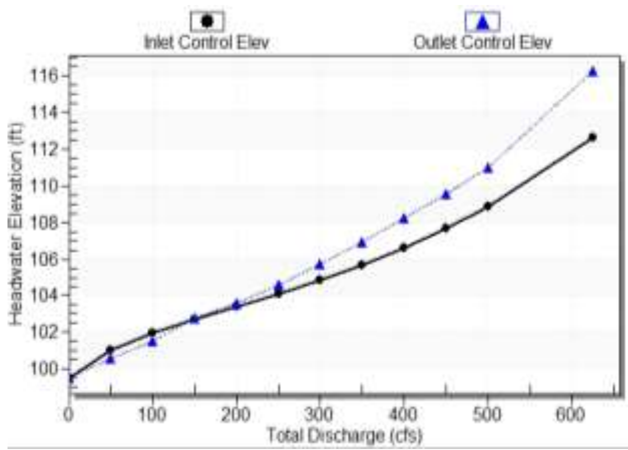

Figure 7: Culvert Performance Curve for Box Culvert.

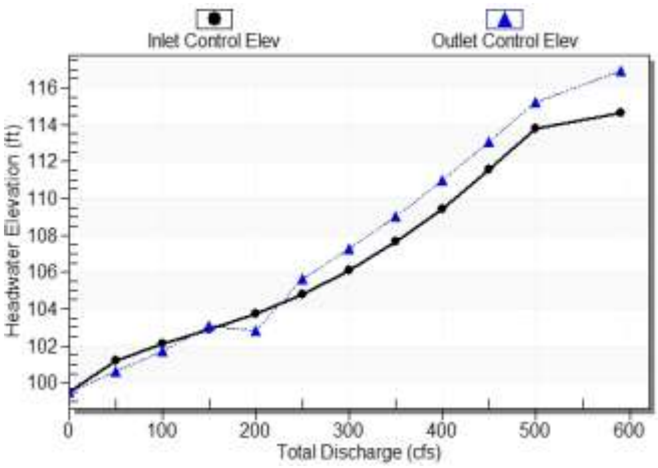

Figure 8: Culvert Performance Curve for Circular Culvert.

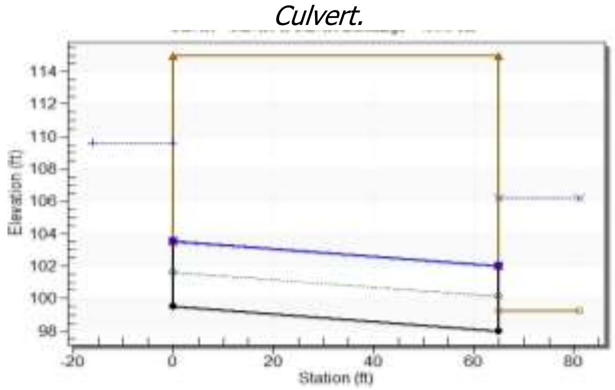

Figure 9: Water Surface Profile for Box Culvert: Culvert 1

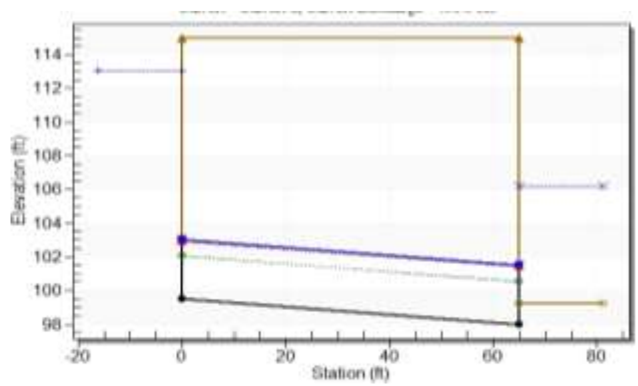

Figure 10: Water Surface Profile for Circular Culvert

3.2 Discussion

The headwater elevation obtained for the actual design discharge of 450 cfs (12.74m^3/s) is 115.72ft (35.27m) which is slightly above the roadway elevation. What this entails is that the culvert will not be able to convey the design discharge without roadway overtopping occurring. Norman *et al.* [21] confirmed that roadway overtopping entails culvert headwater elevation been greater than roadway crest. Furthermore on the design discharge of 450 cfs, the flow accommodated by the culvert is 394.99 cfs (11.18 m^3/s) instead of 450 cfs. The remaining flow goes over the road as roadway discharge (incident of flooding). It is therefore noted that the existing culvert lacked the hydraulic capacity to convey the design flow. Hence this is one of the reasons why the area is always flooded after rainfall incidence.

As a result of the culvert inability to convey the design flow, it was redesigned considering two shapes (circular and box) and the summary of the results obtained from the design are presented in Tables 5 and 6 respectively. It was observed that at design discharge of 450 cfs, the headwater elevation is 113.06 ft(34.46 m) for circular culvert. This is below the roadway elevation of 115 ft (35.05 m). Which means that there will be no roadway overtopping. Furthermore, it was also observed that at design flow of 450 cfs, the headwater elevation was 109.58 ft (33.40 m) for box culvert which by comparison is below that of the circular culvert. Other reports obtained from the analysis as presented in graphs will aid in ascertaining the culvert shape to be used to solve the issue of flooding in this area. Figures 3 and 4 are the rating curves for box and circular culverts, respectively. These are plots of Headwater elevations against a range of flows with the design flow inclusive. The importance of this curve is to aid determination of flow through the culvert if the headwater elevation is known at any given time.

Figures 5 and 6 depict the frontal view of the box and circular culverts respectively. The shape, headwater elevation, number of barrels and roadway elevation of the culvert can be viewed at a glance from these figures.

Figures 7 and 8 are known as performance curves. The flow through a culvert barrel is either controlled by inlet or outlet conditions. Performance curve is a plot of headwater elevations against discharges. Performance curve aims at ascertaining the control condition that is prevalent at a particular headwater elevation with respect to discharge because of difficulty in predicting the actual condition that is governing. From the said figures, the prevalent control condition at the design flow is the outlet control. Culverts with inlet control have high-velocity, low flow that is supercritical and the control section is at the upstream while culverts with outlet control have lower velocity, deeper flow that is subcritical and the control section is at the downstream [22]. Because the prevailing condition is outlet control, the Froude number (Table 9) confirms that the flow is subcritical with low velocity and deep flow.

One very important thing to note is the water profile of the culvert. Figures 9 and 10 present plots of water profile of the box and circular culverts respectively. The water profile is a plot of elevation against station. Station depicts the location of the culvert along the roadway and this also shows the length of the culvert across the roadway. This plot also reveals the roadway elevation. The headwater elevation of the box culvert at the design flow is 109.58 ft (33.40 m) and the tail water elevation is 106.17 ft (32.36 m). However, the headwater of the circular culvert is 113.06 ft (34.46 m) and the tail water is 106.17 ft (32.36 m). Note that the circular culvert comprises of three barrels of 3.5 ft (1.07 m) diameter each and the box culvert comprises of two barrels of 5 ft x 4 ft (1.52 mx 1.22 m) each. From the values of the headwater, the box culvert is more preferable because the headwater is lower than that of the circular culvert and this reduces the tendency of overtopping occurring. Also, note that the tail water elevations for both culverts are the same and this is because the prevailing control condition is outlet control.

4. CONCLUSION

Based on the result of this study, the following conclusions can be drawn:

1. With the aid of HY-8 software, existing culverts were adequately analyzed to ascertain if they have the capacity to convey surface runoff from a watershed. One of the ten existing culverts comprising of 3 barrels of 3 ft (900 mm) each lacks the capacity of conveying the design flow of 450 cfs (12.74 m^3/s) with a head water elevation of 115.72 ft (35.27 m) which is above the roadway elevation of 115 ft. Overtopping of the roadway becomes evident.
2. The re-designed circular culvert with three barrels of 3.5 ft (1050 mm) each has the capacity of conveying the design flow of 450 cfs

(12.74 m^3/s) with headwater elevation of 113.06 ft (34.46 m) which is about 2 ft (0.61 m) below the road way elevation of 115 ft (35.05 m). With this difference in elevation between the roadway and the headwater, roadway overtopping will not occur.

3. The box culvert designed for the same location comprising of two barrels of 5ft x 4ft (1.52m x 1.22 m) (i.e span x rise) has the capacity of conveying 450 cfs (12.74 m^3/s) design flow and has a headwater elevation of 109.58 ft (33.40 m). In comparison, due to the headwater elevation, the box culvert is hydraulically viable than the redesigned circular culvert of three barrels of 3.5 ft (1.07 m) diameter each.

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