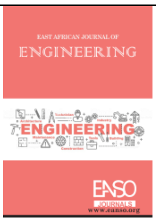


East African Journal of Engineering
eaje.eanso.org
Volume 7, Issue 1, 2024
Print ISSN: 2707-5389 | Online ISSN: 2707-5397
Title DOI: https://doi.org/10.37284/2707-5397

EANSO
EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Design of a Stormwater Management System in Lady Irene Campus

Tukashaba Shafan[1*]

[1] Ndejje University, P. O. Box 7088, Kampala, Uganda.
* Author for Correspondence ORCID ID: https://orcid.org/0009-0002-1265-475X; Email: shafantukashaba@gmail.com

Article DOI : https://doi.org/10.37284/eaje.7.1.2029

Publication Date:

08 July 2024

Keywords:

Stormwater Management, Flood Mitigation, Environmental Impact Assessment, Drainage Design, Sustainable Urbanisation

ABSTRACT

This project aimed to design an efficient drainage system for Ndejje University's Lady Irene Campus, addressing issues of erosion and flooding exacerbated by recent construction projects. The goal was to create a hydraulic conveyance system that balances environmental protection with structural integrity and affordability. The project involved field reconnaissance, data collection, and analysis of the campus's landscape, soil types, and development trends to inform the design. Methodologically, the project used GPS surveying to create topographical maps and obtained rainfall data to size drainage facilities using the rational method. The peak runoff was calculated considering land use characteristics, while Manning's formula was applied to design drainage channels and culverts. The design aimed to ensure high hydraulic capacity and prevent erosion with specific slope and material choices. An Environmental Impact Assessment was conducted, addressing noise, dust, water quality, waste management, and ecological impacts. Mitigation measures were recommended to minimize adverse effects during the construction and operation phases. Despite challenges such as limited access to surveying equipment and data, the project concluded with a comprehensive stormwater management plan. Recommendations include rehabilitating the university's weather station and establishing a project database to support future planning and research. The project underscores the importance of integrating sustainable practices in urban development to safeguard environmental and infrastructural integrity.

APA CITATION

Shafan T. (2024). Design of a Stormwater Management System in Lady Irene Campus *East African Journal of Engineering*, 7(1), 199-216. https://doi.org/10.37284/eaje.7.1.2029

CHICAGO CITATION

Shafan, Tukashaba. 2024. "Design of a Stormwater Management System in Lady Irene Campus". *East African Journal of Engineering* 7 (1), 199-216. https://doi.org/10.37284/eaje.7.1.2029.

HARVARD CITATION

Shafan T. (2024) "Design of a Stormwater Management System in Lady Irene Campus", *East African Journal of Engineering*, 7(1), pp. 199-216. doi: 10.37284/eaje.7.1.2029.

IEEE CITATION

T., Shafan "Design of a Stormwater Management System in Lady Irene Campus" *EAJE*, vol. 7, no. 1, pp 199-216, Jul. 2024.

MLA CITATION

Shafan, Tukashaba "Design of a Stormwater Management System in Lady Irene Campus" *East African Journal of Engineering*, Vol. 7, no. 1, Jul. 2024, pp. 199-216, doi:10.37284/eaje.7.1.2029.

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

INTRODUCTION

Stormwater management is considered crucial for mitigating the adverse effects of surface runoff, particularly in urban areas where impermeable surfaces hinder infiltration. Traditional methods, which primarily focused on draining high peak flows, have given way to modern approaches aimed at mimicking the natural water cycle by storing runoff, recharging groundwater, and utilizing collected water for various purposes (Council et al., 2009). The management of stormwater is essential to prevent erosion of agricultural land and flooding of inhabited areas, which could lead to significant damage and environmental contamination (Barbosa et al., 2012).

In rural areas, the increase in peak flow rates and discharge volume resulting from subdivisions, roads, and buildings has led to flooding and stream erosion. Techniques such as spate irrigation, micro basins, and rooftop harvesting are employed to manage stormwater while preserving water for agriculture and drinking purposes (Ellis & Revitt, 2010; ARC, 2001).

Despite being developed long ago, the Rational Method is still widely used for estimating peak discharge on small catchments with uniform land use. While it provides reasonable results, it does have limitations, particularly for larger catchments. Calculating water quality volumes and controlling peak storm flow are vital aspects of stormwater management design (U.S. Department of Housing and Urban Development, 2016).

Various stormwater management practices, including detention ponds, retention ponds, on-site stormwater detention, rainwater harvesting, green roofs, constructed wetlands, infiltration trenches, filter strips, grassed swales, pervious pavements, and infiltration basins, are discussed (Kellagher et al., 2007). Each practice has specific design considerations and objectives, aiming to control peak flows, improve water quality, and promote groundwater recharge while minimizing environmental impact and maximizing efficiency.

Overall, stormwater management involves a combination of engineering solutions, natural processes, and sustainable practices to address the challenges posed by urbanization and land development while safeguarding the environment and water resources. This includes considerations of cost, health aspects, operation and maintenance, applicability, infrastructure types, and design considerations, all tailored to local conditions and with a focus on passive voice constructions (Arnbjerg-Nielsen et al., 2013).

The Project at Ndejje University aimed to address the pressing need for a comprehensive stormwater management system to mitigate environmental degradation and infrastructure damage caused by rainfall runoff. The project objectives included conducting field reconnaissance studies, data collection, analysis of collected data, developing preliminary designs and architectural and structural drawings, estimating costs, conducting cost-benefit analysis, and developing an environmental management Plan.

The research was conducted at Ndejje University Lady Irene Campus over a one-year duration, encompassing data collection, analysis, design, and report preparation for the stormwater management system. Structural elements, architectural and structural drawings, a bill of quantities, and an operation and maintenance plan were developed as part of the Project (Barbosa et al., 2012; EPA, 2007; Qiao et al., 2018). The implementation of a gravity-dependent stormwater management system was considered cost-effective and essential for sustainable urbanization at Ndejje University.

METHODOLOGY

This chapter contains all the activities carried out to fulfil the design of the stormwater management facility as follows:

- A GPS handheld machine was used to obtain the survey data for creating the topographical map in AutoCAD Civil 3D for cross-section and profile view of the drainage channel.

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

- We then obtained daily rainfall data from Namulonge Station to analyse and size the drainage facilities.

All the data used in the design are attached in the Appendix.

Rainfall Analysis

Rational Method

The rational method is most frequently used in estimating peak discharge/runoff for small catchments (V. T. Chow et al., 1988). The method calculates the peak discharge from the drainage area, A, and the rainfall intensity, I and the runoff coefficient, C, expressed by the mathematical relationship below.

$$Q = CIA$$

Where: Q in m^3/s, C is dimensionless, I in mm/hr, and A in km^2

Runoff coefficient, C

$$C_w = \frac{\left(A_1 * C_1 + A_2 * C_2 + A_3 C_3 + \ldots\ldots\ldots + A_n C_n\right)}{A}$$

Table 1 Statistical analysis of rainfall data and probability distribution

Year	Max rainfall	Ranking	X-Ẋ	(*X*-*Ẋ*)^2	(*X*-*Ẋ*)^3	Log*X*	Normal distribution	Log normal distribution	Exceedance probability
2000	55.4	6	-9.27	85.86	-795.52	1.74351	0.383588	0.026312	0.46
2001	40	2	-24.67	608.40	-15006.78	1.60206	0.215305	0.025684	0.13
2002	52	5	-12.67	160.42	-2031.90	1.716003	0.342845	0.026189	0.38
2003	64	7	-0.67	0.44	-0.30	1.80618	0.491513	0.026595	0.54
2004	73.3	10	8.63	74.55	643.67	1.865104	0.608683	0.026863	0.79
2005	33.6	1	-31.07	965.09	-29981.20	1.526339	0.160441	0.025352	0.04
2006	73.6	11	8.93	79.82	713.12	1.866878	0.612359	0.026871	0.88
2007	46.3	4	-18.37	337.30	-6194.87	1.665581	0.612359	0.025964	0.29
2008	72.5	9	7.83	61.37	480.82	1.860338	0.598832	0.026841	0.71
2009	154.3	12	89.62	8032.49	719905.33	2.188338	0.997907	0.028373	0.96
2010	65.5	8	0.83	0.70	0.58	1.816241	0.510632	0.02664	0.63
2011	45.5	3	-19.17	367.33	-7040.17	1.658011	0.270134	0.025931	0.21
SUM	775.99								
MEAN	64.67								
SD	31.30								

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Catchment Area, *A*

The catchment area was determined using a topographical map of the Lady Irene campus. Most of the catchment area was Lawns (V. T. Chow et al., 1988).

Selection of coefficients was based on ultimate catchment development and where more than one land is encountered, a weighted average was computed.

Table 2*:* Land use characteristics and runoff coefficients

Land use	Area, Km^2	Runoff coefficient, C
Residential area	0.06	0.6
Lawns	0.075	0.3
Roofs	0.06	0.8
Neighbourhood business	0.015	0.6

The formula for calculating the weighted average coefficient is given by.

$$C_w = \frac{(A_1 * C_1 + A_2 * C_2 + A_3 C_3 + \ \ldots\ldots\ldots \ + A_{\cdot}}{A}$$

where A_1, A_2, A_3, A_4, A_n = areas of relatively uniform land use or surface character, each comprising the total area A

C_1, C_2, C_3, C_4 = the corresponding runoff coefficients

Given the above existing conditions, the weighted coefficient C is determined as

$$C_w = \frac{(0.6*0.6+0.075*0.3+0.06*0.8+0.015*0.6)}{0.15} = 0.77$$

Rainfall Intensity: I

$$I = \frac{\text{Rainfall depth}}{\text{mm/hr}}$$

Duration is the period during which rain falls.

The intensity was estimated using the method by Kothyari and Gande (1992) and rainfall data collected from the metrological data centre and was used to determine the rainfall intensity by applying the relevant formula.

Table 3 Maximum daily precipitation and return period analysis (2000-2011)

Year	Maximum daily precipitation (mm)	Rank (r)	Return period (T = (nt1)/r)
2000	55.4	6	2.2
2001	40.0	2	6.5
2002	52.0	5	2.6
2003	64.0	7	1.9
2004	73.3	10	1.3
2005	33.6	1	13
2006	73.6	11	1.2
2007	46.3	4	3.3
2008	72.5	9	1.4
2009	154.3	12	1.1
2010	65.5	8	1.6
2011	45.5	3	4.3

Where, n-number of years from 2000-20011=12 years

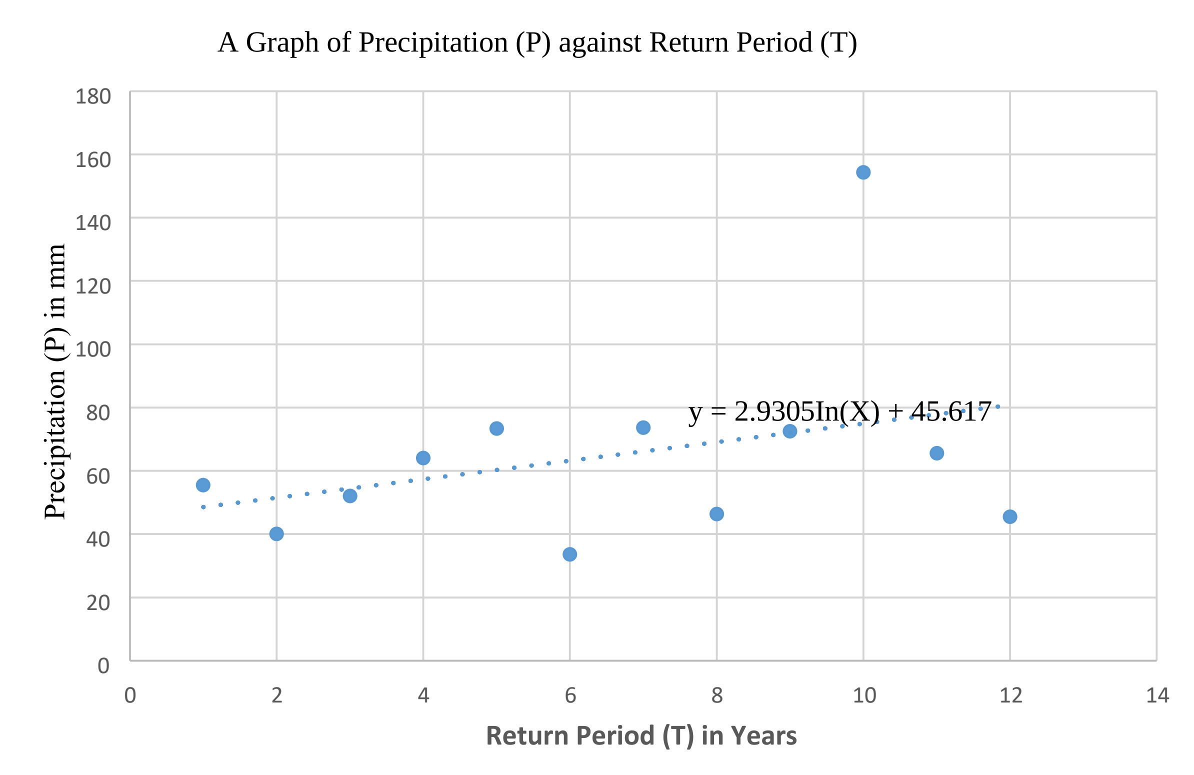
$$I_t^T = \frac{KT^{0.2}\left(R_{24}^2\right)^{0.33}}{T^{0.29}}$$ (Kothyari & Garde, 1992)

where I_t^T is the rainfall intensity in mm/hr of duration 2hrs with a 2-year return period, R_{24}^2 is the 24hr rainfall in mm of duration 24 hours with a 2-year return period, K is a constant that varies by region, t is the duration of rainfall measurement which is 24 years and T is the return period of 2 years.

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

The data was recorded on a graph of Annual Maximum daily precipitation against the return period on a semi-logarithmic scale, as shown in *Figure 1*.

Figure 1*:* **A graph of precipitation against the return period**



The graph was used to generate a mathematical expression of annual maximum precipitation at any time by using the statistical regression feature in a computer spreadsheet package and a least-squares line.

From the graph of rainfall versus time $P = 2.93\ln T + 45.62$ (where P = maximum daily precipitation in mm for a given return period of T years). By substituting T = 2 years in the above formulae, the maximum daily precipitation of 47.7 mm was got hence R_{24}^{2} = 47.7 mm

Where P is R_{24}^{2}. Taking a 2-year Return period, then $P = 2.93\ln 2 + 45.62 = 47.7$ mm

Kothyari and Gardes (1992) offer the values of K as shown for the different parts of India

Table 4: K Values for different regions of India

Geographical region	*K* values
Northern India	8.0
Eastern India	9.1
Central India	7.7
Western India	8.3
Southern India	7.1

The region of India with similar climatological conditions has a K value available in Southern India, and hence, the K value for Southern India was used, which is 7.1

Substituting these values into Kothyari and Garde's equation gives:

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

$$I_t^T = \frac{7.1(2^{0.2})*47.7^{0.33}}{24^{0.29}} = 11.62 \text{ mm/hr}$$

Estimating the Runoff

The peak runoff (Q_{peak}) was determined by Rational Formula.

$$Q = CIA$$

$$= \frac{0.77*11.62*150,000}{3600} = 0.52\ m^3/s$$

This is the quantity of rainfall in a given time.

I = rainfall depth and its units of measurement are normally duration mm/hr

Drainage Facility Design

Manning's formula was used to estimate the capacity of the drainage facilities (V. Te Chow, 1959). It is given as:

$$Q = (1/n)*A*R^{(2/3)}*S^{(1/2)}$$

Where *Q* is the capacity of the drainage facility, *A* is the cross-sectional area, *R* is the hydraulic radius, *S* is the longitudinal slope, and *n* is Manning's coefficient

Culverts

Receives flow from roadway embankment: n=0.013

$R = D/4$

$A = (\Pi D^2)/4$

$$Q = \frac{(1/n)*(\Pi D^2)*(D/4)^2*S^{1/2}}{16}$$

$$0.52 = \frac{(1/0.013)*(\Pi D^2)*(D/4)^2*(0.007)^{1/2}}{16}, D = 0.43$$

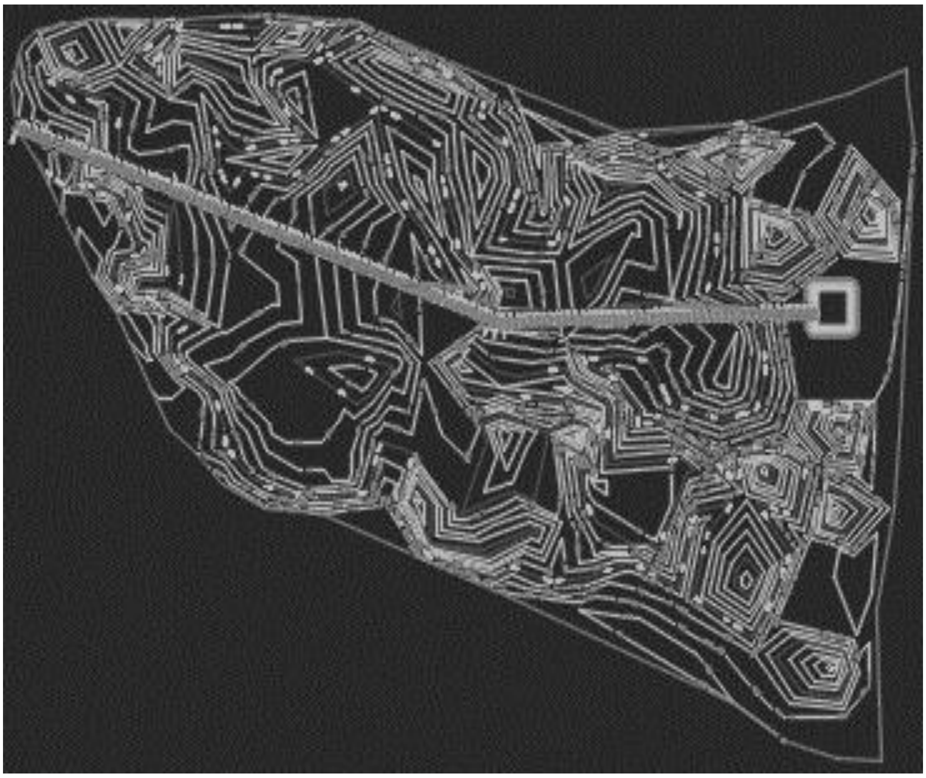
Velocity, *V*

$V = (1/n)*R^{(2/3)}*S^{(1/2)}$ where n=0.013, S=0.007, R=0.43/4

$$V = (1/0.013)*0.11^{(2/3)}*0.007^{(1/2)} = 1.48 \text{ m}^3/\text{s}$$

A 600 mm diameter culvert would appropriately handle this runoff

Figure 2: Channel and pond



Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Drainage Channel/Side Ditches

Assuming a trapezoidal channel due to its high hydraulic capacity.

It should have a float-finished concrete bottom with sides of random stone mortar.

Using a Q = 0.52 m^3/s and Mannings n = 0.019

To avoid erosion, a slope of 0.7% and maximum velocity ranging from 5.2 - 5.8 m/s

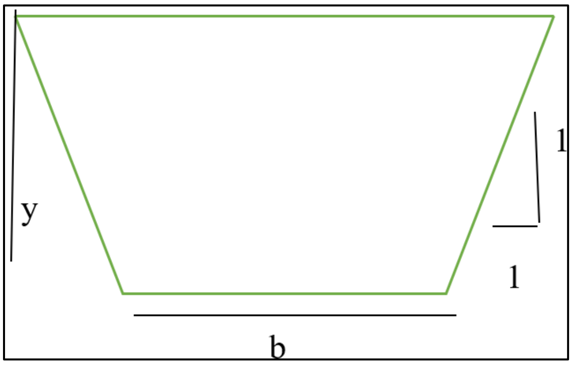
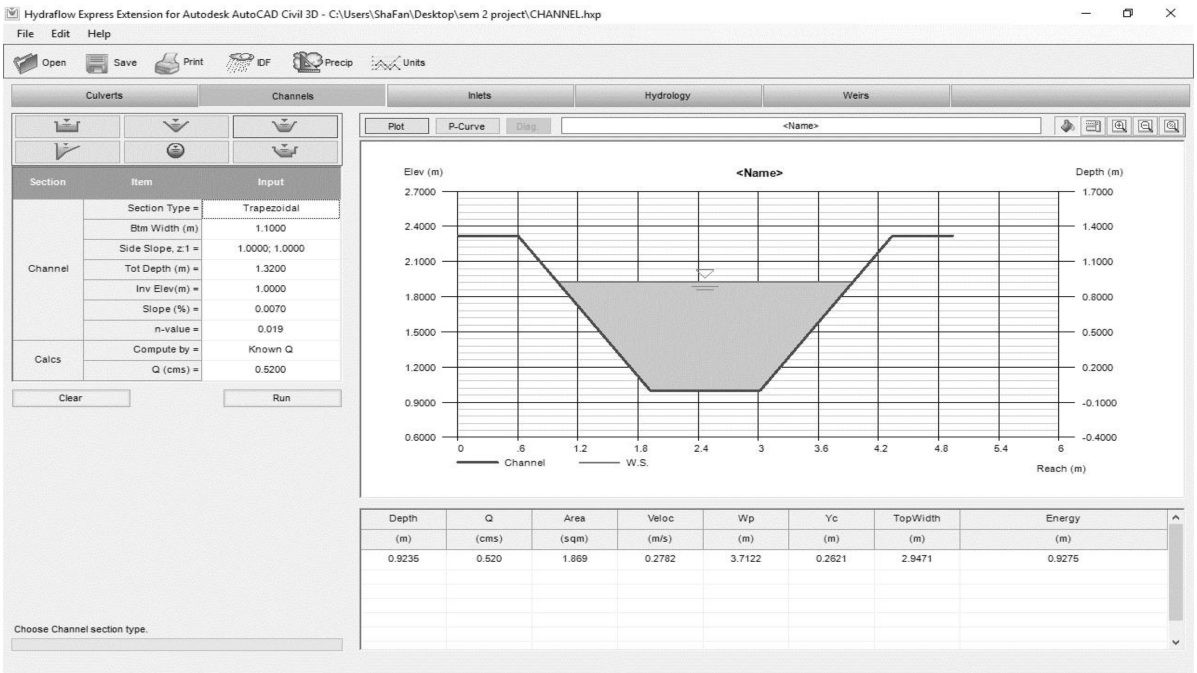


Figure 3*:* **Channel**



Assuming a slope of 1:1 because it is stable, b = 0.828y

Applying Manning's equation

Using Q = 0.52 m^3/s

$$0.52 = \frac{y(b+y)*(y(b+y))^{2/3}*0.007^{1/2}}{0.019(b+2.828y)^{2/3}}$$

Substituting b into the equation gives y = 1.32 m, b =1.10 m

Comparing flow velocity with maximum velocity to avoid erosion, 5.2 m/s

$$V = Q/A = Q/(y(b+y)$$

$$= (0.52)/(1.32(1.10+2(1.32)) = 0.11\ m/s$$

Since the flow velocity is less than 5.2 m/s, channel erosion does not occur; therefore, the drainage design is adequate.

Pond

Assuming a rectangular pond and a minimum depth of 3.0 m

Using the peak flow of 0.52 m^3/s

Volume of stormwater entering pond, V = Discharge (Q) * Duration

$$= (0.52) * 60 * 60 = 1872\ m^3$$

Hence, we take a pond of 2,000 m^3

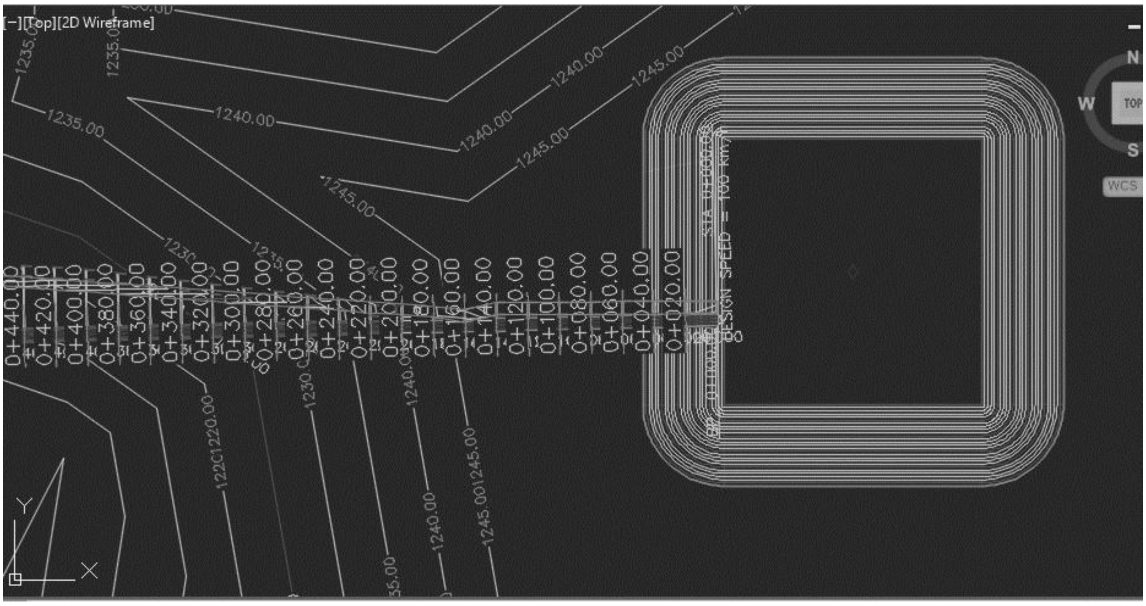
Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Designing pond length and width at a ratio of 4:1, respectively

$V = L*W*H$ where L is length, W is width, and H is depth

$2{,}000 = 4W*W*3$, $W^2 = 166.7$ m, $W = 13$ m, Thus $L = 52$ m

Figure 4 Pond



Environmental Impact Assessment

Environmental Impact Assessment (EIA) is defined in the National Environmental Statute, 1995, as "a systematic examination conducted to determine whether or not a project will have any adverse impact on the environment."

EIA is generally used to accomplish the following (Kidd, 1999);

- Identify whether or not (YES or NO) a proposed policy, project, or activity is likely to have significant impacts (both adverse and beneficial)
- If YES, to identify the potential significant environmental impacts
- Analyse the significance of the adverse environmental impacts
- Determine whether the adverse impacts can be mitigated
- Recommend preventive or mitigation measures
- Identify and assess any other alternatives to the proposed policy, project, or activity and its associated activities.
- Recommend whether or not the proposed policy or project should be implemented.

Impacts Noise and Dust

Certain levels of noise and dust pollution are unavoidable in the vicinity of construction sites, and some elevations of background levels are normally acceptable for limited periods. Excessive noise, particularly when experienced continuously outside normal working hours and on rest days, can be a nuisance to both workers and the public. In extreme cases, it may become a health hazard. Typical noise emissions for plants and equipment likely to be deployed in construction are listed in Table 5, together with typical international standards and the NEMA noise limit.

Night operations will, therefore, exceed these standards and most day operations will be uniformly excessive up to a distance of 20 m.

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Only the noisiest operations are likely to produce excessive noise at 50 m above the NEMA limit.

Table 5: Noise emission levels for various types of construction plant

Type of plant	Distance between plant and observer			Typical international standard		NEMA limit
	5 m	20 m	50 m	Day	Night	
Loader	90	78	70	75	55	70
Grader	90	78	70	75	55	70
Vibration roller	86	74	66	75	55	70
Bulldozer	86	74	66	75	55	70
Generator	98	86	78	75	55	70
Impact drill	87	75	67	75	55	70
Concrete mixer	91	79	71	70	55	70
Concrete pump	85	70	62	70	55	70
Pneumatic hammer	84	86	78	75	55	3

Although the frequent rain showers experienced in Luwero district will suppress dust from excavation and on roads, it may be a general nuisance for short periods within a broad corridor adjacent to the road, which may include gardens and areas used for drying household laundry.

Table 6: Summary of potential temporary impacts

Issue	Potential temporary impact	Risk
Existing communities	Disruption to communications routes	Major
	Disruption of public access	Moderate
Public utilities	Interruption of supply, danger and cost	Variable
Soil and water pollution	Pollution due to temporary activities	Moderate
	Pollution at the construction camp	Major
Drainage, erosion and sediment load	Disruption of existing drainage networks	Minor
	Erosion from spoil heaps, stockpiles and other loose materials	Minor
	Increased sediment loading in watercourses	Moderate
Noise and air pollution	Noise pollution from construction machinery	Major
	Air pollution from construction machinery	Major
	Mud on public roads	Major
Demolition	Public and worker’s safety	Minor
Surplus spoil	Excess fill from pipeline trenches	Minor
Employment	Temporary local job opportunities for construction workers	Moderate and positive
Public safety	General construction activity	Major
	Traffic at construction camps	Major
	Heavy equipment movement and operation in public areas	Major
	Changes in existing traffic circulation	Moderate
Worker's safety	Accidents common on construction sites	Moderate
Resource consumption	Water use at construction camps	Moderate
	Use of aggregate resources	Minor
	Water use for construction	Minor
	Haulage	Moderate

Summary of Potential Permanent Impacts

A summary of the potential permanent environmental impacts of the project is provided in *Table 7*.

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Table 7*: Summary of potential permanent impacts*

Issue	Potential permanent impact	Risk
Public health	Provision of safe and sustainable water and sanitation	Major and Positive
Induced development	Unplanned development in the vicinity of water and sewerage services	Minor if planning system is effective

Summary of Potential Operational Impacts

A summary of the potential risks from operational environmental impacts accruing from the works is provided in *Table 8*.

Table 8*: Summary of potential operational impacts*

Issue	Potential operational impact	Risk
Stormwater overflow	Overflow from detention ponds during heavy rain	Major
Noise and vibration	Noise created during the excavation of pipes for repair	Moderate but for short periods only
Air quality	Dust from excavations for pipeline repair	
Traffic	Vehicular movements of operational staff	Minor
	Disruptions during network repairs	Moderate but for short periods only
Solid Waste	Broken road surfacing and soil from pipeline repairs	Minor
Public and workers, Health and safety	Accidents due to unimpeded public access	Major

Summary of Alternatives of the Project

A summary of the alternatives is presented in *Table 9*.

Table 9*: Summary of alternatives of the project*

Alternative	Potential environmental impact	Ease of mitigation	Capital and recurrent costs	Suitability to local conditions	Institutional requirements	Training needs	Monitoring requirements
Proposed Project	Sustainable	Satisfactory	Unknown	Good, and provides a long-term solution	Moderate	Moderate	Low
Without Project	Serious	Difficult	Zero capital costs. Very high recurrent costs	Will become worse and further derogate public health with time	Moderate	Minor	None. 'Crisis' management only
Do minimum	Less serious	Unknown	Unknown	Good, but only provides a short term solution	Moderate	Moderate	Low

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Table 10*:* **Typical noise standards for construction equipment**

Activity	Source	Day	Night
Earthworks	Bulldozer/excavator	75 dB(A)	55 dB(A)
Trenching	Impact drill	75 dB(A)	55 dB(A)
Surfacing	Roller	70 dB(A)	55 dB(A)
		70 dB(A)	55 dB(A)

Table 11*:* **Summary of impact mitigation requirements**

Impact/issue	Mitigation measure	Responsibility	Comment
Pre-construction impact mitigation			
Water demand	Adequacy distribution pipework sizing	Estates department	Implemented during detailed design.
Drainage flows	Appropriate channel capacities		
	Construction impact mitigation: On-site		
Communication routes	Disruptions to be identified in traffic management plan; inform the public of forthcoming delays; use appropriate signage.	Contractor	‘Good practice’ only
Public utilities	Document all utilities within 50 m of work sites; Coordinate works with utility companies; Damage to defined utilities to be repaired at contractors’ expense.	Contractor and utility companies	‘Good practice’ only
Public access	Disruptions to be identified in traffic management plan; Inform impacted owners ahead of disruption; Maintain vehicular access to emergency services; Maintain pedestrian access to public buildings; use appropriate signage; Keep roads clean.	Contractor, PPC and NWA	‘Good practice’ only
Soil and water pollution	Duty of care to avoid spillage of all polluting materials; Comply with regulations regarding pollution abatement; Contaminated soil to be removed and replaced; Chemical storage to accord to Manufacturer's recommendations; Fuel to be stored within bounded areas; all spillage to be reported; Remedial action to be undertaken as a matter of urgency; Incidents to be remediated at contractors’ expense.	Contractor	‘Good practice’ only
Drainage, erosion, turbidity and sediment load	Site clearance ahead of construction to be restricted; Disruptions to drainage channels to have prior approval; Any short-term increases in turbidity to be approved; Dewatering works to avoid excessive turbidity; Store stripped topsoil in manner suitable for reuse; All stockpiles and soil heaps to remain stable. Excess spoil and materials not to be stored.	Contractor	‘Good practice’ only

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Table 12 Issues to be addressed during construction monitoring

At construction sites	At other sites used by the contractor
Temporary obstruction of access	Arrangements for access
Traffic management	Traffic management
Noise and dust	Noise and dust
Maintenance of existing utility services	Wastewater disposal
On-site materials storage	Solid waste disposal
Security of excavations	Materials storage
Disposal of excess spoil;	Workers Health and Safety
Worker's health and safety public Health and safety.	Public Health and Safety

Table 13 Summary of environmental monitoring requirements

Project Phase	Category	Indicators	Location	Method	Duration	Frequency	Purpose	Expertise required	Responsibility
	Site Inspections	Site Clearance	Lady Irene campus Ndejje University	Visual and Descriptive, against a checklist	For the duration of site clearance	Daily	To ensure compliance with the requirements of the EMP including Health and Safety	Experienced Site supervision staff with knowledge of EMP and H&S requirements	Ndejje Estates Department and Construction Manager
		Disruption to traffic, access and utility services; Materials storage; Disposal of spoil; Health and Safety.	All construction sites	Visual and Descriptive, against a checklist	Throughout the period of construction	Daily when sites active			
		Traffic management; Wastewater disposal; Solid waste disposal; Materials storage; Health and Safety.	Contractor's camp	Visual and Descriptive, against a checklist	Throughout the period of construction	Monthly			
		Traffic management;							
Construction		Wastewater disposal; Solid waste disposal; Materials storage; Health and Safety.	Other sites	Visual and Descriptive, against a checklist	Throughout the period of construction	Quarterly	To ensure compliance with the requirements of the EMP including Health and Safety	Site supervision staff briefed on EMP requirements	Contractor and Construction Manager

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Project Phase	Category	Indicators	Location	Method	Duration	Frequency	Purpose	Expertise required	Responsibility
	Air and Dust	(Particulate Matter) PM10, Ambient Noise	All construction sites and Contractor's camp	Portable air quality monitoring equipment	Over 24 hours, at times to be determined by the Engineer	As deemed necessary by the Engineer	To quantify project impacts	Person trained in the use of the equipment	Contractor and Construction Manager
				Portable noise monitoring equipment	Over 1 hour, at times to be determined by the Engineer				
	Complaint Investigation	Any of the parameters listed above, depending on upon the nature of the complaint	At or in the vicinity of all sites for which a specific complaint has been received	As appropriate for the parameter being monitored	As necessary	As necessary	To fully investigate all complaints and to provide a basis for mitigation and/or compensation	As necessary	Estates Manager Ndejje and Construction Manager
	EMP Compliance	Contractor's compliance with standards and EMP requirements. Low numbers of injuries to workers. Minimal public disturbance.	All sites of construction and project related activity	Site inspection and interrogation of site records	Throughout the period of construction	Every 6 months	To ensure Contractors comply with Standards and EMP requirements	Environmental Advisor	Ndejje Estates Department Construction Manager
Post-construction and operation	Drainage channel condition	Drainage channel degradation	Throughout the gravity drainage channel network	Visual inspection	Ongoing	Annually	To regularly inspect the drainage channel network	Inspection engineer	Estates manager

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Table 14*:* **Summary of training requirements**

Training	b	Duration
EMP Implementation requirements and monitoring	Staff assigned to the Project	1 day
EMP execution and compliance	Contractor's managers and foremen	1 day
Environmental management	Invited attendees	Half day

Conclusions And Recommendations on EIA Air Quality Impact Assessment

The construction of the project may lead to dust generation. It is predicted that various construction activities associated with the earthworks, material handling and tunnel construction would cause temporary minor impacts. "Best practice measures" are recommended to suppress dust emissions from construction activities through good site practice.

Noise Impact Assessment

The construction of the project may lead to noise generation if noise mitigation measures are not undertaken. It is predicted that various construction activities associated with the earthworks, excavation and construction may cause temporary impacts without mitigation. "Best practice measures", quiet plant and mobile noise barriers are recommended to suppress noise emissions from construction activities where noise exceedance is anticipated.

Water Quality Impact Assessment

With appropriate mitigation and precautions measures in place during construction there should be relatively minor impacts associated with this project during or following construction. In the operational phase, the impacts from stormwater discharge are anticipated to be negligible.

Waste Impact Assessment

The potential environmental impacts of the handling and disposal of waste arising from the construction of the Lady Irene Campus Drainage System have been assessed. Operational impacts on the proposed route are not expected to be a key concern and no detailed assessment will be required. Key issues include the need for effective waste management planning during the construction phase. The assessment has concluded that the potential environmental impacts associated with the handling, storage, treatment and disposal of waste arising from the construction of the Lady Irene Campus Drainage System meet the requirements of the EIA standards set by NEMA.

Ecological Impact Assessment

The ecological resources recorded within the Study Area included woodland, plantation, grassland, stream channel, and disturbed/urbanized habitat, as well as the associated wildlife. The loss of stream sections of natural bottom and bank and hydrological disruption to the natural stream habitats downstream to the intake structures, have been minimised and properly mitigated. No adverse residual impact is expected after the implementation of the recommended mitigation measures. Since the affected sections of Lady Irene Campus Drainage System are partially disturbed (with relatively less aquatic faunal diversity) due to the residential sewage and the intake structures have been appropriately designed to minimise habitat loss, the impacts due to the land take for the surface structures and hydrological disruption are considered acceptable. Adverse ecological impacts on the proposed Ecological Park are also unlikely.

Hazard to Life

According to the EIA Study Brief, evaluation of Hazard to Life as the criteria specified is considered unnecessary since no overnight storage of explosives is anticipated for this project. In addition, with the stringent control and monitoring procedures in place, an adverse impact on populated areas or on PHI nearby due to the blasting operation is unlikely.

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Environmental Outcomes

Various measures have been incorporated to protect both the population and environmentally sensitive areas. During the construction phase, efforts such as the utilization of quiet plant machinery, installation of noise barriers, and regular noise monitoring are implemented to mitigate the impact of construction noise on nearby dwellings, thereby ensuring the protection of a significant portion of the population.

Furthermore, through strategic planning and the implementation of environmentally friendly designs, sensitive receivers, water bodies, habitats, and structures are shielded from adverse effects during both the construction and operation phases. The project emphasizes the principle of minimizing environmental impacts wherever possible, with a focus on avoidance when feasible.

Key design elements, such as the optimized placement of intake and outfall structures in pre-disturbed areas or those of lower ecological value, mitigate habitat disturbance. Additionally, environmentally conscious drainage system designs attenuate discharge velocity, prevent scouring and erosion, and minimize drawdown of groundwater, thus preserving water levels in stream courses and reducing impacts on surrounding habitats.

In terms of environmental benefits, significant enhancements are achieved in flood protection levels within the Lady Irene Campus area, with trunk drain resilience being elevated to a 20-year return period. This ensures the safeguarding of urban areas and agricultural lands from crop washout and erosion during severe rainstorm events, contributing to broader environmental sustainability and resilience.

Operation and Maintenance Plan

The maintenance of your stormwater treatment systems is critical to their performance because, without proper maintenance, these structures are likely to fail.

Proper operation and maintenance ensure that the structures remain effective at removing pollutants as originally designed. It will:

- Reduce failure, therefore improve water quality;
- Maintain the volume of stormwater treated in the long term;
- Increase pollutant removal efficiency;

Operation and maintenance plan: The proper operation and maintenance of a stormwater management structure includes frequent inspection and scheduled maintenance activities. The manpower and budget needed to perform the maintenance must be anticipated.

Accessibility: All structures must be easily accessible for inspection and needed equipment. Formal access must be provided and permanent easements must be provided to the entity responsible for maintenance when that entity does not own the property.

Sediment removal schedule: All treatment systems are designed to accommodate a minimum of one year's worth of sediment. Sand deposits from winter storm applications should be accounted for when planning the cleaning of a structure.

Responsibility for Maintenance

The maintenance authority of the system shall be handed to the Estates Manager of Ndejje University who shall carry out the following activities:

- Training of all workers to carry out maintenance
- Regular inspection of the site
- Regular updating of the maintenance plan
- Supervision of maintenance works

Checklist for routine inspection and maintenance-vegetated swale (see maintenance matrix for additional detail)

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

- Examine each area trench drain and clean if necessary.
- Confirm there is no blockage in the trench. drain lines where swales cross the driveways.
- Check rocks at inlets and repair, replace, or replenish as necessary.
- Remove any accumulations of sediment, litter, and debris in the swale.
- Examine the overflow. Remove any debris.
- Observe the structure of the swales and bio-retention area and fix any cracks or failures.
- Note the condition of vegetation.
- Replace any dead vegetation.
- Remove any nuisance or invasive vegetation.
- Clean up fallen leaves or debris.
- Confirm that irrigation is adequate and not excessive. If irrigation is producing underflow from the swales or bio-retention area, reduce irrigation.
- Remove any debris from curb cuts leading to swales or bio-retention areas.

General Maintenance Requirements

Landscape contractors retained by the homeowners individually or jointly must familiarize themselves with the purposes, design specifications, features, and mode of operation of the vegetated swales and bio-retention area and should review the Stormwater Control Plan (in addition to this document) (Yu et al., 2013). As will be reflected in contracts for landscape maintenance and other maintenance services, maintenance supervisors and employees need to be informed of the following specific maintenance requirements for the vegetated swales and bio-retention area.

Maintenance instructions generally include the following (Rieck et al., 2021)*:*

- Inspect inlets for channels, exposure of soils, or other evidence of erosion. Clear any obstructions and remove any accumulation of sediment. Examine rock or other material used as a splash pad and replenish if necessary.
- Inspect outlets for erosion or plugging caused by debris.
- Inspect side slopes for evidence of instability or erosion and correct as necessary.
- Observe soils at the bottom of the Stormwater Facility for uniform percolation throughout. If portions of the Stormwater Facility do not drain within 72 hours after the end of a storm, the soil should be tilled and replanted.
- Remove any debris or accumulation of sediments.
- Confirm that channelization within the Stormwater Facility is effectively prevented.
- Examine the vegetation to ensure that it is healthy and dense enough to provide filtering and to protect soils from erosion. Replenish mulch as necessary, remove fallen leaves and debris, prune large shrubs or trees, and mow turf areas. Confirm that irrigation is adequate and not excessive. Replace dead plants and remove invasive vegetation.
- Abate any potential vectors by filling holes in the ground in and around the Stormwater Facility and by ensuring that there are no areas where water stands longer than 72 hours

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

Table 15: Stormwater treatment facilities maintenance matrix

Item	Inspection schedule	Activity
Vegetated areas	After heavy rains	• Inspect all slopes and embankments and replant areas of bare soil or with sparse growth. • Armor rill erosion areas with riprap or divert the runoff to a stable area. • Inspect and repair down-slope of all spreaders and turnouts for erosion. • Mow vegetation as specified for the area.
Ditches, swales and open stormwater channels	After heavy rains	• Remove obstructions, sediments or debris from ditches, swales and other open channels. • Repair any erosion of the ditch lining. • Mow vegetated ditches. • Remove woody vegetation growing through riprap.
Culverts	After heavy rains	• Remove accumulated sediments and debris at the inlet, outlet, or within the conduit. • Remove any obstruction to flow. • Repair any erosion damage at the culvert's inlet and outlet.
Retention basins	Annually	• Remove floating debris and oils (using oil absorptive pads) from any trap. • Inspect the embankments for settlement, slope erosion, piping, and slumping. • Mow the embankment to control woody vegetation. • Inspect the outlet structure for broken seals, obstructed orifices, and plugged trash racks. • Remove and dispose of sediments and debris within the control structure. • Repair any damage to trash racks or debris guards. • Replace any dislodged stone in riprap spillways. • Remove and dispose of accumulated sediments within the impoundment and forebay.
Propriety devices	As specified by the Manufacturer	• Contract with a third party for inspection and maintenance • Follow the Manufacturer's plan for cleaning devices
Other practices	As specified for Devices	• Contact the department for appropriate inspection and maintenance requirements for other drainage control and runoff treatment measures.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the project successfully completed various stages, including field reconnaissance studies, data collection, analysis, and preliminary designs, adhering to the guidelines set forth by the Ministry of Works and Transport. Despite encountering challenges such as limited access to surveying equipment and expensive design software, the team improvised by utilizing satellite data and making necessary assumptions to progress.

While the design process faced constraints due to the terrain and road network, efforts were made to mitigate potential issues, particularly focusing on reducing frictional losses. However, difficulties in obtaining crucial data, such as rainfall information, posed significant hurdles.

To address future challenges, it is recommended that the university invests in rehabilitating its weather station and facilitating access to essential equipment for data collection and analysis. Additionally, establishing an easily accessible database for past projects and institutional records

Article DOI: https://doi.org/10.37284/eaje.7.1.2029

would enhance future project planning and research endeavours.

REFERENCE

ARC (2001). *Georgia Stormwater Management Manual - Volume 2*. [Online] Atlanta Regional Commission. Available at: http://documents.atlantaregional.com/gastormwater/GSMMVol2.pdf [Accessed 26 Feb 2017].

Arnbjerg-Nielsen, K., Willems, P., Olsson, J., Beecham, S., Pathirana, A., Bülow Gregersen, I., Madsen, H., & Nguyen, V.-T.-V. (2013). Impacts of climate change on rainfall extremes and urban drainage systems: a review. *Water Science and Technology*, *68*(1), 16–28.

Barbosa, A. E., Fernandes, J. N., & David, L. M. (2012). Key issues for sustainable urban stormwater management. *Water Research*, *46*(20), 6787–6798.

Chow, V. T., Maidment, D. R., & Mays, L. W. (1988). *Applied hydrology*.

Council, N. R., Earth, D. on, Studies, L., Science, W., Board, T., & Pollution, C. on R. S. D. C. to W. (2009). *Urban stormwater management in the United States*. National Academies Press.

Ellis, J. B., & Revitt, D. M. (2010). The management of urban surface water drainage in England and Wales. *Water and Environment Journal*, *24*(1), 1–8.

EPA, U. S. (2007). Reducing stormwater costs through low-impact development (LID) strategies and practices. *United States Environmental Protection Agency, Nonpoint Source Control Branch (4503T)*.

Kellagher, R., Martin, P., Jefferies, C., Bray, R., Shaffer, P., Wallingford, H. R., & Wallingford, H. R. (2007). The SuDS manual - 1º EDITION. In *Ciria*.

Kidd, M. (1999). The national environmental management act and public participation. *South African Journal of Environmental Law and Policy*, *6*(1), 21–31.

Kothyari, U. C., & Garde, R. J. (1992). Rainfall intensity-duration-frequency formula for India. *Journal of Hydraulic Engineering*, *118*(2), 323–336.

Qiao, X.-J., Kristoffersson, A., & Randrup, T. B. (2018). Challenges to implementing urban sustainable stormwater management from a governance perspective: A literature review. *Journal of Cleaner Production*, *196*, 943–952.

Rieck, L., Carson, C., Hawley, R. J., Heller, M., Paul, M., Scoggins, M., Zimmerman, M., & Smith, R. F. (2021). Phase II MS4 challenges: moving toward effective stormwater management for small municipalities. *Urban Ecosystems*, 1–16.

Te Chow, V. (1959). *Open channel hydraulics*.

U.S. Department of Housing and Urban Development. (2016). The Practice of Low Impact Development. *2016 International Low Impact Development Conference*, 1–8.

Yu, J., Yu, H., & Xu, L. (2013). Performance evaluation of various stormwater best management practices. *Environmental Science and Pollution Research*, *20*, 6160–6171.