Feasibility of Decentralised Sustainable Refugee Camp Drainage System (SRCDS)

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ABSTRACT

In this research, a new decentralised drainage system, Sustainable Refugee Camp Drainage System (SRCDS), is developed for effective management of storm water and greywater in Dadaab refugee camp, Kenya. The SRCDS uses the principle of Best Management Practices (BMPs) to manage storm water and greywater point sources before they can mix. The numerical modelling of the drainage system was undertaken using the Storm Water Management Model (SWMM) and Micro Drainage Sustainable Drainage Systems (MDSuDS) software packages. The numerical modelling of the drainage system was carried out in two main stages (i) the total storm water flow in a sub-catchment in order to obtain total runoff volume and peak runoff rate and (ii) to obtain required dimensions of the SRCDS required to drain and store the generated runoff for reuse. The results obtained showed that (i) the total volume of runoff generated over the sub-catchment area reduces significantly as the volume of water drained by the SRCDS increases and (ii) the peak runoff rate decreases as the sizes of the SRCDS increases. The sizes of the SRCDS were iteratively modified until adequate sizes to cope with the peak runoff rate and total runoff were achieved.

KEYWORDS: Drainage systems, numerical modelling, refugee camps, sustainable storm water and greywater management

1. INTRODUCTION

Problems associated with ineffective stormwater and greywater management across camps in Africa persist (Bastable and Russell, 2013; Ove Arup & Partners Ltd, 2017). In the Dadaab refugee camp, these problems include frequent flooding after prolonged drought periods and localised ponding of water. A recent example is the 2018 flooding event after prolonged drought period in the Dadaab camp (AFPNA, 2018). Similarly, localised ponds of water become breeding ground for disease vectors such as; mosquitoes which are responsible for transmitting a number of life threatening diseases including: Malaria fever, Dengue fever, West Nile virus, Chikungunya and Filariasis (AMCA, 2016). These problems in the Dadaab camp persist because: (i) existing centralised conventional open-earth drainage system is no longer effective, (ii) the camp is relatively flat and there is no nearby river to receive surface water flow, (iii) the soil in the frequently flooded parts of the camp is poorly drained and (iv) there is limited data & time for designing drainage system for the camp (AFPNA, 2018; Cambrézy, 1999; Ove Arup & Partners Ltd, 2017).To aid in addressing these problems, the effectiveness of SRCDS is evaluated for managing storm water and greywater in a sub-catchment of the Dadaab refugee camp in order to prevent localised ponding of water and reduce flooding of inhabited areas of the sub-catchment.

2. METHODS

2.1 Dividing the camp into sub-catchments (Step 1)

The entire Dadaab camp was divided into sub-catchments (Fig. 1) and the perimeter and area of first sub-catchment (SC1) were determined using Google Earth Pro software (Fig. 2).

Fig. 1: The Dadaab camp catchment area.

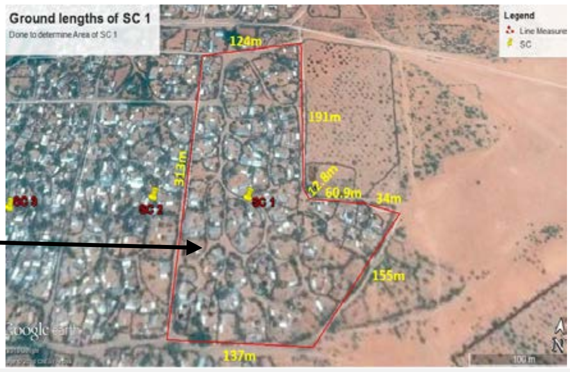

Fig. 2: dimensions of SC1 (Area = 47602 m^2).

CAD Earth tool in AutoCAD was used to obtain the ground elevations of the SC1 (Fig. 3).

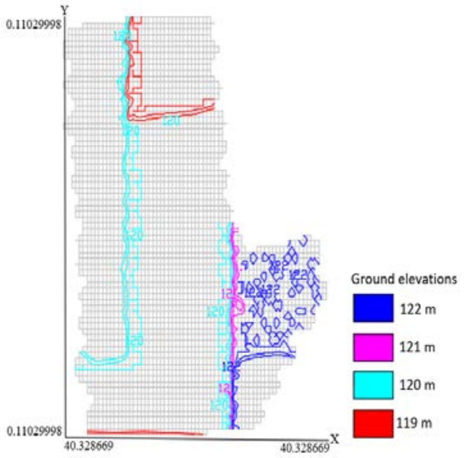

Fig. 3: Ground elevations of SC1

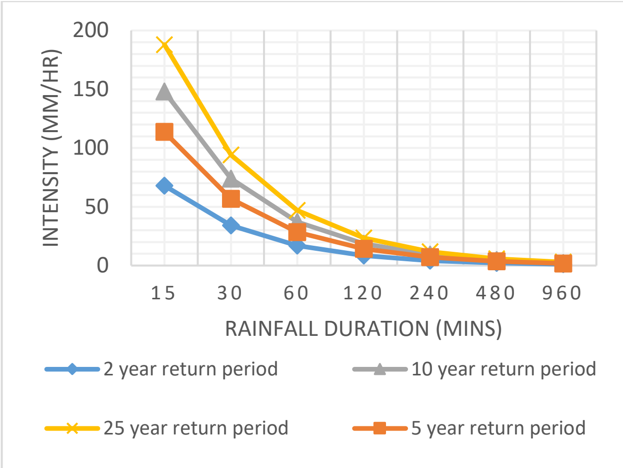

Fig. 4: IDF curves for return periods T = 2, 5, 10 and 25 years for Dadaab refugee camp.

Historical weather datasets that include rainfall, sunshine hours, monthly raining days and temperature records were obtained from the Kenya Meteorological Department and the World Weather and Climate database from 2014 to 2018. From the historical weather datasets, Intensity Duration Frequency (IDF) curves were developed (Fig. 4) using Gumbel statistical distribution plotted manually on Fisher-Tippett Type 1 Extreme Distribution probability paper. Soil data for the camp were obtained from Cambrézy (1999).

2.2 Numerical modelling of the total storm water flow across SC1 area (Step 2)

The outcomes of step 1 were input for step 2 and the outputs are total runoff volume generated over the SC1 area and peak runoff rate without the drainage system. The numerical modelling process undertaken with the SWMM and MDSuDS software packages include calculation of the time of concentration using Kinematic Wave method, infiltration rates using Modified Horton's equation and peak runoff rates and runoff volume using Unit Hydrograph method. The design storm of 28.4 mm for T = 5 years from Fig. 4 was used for the modelling. Similarly, the volume of greywater across SC1 was estimated as 12 litres per person per day (60% of standard 20 l/(person/d) water supply to a refugee) used for laundry, taking bath and washing plates (UNHCR, 2017).

2.3 Repeating step 2 with the SRCDS (Step 3)

The outcomes of step 2 were input for step 3. The contour data presented in Fig. 3 were used to identify depressed areas of SC1 in order to correctly layout the SRCDS (Fig. 5). The properties of materials evaluated in Ajibade and Tota-Maharaj (2018) were used for the vertical flow component of the SRCDS (Fig. 6). Subsequently, processes undertaken in step 2 were repeated with the SRCDS. The outputs of step 3 were proportion of runoff and greywater drained by the SRCDS and the infiltration rates.

Fig. 5: Layout of the SRCDS D1a, D1b, D2 and reservoirs (R1 & R2)

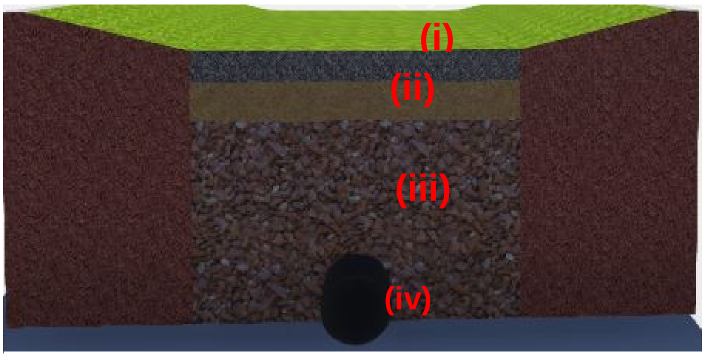

Fig. 6: Cross section of SRCDS D1a, D1b and D2 with materials (i) grass with side slope to reduce silt, (ii) filtration layers to reduce pollutants (0.14 m deep), (iii) storage layer to store drained water before reaching underdrain pipe (0.86 – 1.36 m), and (iv) underdrain pipe connected to storage reservoirs (0.15 m diameter).

2.4 Evaluation of performance of the SRCDS (Step 4)

The infiltration rates of the vertical flow components of SRCDS D1a, D1b and D2 shown in Fig. 6 was compared with Ajibade and Tota-Maharaj (2018). If the sizes of the SRCDS were not adequate, step 3 was repeated iteratively until adequate sizes were achieved.

3. RESULTS AND DISCUSSIONS

The results illustrated in Fig. 7 show that the runoff generated from the design storm decreases as the duration of storm increases with peak runoff rate and runoff coefficient of: 0.18 m^3/s and 0.832 respectively for 3 hr duration, 0.14 m^3/s and 0.812 respectively for the 6 hr duration and 0.12 m^3/s and 0.763 for the 12 hr duration. Conversely, the infiltrated proportion of the storm increases as the duration of storm increases. From the results in Table 1 for the performance of the final dimensions of the drainage systems. The total volume of runoff (total lost volume) generated over the sub-catchment area reduces significantly as the volume of water drained (total discharge volume) by the SRCDS increases.

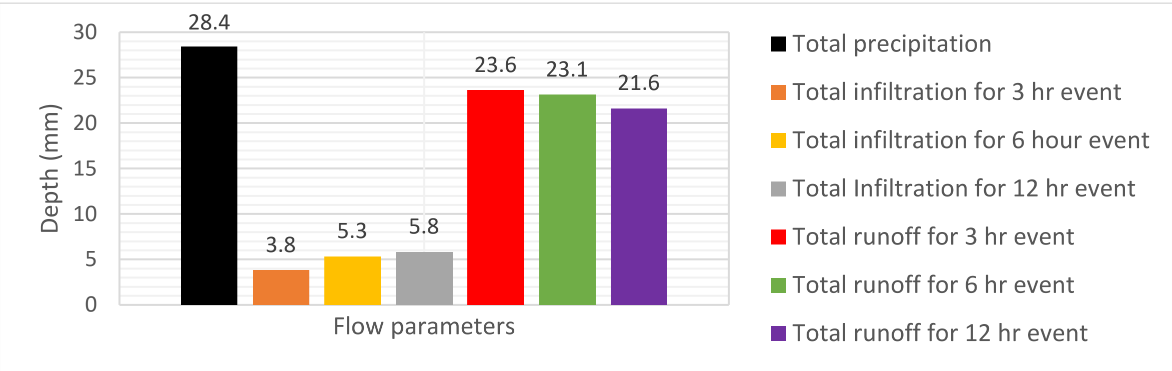

Fig. 7: Comparison of total infiltration with total runoff over SC1 from the design storm of 28.4 mm for durations 3hours, 6 hours and 12 hours events.

Table 1: Performance of the SRCDS (drains D1a, D1b, D2 and reservoirs R1 and R2) for draining and storing generated runoff across SC1 area from the design storm of 28.4 mm for 3 hr duration.

SRCDS	Max. Level (m)	Max. Depth (m)	Max. Inflow (L/s)	Max. Resident Volume (m^3)	Total Lost Volume (m^3)	Max. Outflow (L/s)	Total Discharge Volume (m^3)	Status
D1a	121	4.3	40.7	37.6	0.25	20.8	230.7	OK
D1b	119.7	1.7	19.1	1.13	0.0	19.1	109.1	OK
D2	121	4	40.6	27.13	0.18	26	230.5	OK
R1 (section i)	118.8	4.31	39.8	336.7	0.0	0.0	0.0	OK
R1 (section ii)	118.2	4.28	39.8	312.7	0.0	0.0	0.0	OK

R2 (section i)	119.2	4.21	26.1	228.4	0.0	0.0	0.0	OK
R2 (section ii)	119.1	4.2	26	204.4	0.0	0.0	0.0	OK

CONCLUSION

The effectiveness of the SRCDS for reducing the runoff over a sub-catchment of the Dadaab camp has shown that the decentralised drainage system can be an ideal solution to frequent flooding of the Dadaab camp area. Similarly, water stored in the reservoir components of the SRCDS can be a useful source of water for non-potable uses during the drought periods.

LIST OF REFERENCES

AFPNA (AFP News Agency) (2018). After drought, Kenya's Dadaab refugee camps hit by floods. AFP News Agency. [Online] Available at: https://www.youtube.com/watch?v=_CZRtMxK-SY. (Accessed: 27 – 05 – 2018).

Ajibade, O. O. and Tota-Maharaj, K. (2018). Comparative study of Sustainable Drainage Systems for stormwater management in refugee camps. *Proceedings of the Institution of Civil Engineers - Municipal Engineer*. ICE Publishing, UK, 171(3), September, 2018, pp. 149-162. ISSN 0965-0903 | E-ISSN 1751-7699.

AMCA (American Mosquito Control Association) (2016). Mosquito-Borne Diseases, American Mosquito Control Association, United States of America.

Bastable, A. and Russell, L. (2013) *Gap analysis in Emergency Water, Sanitation and Hygiene Promotion*, Humanitarian Innovation Fund (HIF).

Cambrézy A. B. (1999) *Refugee Camps and Environment: Landscape and Deforestation in Dadaab Region (Kenya)*. UNHCR – IRD, Dadaab, Kenya.

Kenya Meteorological Department (2018) Agrometeorological Bulletins of Rainfall and Temperature Records for Garissa Station. Agro Meteorological Advisory Services Division, Kenya Meteorological Department, Dagoretti Corner, Ngong Road, Kenya.

Ove Arup & Partners Ltd (2017) *Surface Water Management in Refugee Camps*. Humanitarian Innovation Fund.

UNHCR (2017) *Kenya 01– 30 September 2017 Fact Sheet*. United Nations High Commissioner for Refugees (UNHCR), Geneva, Switzerland.

World Weather and Climate (2017) Average Monthly Weather in Garissa. [Online] Available at: https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Garissa,Kenya (Accessed on: 18 – 02 – 2018).