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Sensitivity analysis of Pit characteristics in Urban Stormwater drainage design

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Abstract

Stormwater management is one of the main increasing challenges of rapid urbanization, environmental deterioration, and climate change. Stormwater drainage systems have been using in urban areas for years to address those challenges. Suitable design and evaluation of that systems are needed to effectively manage floods in a specific area. Drainage systems of varied pit characteristics were analyzed in a residential area of the city of Onkaparinga in South Australia (SA) using DRAINS software to convey minor storm events of 20% annual exceedance probability (AEP) and major storm events of 1% AEP. Pit size and type, blockage factor, and pressure head loss coefficient were the properties of pit considered in the sensitivity analysis. The outputs were compared in terms of maximum flow rate in pipes and hydraulic grade lines in pits. The results showed that the pit size and type were influential for stormwater management, whereas blockage factor and pressure head loss coefficient were not sensitive to the design of water drainage systems considered in this study. Other drainage components and climate change impacts have been recommended in the future study. This research has set up a method that can be used by other city councils of SA to evaluate their practice of designing drainage systems. The findings from this research project can be beneficial for designers, researchers, managers, and planners of stormwater management.

1. Introduction

A stormwater drainage system is installed in the urban catchment for managing the risk of flood and minimizing water pollution in the natural water body [1]. Stormwater is the water that flows over the earth's surface due to precipitation on various structures, paved surfaces, and the ground. With the aim of protecting public spaces from floods, stormwater drainage systems are widely used, which rapidly redirect stormwater from residential areas [2]. Storm drains are commonly used to drain stormwater, which is also known as storm sewers and drainage wells [3]. Poorly managed stormwater may cause difficulties both on and offsite by causing erosion and transporting contaminants to downstream rivers [4]. Flood in Nepal in 2024 caused several socio-economic losses including more than 200 casualties [5]. In 2022, various storms caused higher than 20 casualties and insured losses of AUD 3.35 billion around Queensland and New South Wales, Australia [6]. It is essential to forecast design flows correctly during the design of urban drainage systems that ensures effective stormwater management.

Factors affecting drainage design include the geographical and climate conditions of the area, intensity and pattern of rainfall, location of drainage pipes and pits, and runoff coefficient. A social parameter, land use patterns, also influences drainage design [7]. Rainfall and

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economic considerations should be examined when designing drainpipes and pits for proper drainage systems [4]. A suitable drainage design must be capable of dealing with issues such as a stormwater collection to prevent flooding while predicting the future intensity and frequency of rainfall and then draining it into a proper drainage system, such as a nearby watercourse [8]. An efficient design of the drainage system accounts for the economic and environmental sustainability [9].

The pit is an essential component of the stormwater drainage network which receives rainwater and transfers it to drainage pipes [10]. The performance of the system depends on the effectiveness of the pits [11]. Being the most nature-exposed part compared with other elements of the system, pits are more susceptible to receiving unpredictable quantities and quality of materials along with stormwater. Pits may become partially or fully clogged, with debris or leaves carried with storm flow during storm events or even on dry days due to inadequate cleaning or maintenance. Even the blockage phenomena of pits are related to the human habits in a certain locality. For instance, it will be more in the area where people are not aware of refraining from throwing plastic or other litter here and there. Therefore, the quantity or nature of materials carried with stormwater or received by the pit in any other way can vary in a wide range which makes the pit's performance uncertain.

The pit is designed using some recommended values in Australia [12]. The suitable pit features in a stormwater drainage system may be area specific. Also, relying upon the traditional parameters to design a suitable water management device has become challenging due to the progressive and fast alterations in urban composition, land-use patterns, and other anthropogenic activities [13]. Because there are few sources that connect this information with pit characteristics, which could influence the efficiency of stormwater drainage systems, the research is crucial [14]. To understand the relationship between the pit characteristics with the efficiency of a stormwater drainage network, the sensitivity analysis of pit characteristics is necessary.

The advancement in modelling technology using software has enabled designers to perform the task more precisely in a shorter time [11]. At present, many conventional storm-water drainage systems are in place and being operated and maintained following guidelines provided by concerned authorities. The maintenance processes can be evaluated and updated through sensitivity analysis. Moreover, several drainage systems have been designed to install or upgrade in newly developed areas in Australia using the recommended values for different properties provided by standards and guidelines. These recommendations need to be evaluated for ensuring accuracy in the specific areas or scenarios.

This research aims to analyze the pit sensitivity for stormwater drainage system using design criteria associated with pits (the blockage factor, size and type, and pit pressure loss coefficient) for the evaluation of existing design process and improvement of the design in future. To design an appropriate stormwater drainage system in a residential area of Aldinga, South Australia (SA), the guidelines of City of Onkaparinga [15], other relevant guidelines and standards were followed. Ten different models of stormwater drainage systems were generated using different pit properties under major and minor storm events in the study area. Statistical analysis was also performed to observe the relationship between input parameters and design outcomes using Statistical Package for Social Science (SPSS) software [16]. This sensitivity analysis can help to better understand performance of drainage system with different pit properties considered here and assist in decision making for the designers, planners, and managers.

2. Methodology

Models of stormwater drainage systems were developed using DRAINS software [10] for a residential plot of Aldinga, City of Onkaparinga, South Australia under major and minor storm events to observe the influence of pit characteristics. Results were analyzed with the help of data visualization and statistical tools to better understand the sensitivity of the pit characteristics.

2.1. Study area

The research site is located in the city of Onkaparinga (local government area), SA, Australia as shown in Figure 1. The residential plots are located along Old Coach Road in the suburb of Aldinga surrounded by existing buildings (Figure 1d). There is the Willunga creek on the north side where stormwater from the designed system would be drained. Aldinga is a residential zone located approximately 45 km south of Adelaide city center. The site's land use includes impermeable portions like residential structures, public places, and roadways, as well as pervious regions like green areas and parks. The total area was measured as approximately 1.8 ha based on Figure 1d. A total of 21 individual residential allotments were used for estimating the area of subcatchments.

2.2. Modelling of drainage system

Basic steps adopted for the DRAINS modelling are shown in Figure 2. Initially rainfall data and hydrological model were assigned in the model. Then, the network of components of the drainage system was deter-

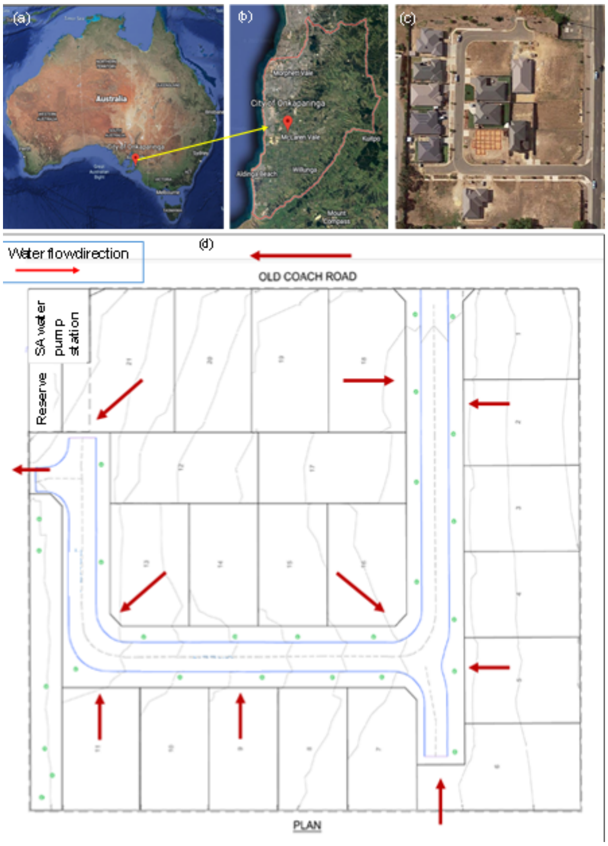

Figure 1: The study area (a) location of the city of Onkaparinga, Australia. (b) magnified map of the Onkaparinga, (c) surroundings of the project area [17], and (d) plan of the individual allotments [15].

mined. In the third step, the data related with subcatchment, pit, pipe and overflow were assigned. Afterwards, the model was run for minor storm event followed by major storm event, and the basic design model was finalized with addressing errors, if any. Then this basic design model was subjected to sensitivity analysis.

Rainfall intensity-frequency-duration (IFD) data were collected from Bureau of Meteorology (BOM) [18] as shown in Appendix A (Figure A1) by selecting the geographic location (35.27°S, 138.48° E) nearest to Aldinga in the city of Onkaparinga. As per the council's guideline by City of Onkaparinga [15], a 20 years of average recurrence interval (ARI) (can also be expressed as 5 % AEP- annual exceedance Probability) was selected as the minor storm and a 100 years of ARI (1% AEP) as major storms. The rainfall intensities corresponding to minor and major storm events were computed from DRAINS software [10]. Out of various hydrological models available in DRAINS manual [10], the ILSAX hydrological model was considered suitable for small urban sub-catchments. The ILSAX model requires soil type and depression storage. In DRAINS manual, four types of soils are applicable for the ILSAX model based on infiltration rates, and soil of low infiltration rates (soil type 3) was considered in this study. The depression storage was chosen as 1 mm for impermeable, 0 mm for supplemental, and 5 mm for pervious areas according to council guideline City of Onkaparinga [15].

The network of the stormwater drainage system was drawn on the DRAINS software [10] adding subcatchment (C), pit (T), pipe (p), and overflow route (OF) as shown in Figure 3 based on the network of the flowlines. Then, all the required properties of the components were assigned according to the design guidelines and standards [10][15]. A catchment's characteristics include area, impervious (paved) area (road area and roof area), supplementary paved area (other paved, e.g., footpath and driveway), pervious (grassed) area, and time of concentration for runoff to concentrate at the catchment outlet. The catchment data including the percentage of paved area and pervious area were determined for the site based on Figures 1c and 1d. A total of 13 sub-catchments were developed in the model and one pit was assigned for each sub-catchment. A minimum time of concentration of 5 min was adopted.

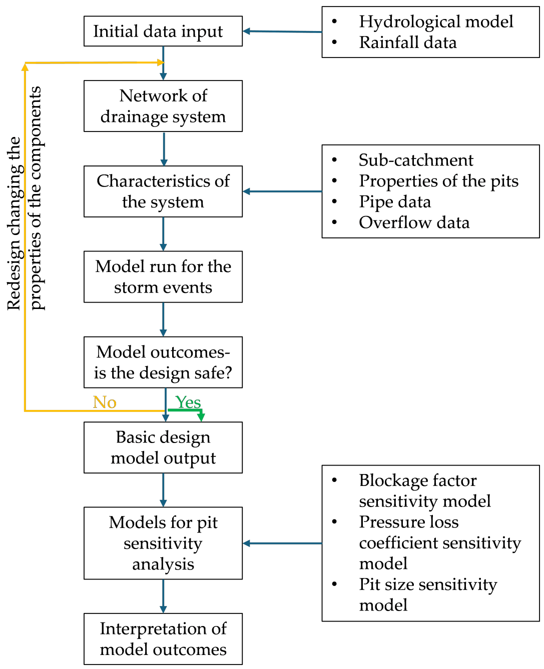

Figure 2: Methodology adopted in the DRAINS modelling.

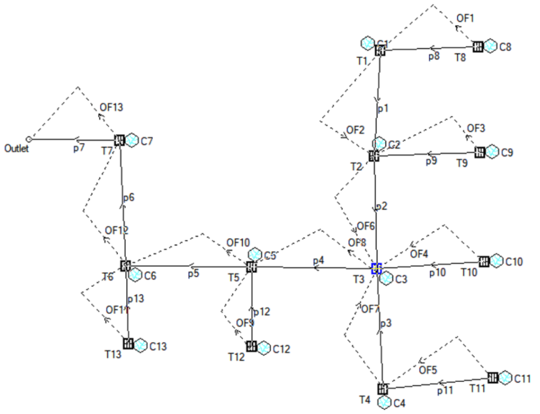

Figure 3: Network of drainage components in the DRAINS model.

The pit data available for South Australia in DRAINS software [10] was chosen initially. A pit is a node in a storm drainage system where water enters. At a node point, the pipe's direction, slope, or size might alter. The surface elevation for each pit was determined using contour map. In Australia, the two most popular forms of pits are sag pits and on-grade pits and were followed. The pressure (head) loss coefficient (k_u) is a dimensionless coefficient for full pipe flow and varies based on the geometry of the pit. The k_u allows to determine the changes in hydraulic grade line (HGL) in a pipe system. Drain manual [10] provides k_u values as per the location such as a value of 5 at the start of the drainage line. Likewise, the blockage factor of 0.5 for sag pits and 0.2 for on-grade pits has been recommended. The Appendix B (Table B1) lists the pit properties for basic design.

The pipe in the drainage system transports the collected stormwater in the pit from one to another. According to the local council guidelines of City of Onkaparinga [15], the minimum values for pipe size, slope, and maximum pipe length adopted were 375 mm, 0.5%, and 100 m respectively. The concrete pipes, under roads of roughness coefficient 0.013 were used. The Appendix B (Table B2) shows the pipe details used in this study. If the water volume from a storm event exceeds the drainage system's design capacity, there will be an overflow of stormwater. Overflow routes were drawn in the models as shown in Figure 3. The surface elevations of the upstream and downstream pits, respectively, were used to calculate the invert levels at the upstream and downstream ends of each overflow channel. According to council recommendations [15], the safe depth for the stormwater drainage system for major and minor storms has been chosen at 0.15 and 0.45 meters, respectively.

After establishing all relevant design inputs, the DRAINS model was repeatedly run under major and small storm events. The intended model was unable to satisfy the design requirements with the initial inputs, such as safe flow through the overflow routes and allowable freeboard at all pits. Some modifications, such as pipe diameters, were made to satisfy the requirements. After several trials and errors, one model was finalized as the basic design for the study area.

2.3. Sensitivity analysis

Sensitivity analyses are used to assess how design parameters would affect the design outcomes. The basic model was subjected to sensitivity analysis to observe the effect of the blockage factor, pit size and type, and pressure change coefficient on the stormwater drainage system under major and minor storm events. Table 1 shows different pit sizes and types used during the sensitivity analysis where other parameters remained unchained as that of basic model. Table 2 shows the pressure change coefficients used. Three models were created with the increment on the pressure coefficient of the pits by 10%, 20%, and 30% to that of basic model. The blockage factors were changed as shown in Table 3. These three sets of pit properties were analyzed for the major and minor storms. Then, the design outcomes were compared among different components with maximum hydraulic grade lines (HGLs) and maximum water flows in the pipes.

Table 1: Various pits used for the sensitivity analysis [10]

Pit			
Model name	**Type**	**Size**	**Inlet dimension of Kerb**
Pit size 1 (basic model)	City of Onkaparinga	Double pit	1.9 m long
Pit size 2	City of Adelaide	Single pit	0.9 m long
Pit size 3	Transport SA	Single bay	0.9 m long
Pit size 4	Transport SA	Double bay	1.9 m long

Table 2: Various pressure change coefficients used for the sensitivity analysis

Pressure change coefficient (k_u) of pit		
Model name	**Starting point**	**Changing direction**
k_{u1} (basic model)	4.0	1.5
k_{u2}	4.4	1.65
k_{u3}	4.8	1.8
k_{u4}	5.2	1.95

Table 3: Various blockage factors used for the sensitivity analysis

Blockage factor		
Model name	**Grade pit**	**Sag pit**
BF1 (Basic Model)	0.2	0.5
BF2	0.3	0.6
BF3	0.2	0.6
BF4	0.3	0.6

BF and the number after BF denote the blockage factor and model number, respectively.

2.4. Statistical analysis

Statistical analysis was performed to define the relationship between dependent and independent variables. The dependent variables considered in this study were HGL and maximum flow rates in the pipes. The independent variables were pit properties used in the sensitivity analysis. (SPSS) software [16] was used for the statistical analysis to perform Kruskal-Wallis test as the dependent variables were nonparametric and the number of comparison groups were more than three. After defining the hypothesis testing as shown in Table 4, the statistical analysis for three sensitivity cases were performed for both major and minor events. The independent variables were divided into four distinct groups for all three sensitivity cases. For example, the blockage factors were divided into four groups where group 1 was the data from the BF1, group 2 was from the BF2, and so on. Similarly, the other variables from pressure coefficient and pit size and type sensitivity analysis were divided into four groups.

3. Results and discussion

The results from the basic design for 25 minutes minor storm and major storms are shown the Figures 4 and 5 respectively. The meaning of color in the figure is explained in Table 5. No overflow was created by the minor storm as all the red-colored values are shown to be zero in Figure 4. The maximum flow rate was 0.283 m^3/s at the last pipe (P7) of the network which was connected to the outlet. This pipe carried the maximum flow from all sub-catchments. There was no overflow under the major storm as all the red-colored values are shown to be zero or near to zero in Figure 5. The flow rate was much higher for the major storm compared to that of the minor storm. The maximum flow rate was 0.472 m^3/s at the last pipe (P7) of the network. The model outcomes from the basic model were compared to the results from the sensitivity analysis which are discussed here after.

The maximum HGL at pits for different pit sizes and types are presented in Figures 6 and 7 for the minor and major storms respectively. The values of maximum

Table 4: Assumptions made during hypothesis testing

Sensitivity tests / Independent variable	**Flood event**	**Dependent variable**	**Null Hypothesis**	**Alternative Hypothesis**
Blockage Factor	Major	HGL	The blockage factor will have no effect on the HGL of major storm events.	The blockage factor will have an effect on the HGL of major storm events.
	Major	Maximum flowrate in pipes	The blockage factor will have no effect on the maximum flow rates of major storm events in pipes.	The blockage factor will have an effect on the maximum flow rates of major storm events in pipes.
	Minor	HGL	The blockage factor will have no effect on the HGL of minor storm events.	The blockage factor will have an effect on the HGL of minor storm events.
	Minor	Maximum flowrate in pipes	The blockage factor will have no effect on the maximum flow rates of minor storm events in pipes.	The blockage factor will have an effect on the maximum flow rates of minor storm events in pipes.
Pit size	Major	HGL	The pit size will have no effect on the HGL of major storm events.	The pit size will have an effect on the HGL of major storm events.
	Major	Maximum flowrate in pipes	The pit size will have no effect on the maximum flow rates of major storm events in pipes.	The pit size will have an effect on the maximum flow rates of major storm events in pipes.
	Minor	HGL	The pit size will have no effect on the HGL of minor storm events.	The pit size will have an effect on the HGL of minor storm events.
	Minor	Maximum flowrate in pipes	The pit size will have no effect on the maximum flow rates of minor storm events in pipes.	The pit size will have an effect on the maximum flow rates of minor storm events in pipes.
Pressure loss coefficient	Major storm	HGL	The pressure coefficient will have no effect on the HGL of major storm events.	The pressure coefficient will have an effect on the HGL of major storm events.
	Major storm	Maximum flowrate in pipes	The pressure coefficient will have no effect on the maximum flow rates of major storm events in pipes.	The pressure coefficient will have an effect on the maximum flow rates of major storm events in pipes.
	Minor storm	HGL	The pressure coefficient will have no effect on the HGL of minor storm events.	The pressure coefficient will have an effect on the HGL of minor storm events.
	Minor storm	Maximum flowrate in pipes	The pressure coefficient will have no effect on the maximum flow rates of minor storm events in pipes.	The pressure coefficient will have an effect on the maximum flow rates of minor storm events in pipes.

HGL generated from minor storm analysis showed no significant differences among one another. However, a significant variation in maximum HGL was observed for all pits under major storm conditions. Figures 8 and

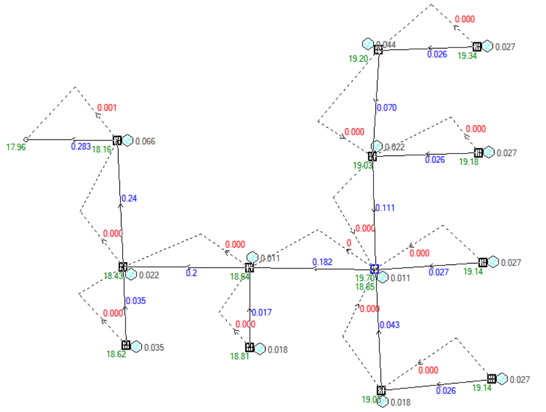

Figure 4: Model outcomes for minor storm event for the basic stormwater drainage system.

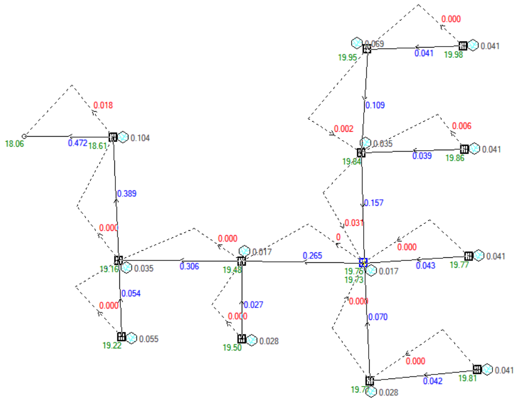

Figure 5: Model outcomes for major storm event for the basic stormwater drainage system.

Table 5: The colors in Figures 4 and 5, and their meaning

Color of values	Meaning of color
Black	Maximum flowrates from the sub-catchments, m^3/s
Blue	Greatest flowrates in each pipe, m^3/s
Green	Highest levels attained by the hydraulic grade lines (HGLs) throughout the pipe system due to the storm event, m
Red	Greatest overflows from pits, m^3/s

9 show the maximum pipe flow rates for different pit sizes and types under minor and major storm events, respectively. The maximum pipe flow values were varied significantly for pipes p1 to p7 for both minor and major storm events. The maximum pipe flow in the basic model was significantly higher than almost all sensitivity cases. The minimum value of maximum pipe flow rate occurred for the size 3 scenario which was the Transport SA type pit of single bay of 0.9 m length for both minor and major storm conditions. It can be inferred that pit size and type significantly influences the maximum HGL of a pit when rainfall is adequately intensive. However, this effect may not be much influential for minor storms in the study area. Besides, the maximum pipe flow rates can be significantly impacted by the size and type of pit regardless of the rainfall intensity.

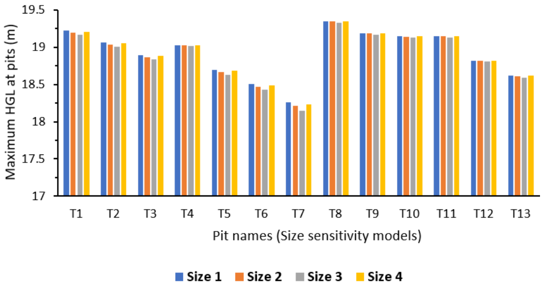

Figure 6: Maximum HGL at pits for different pit sizes and types under minor storm event.

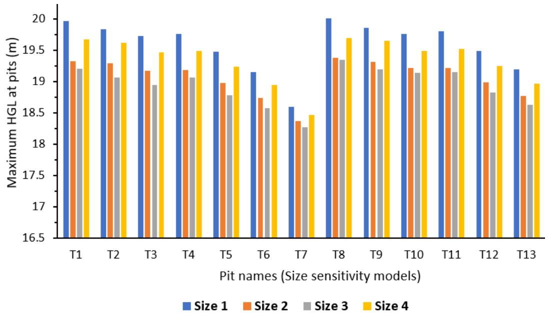

Figure 7: Maximum HGL at pits for different pit sizes and types under major storm event.

Maximum HGL at pits for the scenarios of different blockage factors under minor and major storms are presented in Figures 10 and 11 respectively. It was observed that no major variation exists in all sensitivity cases for both storms. However, the maximum HGL values were higher under major storm event compared to the minor event. Figures 12 and 13 show the maximum pipe flow rates for different blockage factors under minor and major storm events. No major changes were found in the maximum pipe flow rates for all sensitivity cases based on pit blockage factors under both storms. Relatively large volumes of water flow were observed

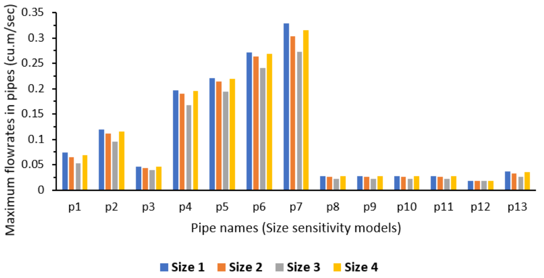

Figure 8: Maximum flowrates in pipes for different pit sizes and types under minor storm event.

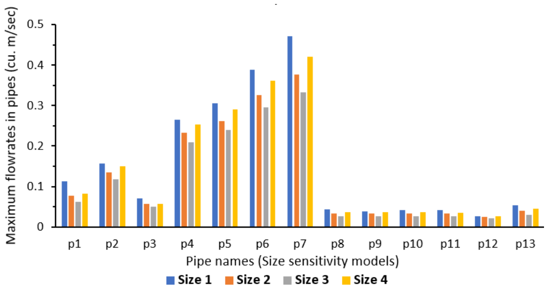

Figure 9: Maximum flowrates in pipes for different pit sizes and types under major storm event.

through pipes p4, p5, p6, and p7 (pipes are shown in Figure 3), which were closer to the outlet of the system and carried relatively larger flow than other pipes of the system. The minor and major storms produced 0.282 to 0.283 m^3/s and 0.465 to 0.472 m^3/s maximum overflow rates at pipe p7 for all cases. The blockage factor sensitivity analysis showed that three different combinations of blockage factors generated almost similar results under both storms irrespective of maximum HGL and maximum flow rate in pipes.

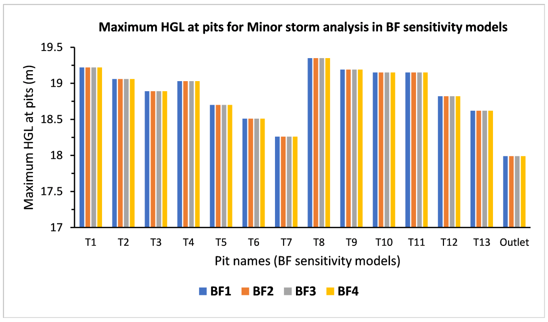

Figure 10: Maximum HGL at pits for different blockage factors under minor storm event.

The sensitivity analysis for the various pressure loss showed no major changes on the maximum HGL and maximum pipe flow rates based on pressure loss coefficient under both major and minor storms.

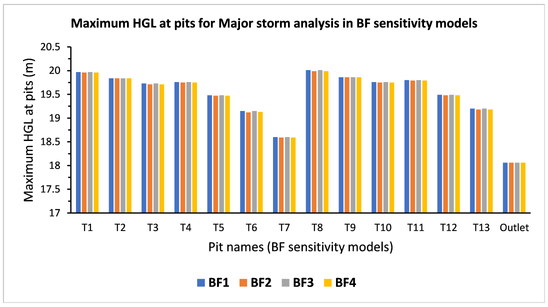

Figure 11: Maximum HGL at pits for different blockage factors under major storm event.

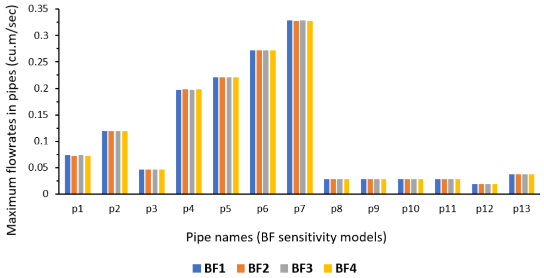

Figure 12: Maximum flowrates in pipes for different blockage factors under minor storm event.

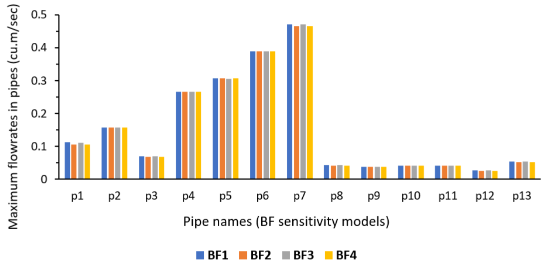

Figure 13: Maximum flowrates in pipes for different blockage factors under major storm event.

Table 6 summarizes the result from the Kruskal Wallis test through the SPSS software. The statistical analysis of three sensitivity scenarios, each for both major and minor storms showed that most of them were statistically insignificant. Only pit size and type sensitivity analysis for major storms showed the difference in the distribution of HGL values which was statistically significant. Figure 14 demonstrates the box plot for this specific case which showed that values of HGL vary in different ranges.

4. Limitations and future study

The research project has come across several limitations. Three characteristics of pits were considered in this study for the sensitivity analysis. Other properties

Table 6: Observations from the hypothesis testing

Sensitivity parameters	**Flood event**	**Analysis output**	**Result from the hypothesis test**
Blockage Factor	Major storm	Maximum HGL in pits	No association between the cases
		Maximum flowrate in pipes	No association between the cases
	Minor storm	Maximum HGL in pits	No association between the cases
		Maximum flowrate in pipes	No association between the cases
Pit size	Major storm	Maximum HGL in pits	Association between the cases
		Maximum flowrate in pipes	No association between the cases
	Minor storm	Maximum HGL in pits	No association between the cases
		Maximum flowrate in pipes	No association between the cases
Pressure loss coefficient	Major storm	Maximum HGL in pits	No association between the cases
		Maximum flowrate in pipes	No association between the cases
	Minor storm	Maximum HGL in pits	No association between the cases
		Maximum flowrate in pipes	No association between the cases

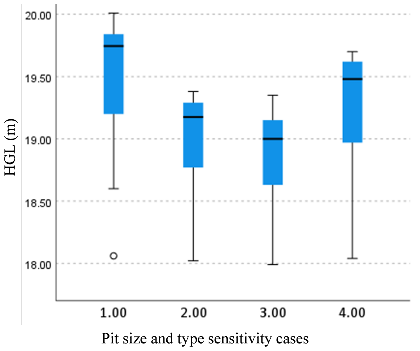

Figure 14: Boxplot of maximum HGL at pits under major storm event during pit size and type sensitivity models.

of pit such as locations, configurations and other components of drainage system were not included. Similarly, the maximum HGL in pits and maximum flow rates in pipes were incorporated, however outcomes form overflow routes and catchments were not analyzed. The climate of Australia is projected to change in the future [19][20][21][22][23] which was not considered in this study. Increase rate of heavy rainstorms associated with climate change may result in more frequent urban flash floods and water contamination of the rivers [24]. So, the effect of climate change needs to account for the stormwater drainage design and management. Likewise, lightweight structures such as drainage pipes, residential footings, pavements etc., have been severely affected by/vulnerable to the shrink-swell movement of expansive soils in Australia [25][26][27][28][29] which needs to be included in the future study for the long-term serviceability of the drainage system constructed in/on such soils throughout the design life.

5. Conclusion

The research provides in-depth understanding on stormwater drainage design through a modelling approach. Pit sensitivity analyses in three distinct aspects such as pit sizes and types, pit blockage factors, and pit pressure loss coefficient were performed in the stormwater drainage design of city of Onkaparinga. The basic model and different sensitivity models developed using varied pit properties were analyzed with respect to the maximum HGL at pits, and the maximum pipe flow rates. It was found that the pit sizes and types were identified as the most sensitive properties of pit for the design under major storm condition. Pit blockage factor and pit pressure loss coefficient (k_u) were not found to be sensitive to the design of water drainage systems considered in this study. The current practice of designing stormwater drainage system, especially pit characteristics considered here can be assumed to be safe for flood management in the city of Onkaparinga provided that further research is required. Future research has been recommended to analyze the resilience of drainage structures under various scenarios such as areas with greater rainfall intensity, future climate, water quality, cost analysis and other properties of the drainage system. The method discussed here can be applied under these scenarios for evaluating the design and maintenance process of a stormwater drainage system. The key findings on the sensitivity analysis of pit characteristics in drainage system can be useful for engineers, researchers, planners, and managers for the stormwater management.

6. Acknowledgements

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Appendix A

Appendix A includes the IFD chart for the study area taken from Bureau of Meteorology (BOM).

Appendix B

Appendix B includes the Pit details of the drainage system for basic design and Pipe details of the drainage system for basic design.

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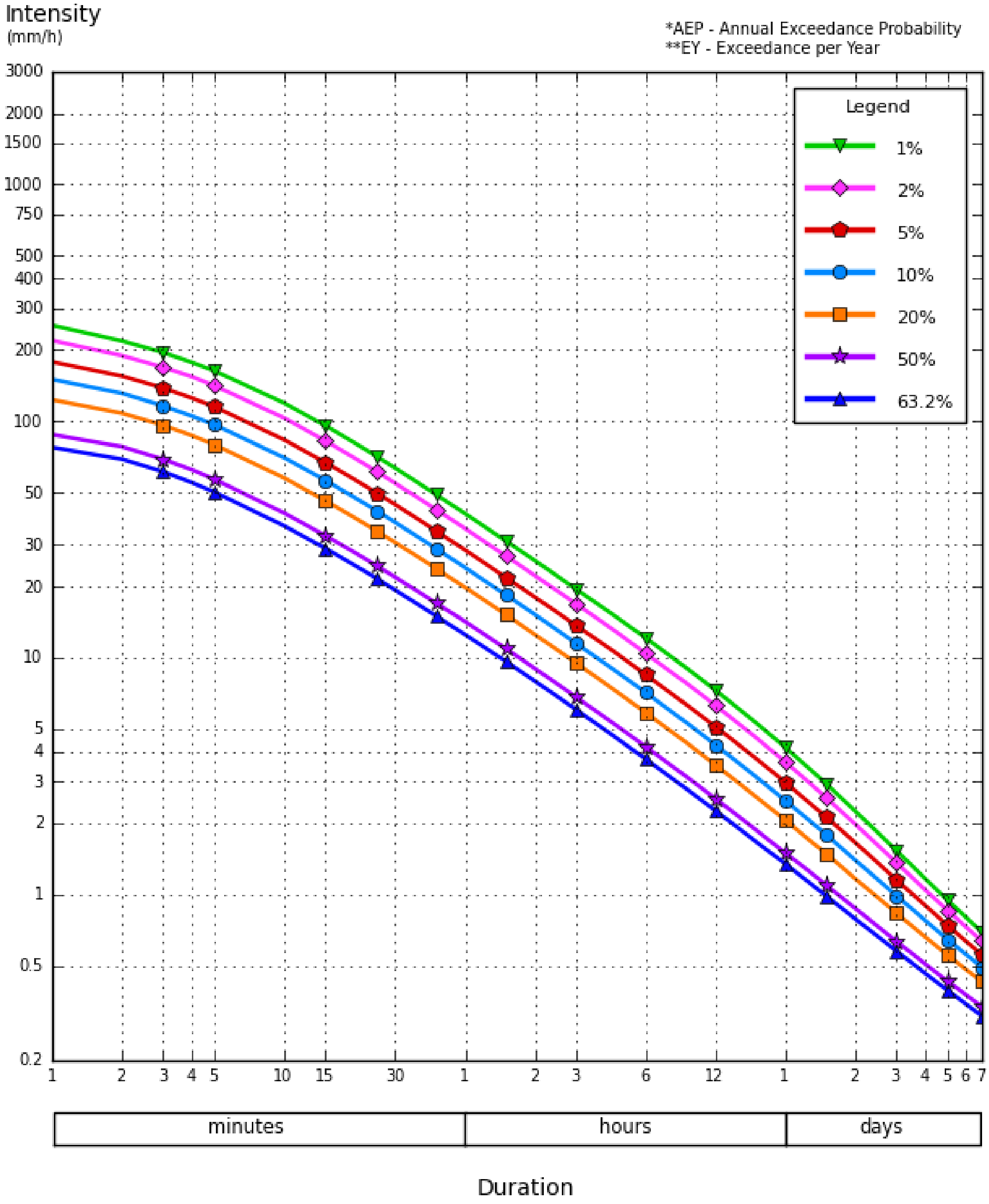

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IFD chart for the study area taken from Bureau of Meteorology (BOM) [18]

Table B1: Pit details of the drainage system for basic design

Name	Type	Family	Size	Pressure Change Coeff. k_u	Surface Elev (m)	Blocking Factor
T1	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	20	0.2
T2	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	19.84	0.2
T3	Sag	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	19.675	0.5
T4	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	19.8	0.2
T5	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	19.5	0.2
T6	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	19.32	0.2
T7	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	1.5	19.145	0.2
T8	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	4	20.04	0.2
T9	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	4	19.88	0.2
T10	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	4	19.84	0.2
T11	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	4	19.84	0.2
T12	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	4	19.54	0.2
T13	OnGrade	City of Onkaparinga Pits, 3% crossfall, 0.5% grade	Double	4	19.36	0.2

Table B2: Pipe details of the drainage system for basic design

Name	Length, m	U/S IL, m	D/S IL, m	Slope, %	Type	Dia, mm	Roughness coefficient
p1	32	18.99	18.83	0.5	Concrete, under roads, 0.5% minimum slope	450	0.013
p2	33	18.748	18.583	0.5	Concrete, under roads, 0.5% minimum slope	450	0.013
p3	25	18.869	18.744	0.5	Concrete, under roads, 0.5% minimum slope	450	0.013
p4	35	18.505	18.33	0.5	Concrete, under roads, 0.5% minimum slope	525	0.013
p5	36	18.255	18.075	0.5	Concrete, under roads, 0.5% minimum slope	525	0.013
p6	35	18.022	17.814	0.59	Concrete, under roads, 0.5% minimum slope	525	0.013
p7	15	17.677	17.602	0.5	Concrete, under roads, 0.5% minimum slope	525	0.013
p8	8	19.184	19.144	0.5	Concrete, under roads, 0.5% minimum slope	375	0.013
p9	8	19.024	18.984	0.5	Concrete, under roads, 0.5% minimum slope	375	0.013
p10	8	18.984	18.819	2.06	Concrete, under roads, 0.5% minimum slope	375	0.013
p11	8	18.984	18.944	0.5	Concrete, under roads, 0.5% minimum slope	375	0.013
p12	8	18.684	18.644	0.5	Concrete, under roads, 0.5% minimum slope	375	0.013
p13	8	18.429	18.389	0.5	Concrete, under roads, 0.5% minimum slope	375	0.013