FLOOD ASSESSMENT & STORM WATER MANAGEMENT PLAN

FOR THE PROPOSED EXPANSION OF WOODBURN SHOPPING CENTRE IN PIETERMARITZBURG, MSUNDUZI LOCAL MUNICIPALITY, UMGUNGUNDLOVU DISTRICT, KWA-ZULU NATAL

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FINAL REPORT

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Specialist Details & Declaration

This report has been prepared in accordance with Section 13: General Requirements for Environmental Assessment Practitioners (EAPs) and Specialists as well as per Appendix 6 of GNR 982 – Environmental Impact Assessment Regulations and the National Environmental Management Act (NEMA, No. 107 of 1998 as amended 2017) and Government Notice 704 (GN 704). It has been prepared independently of influence or prejudice by any parties.

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1. INTRODUCTION

1.1 Project Background and Description of the Activity

NatureStamp has been contracted to conduct a flood assessment for the extension of the existing Woodburn Shopping Centre. A development has been proposed on Sub 0 and Sub 5 of Erf 10278 of Pietermaritzburg. Given the proximity of the site to a stream/canal, a flood assessment is required. The proposed development is located on the following erven sites:

Sub Div	Farm No.	Town Name	Latitude	Longitude	Area (m^2)	SG Code	Deed
5	10278	Pietermaritzburg	30.3908	-29.6162	17 824	N0FT02580000434600005	N/A
0	10278	Pietermaritzburg	30.3911	-29.6106	64 573	N0FT02580000434600000	N/A

Uninformed and poorly planned infrastructural developments in the vicinity of water resources, such as sensitive surface and groundwater, can rapidly degrade these resources. Thus, pre-development (or in some cases post development) assessments are required to gain an understanding of the natural environment and guide the developmental process in order that site-specific mitigation measures can be put in place.

The key requirements for this study are as follows:

1. Desktop hydrological assessment.
2. Catchment analysis.
3. Storm water management plan.
4. Design flood investigation.
5. Reporting (report & maps in pdf format).

The receiving environment as of May 2022 can be seen in Figure 1 with the layout of the site in Figure 2.

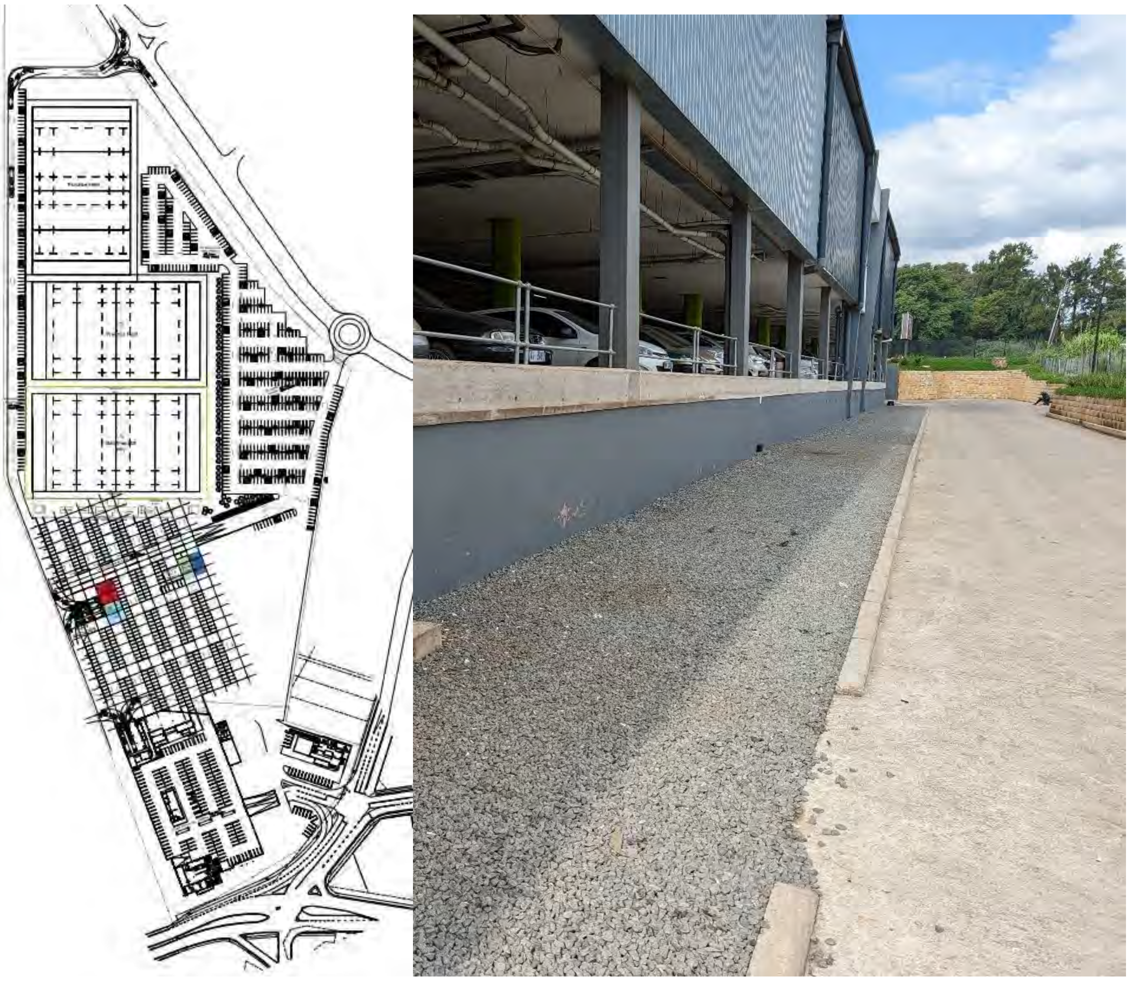


Figure 1 The receiving environment of the Woodburn Shopping Centre Expansion area

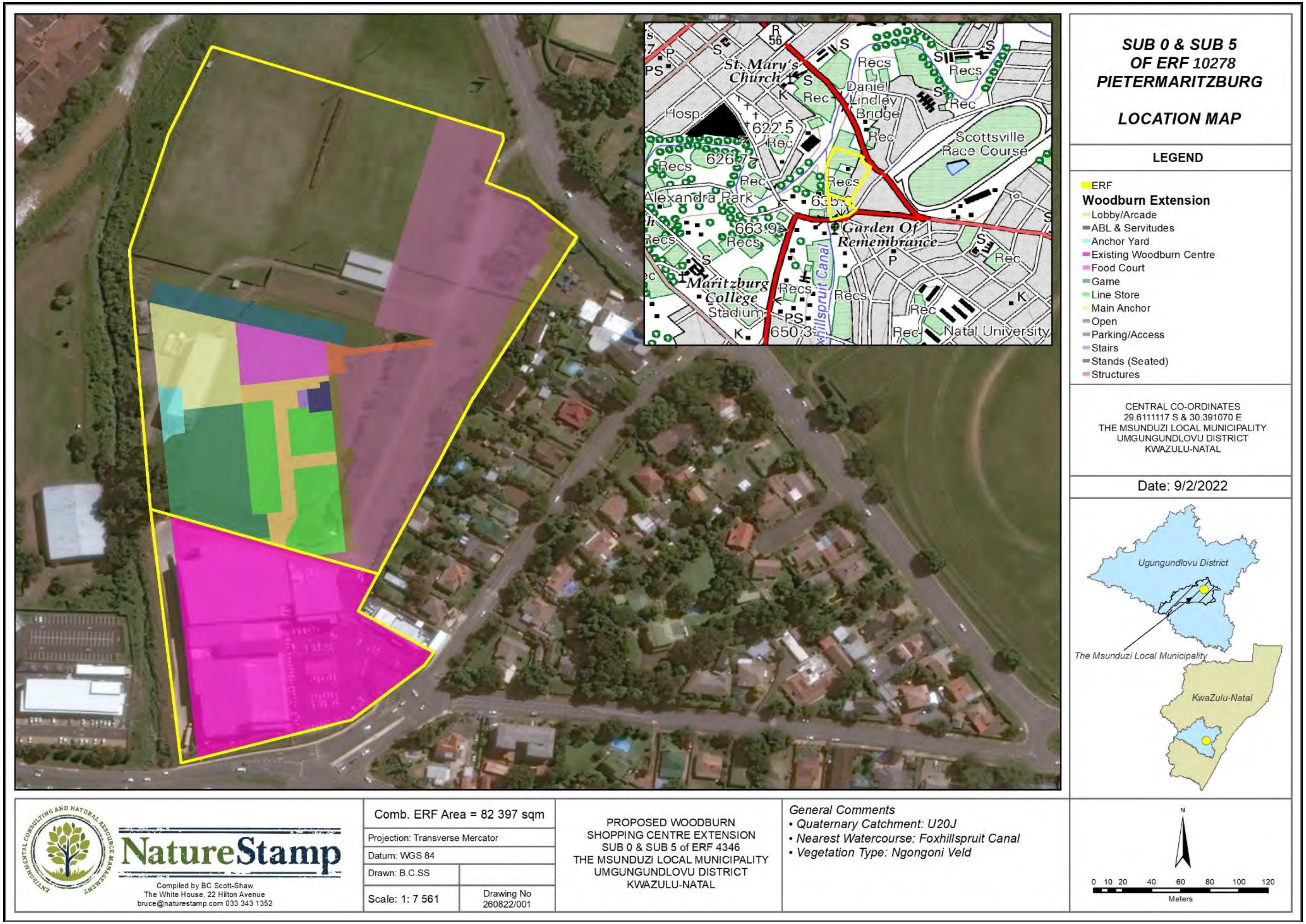


Figure 2 Locality map of the Woodburn Shopping Centre Expansion

1.2 Terms of reference

i. Flood Hydrology:

a. Hydraulic analysis, illustrated by the:
- Catchment delineation;
- Analysis or derivation of peak flow events (using observed flow or design methods);
- Compilation of the river reach model and flood line using HEC-RAS and HEC-geoRAS;
- Backwater calculations and findings;
- Determination of the flood risk and flood hazard throughout the study site; and
- Recommendation of mitigation options associated with the hydraulic analysis.

b. Consolidate results in a report with:
- 1:50 and 1:100 Flood line maps (drawing in pdf format, flood lines plot in dwg/dxf format);
- A final flood line report; and
- Recommendation of mitigation options associated with the hydraulic analysis.

ii. Storm Water Management Plan

- Site hydrological assessment, undertaken by the:
  a. Analysis of surface areas of the site;
  b. Analysis of sensitive areas on site;
  c. Analysis of existing storm water structures on site; and
  d. Determination of areas with clean and dirty water.
- Hydraulic design analysis, illustrated by the:
  a. Determination of the design storm event (1:2, 1:10 & 1:50 year return period);
  b. Determination of the capability of proposed structures; and
  c. Recommendation of mitigation options and improvements.
- Erosion control plan
  a. Compilation of erosion control measures;
  b. Identification of high risk areas, exclusion areas and potential stockpile areas;
  c. Final erosion mitigation measures and rehabilitation objectives.
- Consolidate results in a report with:
  a. Storm water maps;
  b. CAD storm water drawings; and
  c. A storm water management plan.

1.3 Gauged versus Ungauged Catchments

Flood hydrology assessments can be limited if the information available is scant. In the Pietermaritzburg area (which, in recent years experienced a severe drought) most of the smaller tributaries (excluding large rivers) do not flow all year round as they have done in the past. This can be explained by changes in land use through intensification and increased areas under crops or commercial forests, an increase in water extraction (irrigation, dams, industrial needs and human needs), cyclic drought and climate change. Much of the flow in these rivers is not always accurately recorded by weirs. When a flood hydrology assessment is undertaken, depending on the data available, either gauged or ungauged catchments can be assessed. Gauged data are the most accurate approach assuming that the data quality is reliable and over a long period of time. In the absence of such data, an ungauged catchment is assessed using observed rainfall. This data (assuming it is of good quality) is used as an input to a rainfall-runoff model. The design flood is determined using a statistical analysis of the rainfall and the catchment characteristics.

In large catchment areas the antecedent moisture content is important for 1:100 year flood events. If the catchment is very dry before such an event, dams may fill up first from the flood waters and part of the rainfall may infiltrate, resulting in a reduced flow through the system, whereas a saturated catchment would result in a shorter lag time and a larger flow volume in the channel. This can lead to a difference in a simulated flood using design rainfall (ungauged) and a flood using observed streamflow (gauged). Furthermore, the large flood events are often poorly recorded in weirs due to poor maintenance and overtopping.

For the study area, streamflow data was not available. As such, a detailed rainfall and flow assessment was undertaken to determine the design events.

2. STUDY SITE

The site is located within Quaternary Catchment U20J; falling under the uMvoti to Mzimkulu Management Area (WMA) and the uMgeni waterboard (uMgeni Water). The proposed area sits on a modified tributary of the uMsunduze river, known as the Foxhillspruit canal.

The Foxhillspruit and the Msunduzi are highly degraded due to the presence of settlements, rubbish dumps and factories that have encroached along the edge and impacted upon of this watercourse. Given the vulnerable state of these watercourse systems, and their associated high population, all catchments areas contributing to this system should be given extra attention and precaution regarding development proposals.

Rainfall in the region occurs in the summer months (mostly December to February), with a mean annual precipitation of 859 mm (observed from rainfall station 0239756 W). The reference potential evaporation (ET_o) is approximately 1667 mm (A-pan equivalent, after Schulze, 2011) and the mean annual evaporation is between 1300 – 1400 mm, which exceeds the annual rainfall. This suggests a high evaporative demand and a water limited system. Summers are warm to hot and winters are cool. The mean annual temperature is approximately 21.5 ºC in summer and 13.8 ºC in the winter months (Table 1). The underlying geology of the site is sedimentary Ecca Shale and the soils overlain are sandy-clay-loam ranging from Mispah, Glenrosa to Oakleaf form in this particular area. Much of the soils identified on site were transported material and highly modified.

Table 1 Mean monthly rainfall and temperature observed at Scottsville (derived from historical data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Rainfall (mm)	119	110	98	42	17	7	6	19	37	81	97	108	756
Mean Temperature (ºC)	21.5	21.6	21.0	18.5	16.0	13.7	13.8	15.3	17.3	18.0	19.2	20.8	18.1

3. METHODOLOGY

The following methodology was followed in order to meet the objectives as detailed in the terms of reference. The assessment of these systems considered the following databases where relevant:

Table 2 Data type and source for the assessment

Data Type	Year	Source/Reference
Aerial Imagery	2016	Surveyor General
1:50 000 Topographical	2011	Surveyor General
2 m Contour	2010	Surveyor General
River Shapefile	2011	EKZNW
Geology Shapefile	2011	Durban Geological Sheets/National Groundwater Archive
Land Cover	2014	EKZNW
Water Registration	2013	WARMS - DWS

*Data will be provided on request

3.1 Site Visit

A site visit was conducted by Bruce Scott-Shaw of NatureStamp on the May 2022. A pre-development state was assessed. The current condition was assessed as follows -

- The vegetation characteristics of the watercourse were assessed for the determination of the Manning's n-values;
- The presence and dimensions of any crossings, such as culverts and bridges, that would act as a barrier to a flood event and that may be damaged during the occurrence of such an event were noted;
- The overall state of drainage channels, streams and rivers was assessed;
- The slope of the study site as well as evidence of flood damage and erosion around the site were noted;
- The state of existing gauging stations (nearby) was assessed to determine if the structure is accurately recording streamflow (e.g. evidence of under cutting or damaged features); and

- The elevation at the water level and crossing level in order to verify contour data.

The watercourse systems were flowing at the time of the site visit. As a result, a full river profile was undertaken. Depth poles were used to measure the depth of the channel where possible.

Figure 3 General site conditions and structures observed during the site visit

3.2 Critical Catchment Delineation and River Reach Analysis

The critical contributing catchment area was determined for use in both the watershed delineation tool and HEC-HMS and SWAT models. The sub-catchments were delineated using the 2 m contour set provided by the topographical survey as an input. This was used to create a Digital Elevation Model (DEM) that was then used as an input to the watershed tool (Figure 4).

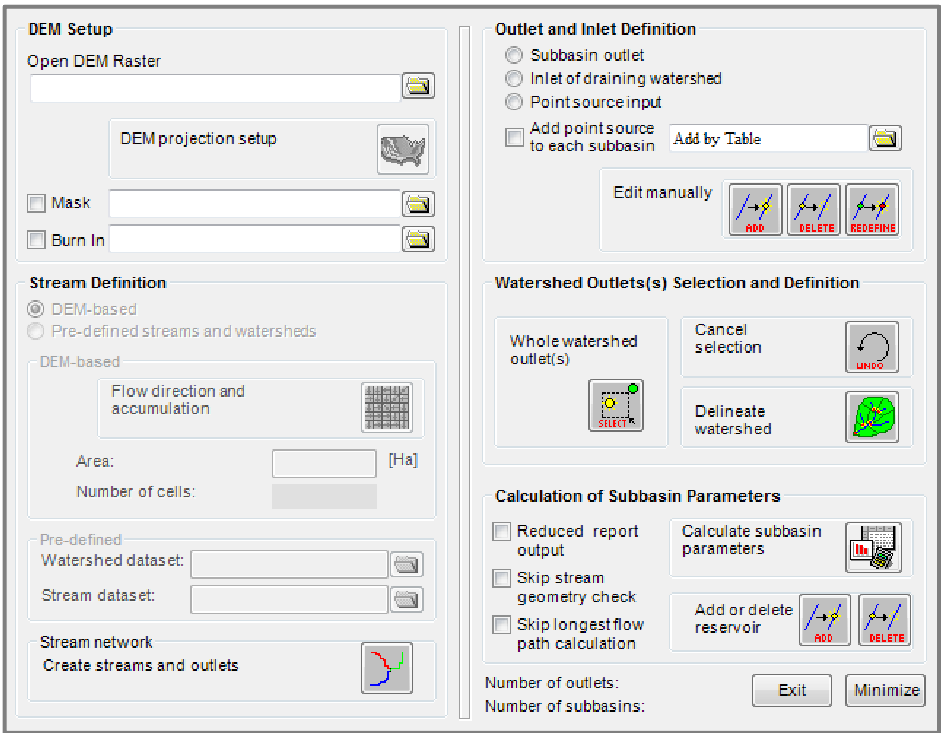


Figure 4 Soil Water Assessment Tool (*SWAT*) watershed delineation tool for sub-catchment delineation and stream network creation

The pre-development conditions were assessed as follows -

- The vegetation and surface characteristics of the watercourse were assessed for the determination of the Manning's n-values;
- The presence and dimensions of any storm water structures, such as culverts, bridges, drains, berms and gutters that would divert flow during a storm event were noted;
- The overall state of drainage channels, streams and nearby rivers was assessed;
- The slope of the study site as well as evidence of erosion around the site were noted; and
- The elevation throughout the site in order to verify contour data.

In accordance with Government Notice 704 (GN 704) and Best Practice Guidelines (BPG), the main objectives of a SWMP were:

1. To accommodate post-development storm events;
2. To keep clean and dirty water separated;
3. To contain any dirty water within a system; and
4. To prevent contamination of clean water.

A range of storm water design events were considered. 2-meter contours obtained from the Surveyor General were obtained and improved using a GPS. Rainfall data was extracted using the rainfall extraction utility tool (Kunz, 2003). Contributing catchment areas were calculated using the derived elevation model.

The critical contributing catchment area was determined for use in both the watershed delineation tool and HEC-HMS and SWAT models. The sub-catchments were delineated using the 2m contour set as an input. This was used to create a Digital Elevation Model (DEM) that was then used as an input to the watershed tool (Figure 4). Design rainfall depths using the Design Rainfall Estimation (DRE) tool was used for the nearest rainfall station.

3.3 Design Storm Determination

The peak flows for the 1:2, 1:5, 1:10, 1:50 and 1:100 storm events were calculated for the catchments using the SCS-SA method as outlined in the SANRAL Drainage Manual (6th Edition, 2013). The type of surface in the drainage basin is an important component in the design calculations. The SANRAL Rational Method becomes more accurate as the amount of impervious surface, such as pavements and rooftops, increases. As a result, the Rational Method is most often used in urban and suburban areas (ODOT Hydraulics Manual, 2014). The

Utility Programme for Drainage (Sinotech) was used to run the rational method, determine drainage grid and kerb drainage calculations.

It generally recognised that the 1:50 year return design for a 30-minute storm event be used as the typical event to design for.

3.4 Storm Water Design Principles

The objective of the Stormwater Management Plan is to control runoff flows and prevent detrimental impacts on receiving waters, considering both the quality and quantity of the stormwater runoff. As the existing site has natural impervious areas, steep slopes and shallow soils, the velocity of stormwater runoff would be considered high. However, as the site is located near the catchment divide, there are little to no upper catchment contributions.

Stormwater management design principles to be followed on site include:

- Clean water should be kept clean, as far as possible, and be routed to a natural watercourse by a system separate from the dirty water system and should be allowed to pass through to downstream users, while preventing or minimising the risk of spillage of clean water into dirty water systems.
- The establishment and maintenance of grass and plants adjacent to newly constructed infrastructure and roads.
- Dirty water must be collected and contained in a system separate from the clean water system and the risk of spillage or seepage into clean water systems must be minimised. The containment of dirty or polluted water will minimize the impact on the surrounding water environment.
- The design standard stipulated by GN704 is not that a 1 in 50-year flood should be captured, but that the structure may not spill more than once every 50 years. Design storage volumes are a function of peak storage requirements that often correspond to abnormally wet conditions that continue for an extended period of time, and not to a specific flood event
- Hazardous or environmentally dangerous chemicals kept on site must be kept outside of the 1:100 year flood line and watercourses or appropriately bunded.
- Regulations stipulate a clear hierarchy of water use. Firstly, recycle any captured dirty water and minimise the import and use of clean water resources. Should excess water be released from a dirty water area, it must be treated to a standard agreed to by the regulator, the Department of Water Affairs and Sanitation (DWS), and any plan to treat and release excess water must be approved and licensed.
- The SWMP must be sustainable over the life cycle of the development and over different hydrological cycles and must incorporate principles of risk management.
- Groundcover should be maintained during construction to ensure erosion protection.
- Flow concentration points should avoid unstable soil areas and/or stockpiles.
- Ensure aesthetic designs.

The above-mentioned principles are to be used as a conceptual stormwater management guide.
The Msunduzi Municipality recognises the following:

- The difference between the Pre and Post storm water flows would need to be calculated using the rational method.
- The difference would need to be stored on site and released at the pre-development flow.
- These calculations would be based on the following -
  - 1: 50 year return storm design.
  - 30 minute storm (Hydrograph peaking at 15 minutes)
  - Intensity of 165 mm/hr.
  - "C" Factors: Pre-dev C factor = 0.35 (for the entire site, in original undeveloped state).
    - Post –dev C factor for landscaped/grassed areas = 0.45
    - Post –dev C factor for hardened surfaces =0.85

These calculations can be simplified to:

- 1m^3 to be attenuated for every 48 m^2 of hardened surface.
- 1m^3 to be attenuated for every 242 m^2 of soft / landscaped surface.

3.5 Design Flood Determination

The peak flows for the 1:10, 1:50 and 1:100 flood events were calculated for the catchments using the rational method, the SCS-SA model and the Standard Design Flood Method as outlined in the SANRAL Drainage Manual (2013). The 1:10 and 1:50 year events were included for comparative reasons even though they were not a required output. The SCS-SA model is a hydrological storm event simulation model suitable ideally for application on catchments that have a contributing catchment of less than 30 km². The model has been used widely both internationally and nationally for the estimation of flood peak discharges and volume (Schulze *et al*., 1992). The type of surface in the drainage basin is also important. The Rational Method becomes more accurate as the amount of impervious surface, such as pavements and rooftops, increases. As a result, the Rational Method is most often used in urban and suburban areas (ODOT Hydraulics Manual, 2014).

3.6 Flood Line Determination

Modelling of the flood lines was undertaken using the U.S. Army Corps of Engineers' HEC-RAS v5.05 programme, which is commonly used throughout South Africa. Numerous cross sections were created throughout the contributing area (Figure 5). Ineffective areas/hydraulic structures were digitized and included in the model. Land use coverage was used to determine the Manning's n-values in a GIS platform. Each cross section may have had numerous values on either side of the channel depending on the site characteristics. Manning's N-values were obtained from the HEC-RAS Hydraulic Reference Manual (2010) for the channel areas (a value of between 0.03 and 0.04 was used depending on the presence or absence of rock features and debris). Design flood values were used as an input for the relevant reaches.

Given the slope of the catchment and the distance to downstream hydrological infrastructure, no inundation within the study site would occur from external features on the watercourse. As such, Normal Depth was selected for the reach boundary conditions. The slope of the channel was used as the value for the backwater calculation of the initial condition. Some inundation structures were included in the cross sections where there were structures present (Figure 5).

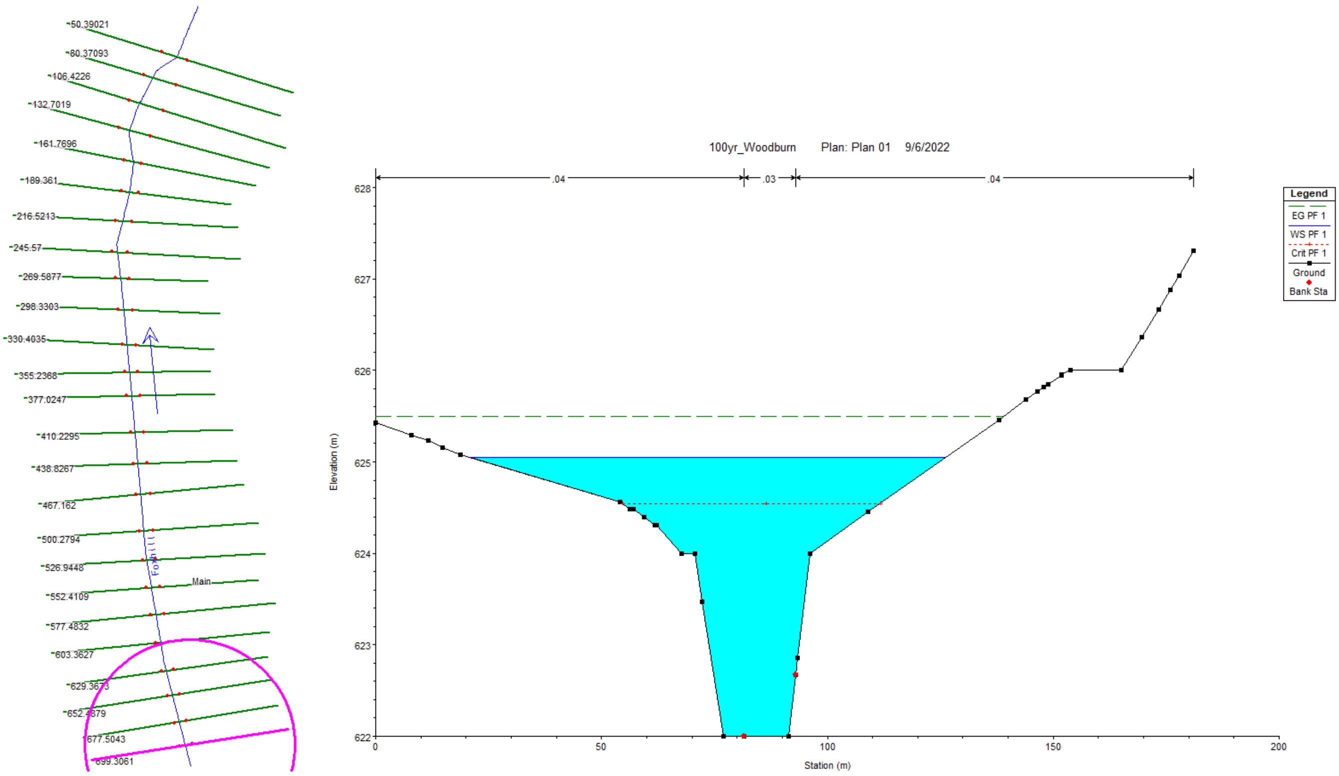


Figure 5 Longitudinal profile and channel cross sections developed for a section of the Foxhillspruit

3.7 Flood Line Determination for Minor Channels

As HEC-RAS and HEC-geoRAS are highly sensitive to the resolution of the terrain data used in the model, small non-perennial channels such as drainage lines are often not captured within the model. In most cases the flood output is not required for such channels as the flood generated would be negligible. However, it is good practice to ensure that all channels or drainage lines are adequately covered. As such, the author has developed a simple model to generate a flood depth through GIS. The model considers the flood generated for nearby smaller catchments and applies and area weighted correction. The model generates a flood height based on this estimation within the existing terrain model. Figure 6 provides a schematic of this model.

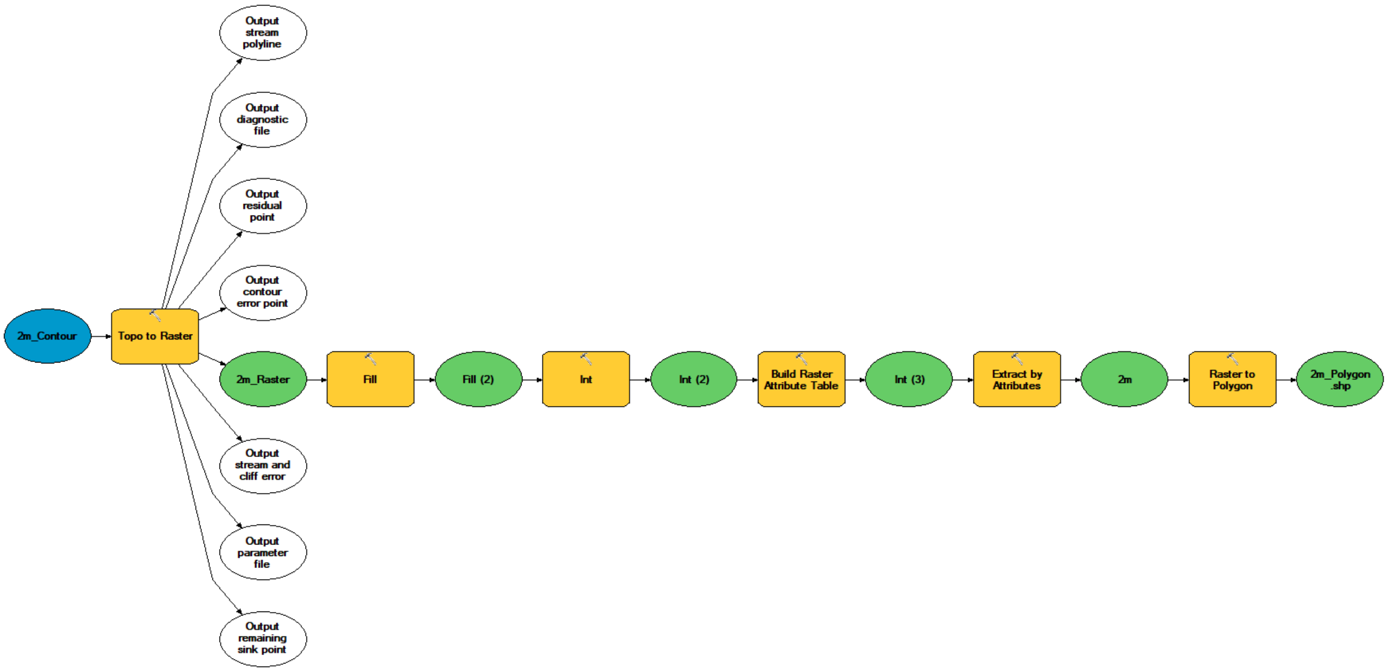


Figure 6 GIS model for flood generation in small channels

4. LIMITATIONS AND ASSUMPTIONS

In order to apply generalized and often rigid design methods or techniques to natural, dynamic environments, a number of assumptions are made. Furthermore, a number of limitations exist when assessing such complex hydrological systems. The following constraints may have affected this assessment:

- Manning's n - values (the channels roughness coefficient) was estimated. However, n- values in areas outside of the study area were estimated using a desktop approach due to the extent of the catchment.
- 0.5 & 2 meter contour interval data and Digital Elevation Models (DEMs) were used in the design flood estimation (development of the elevation model). However, outside of the immediate study area, the 2 meter contours were used. Given the flood proposed, this resolution was considered to be of sufficient accuracy for the flood line determination.
- Given the setting of the site (low flow during the site visit) it was difficult to determine which channels would be fully active in a flood and which are remnant channels which have since been bypassed. HEC-geoRAS and HEC-RAS models cannot be used to a very high level of accuracy on smaller non-perennial systems as they are usually used on larger catchment areas.
- There was little to no data on flows out of the system. The catchment is very small and the watercourse associated with the site has been transformed.

5. RESULTS AND DISCUSSION

A detailed desktop assessment was undertaken for the site. This was the point of departure for the calculation of design flood volumes. These adopted values were then used in the HEC-RAS and HEC-geoRAS models to route this flood event through the channel.

5.1 Desktop Hydrological Assessment

A detailed assessment of the climate was undertaken. Rainfall stations were considered based on their proximity to the site (contributing catchment), altitude and length/reliability of the data record. The long-term mean annual rainfall of the site that was used in the design was 853 mm (Figure 7).

Table 3 Comparison of values from some of the rainfall stations that were assessed during the data analysis

Station No.	Estimated MAP (mm)	Observed MAP (mm)	Years	Reliable	Patched	Altitude (m)	Station Name
0239133W	1054	1051	112	57.4	46.5	1443	Vaucluse
0209296W	756	756	42	60.0	35.0	1196	Oxton
0239097A	952	946	113	61.5	37.4	1579	Elandshoek
0239518W	763	758	107	39.9	59.2	816	Edendale
0239577W	891	885	107	41.1	58.0	754	Pietermaritzburg (PUR)
0239196U	1084	1084	9	92.1	0	978	Henley Dam

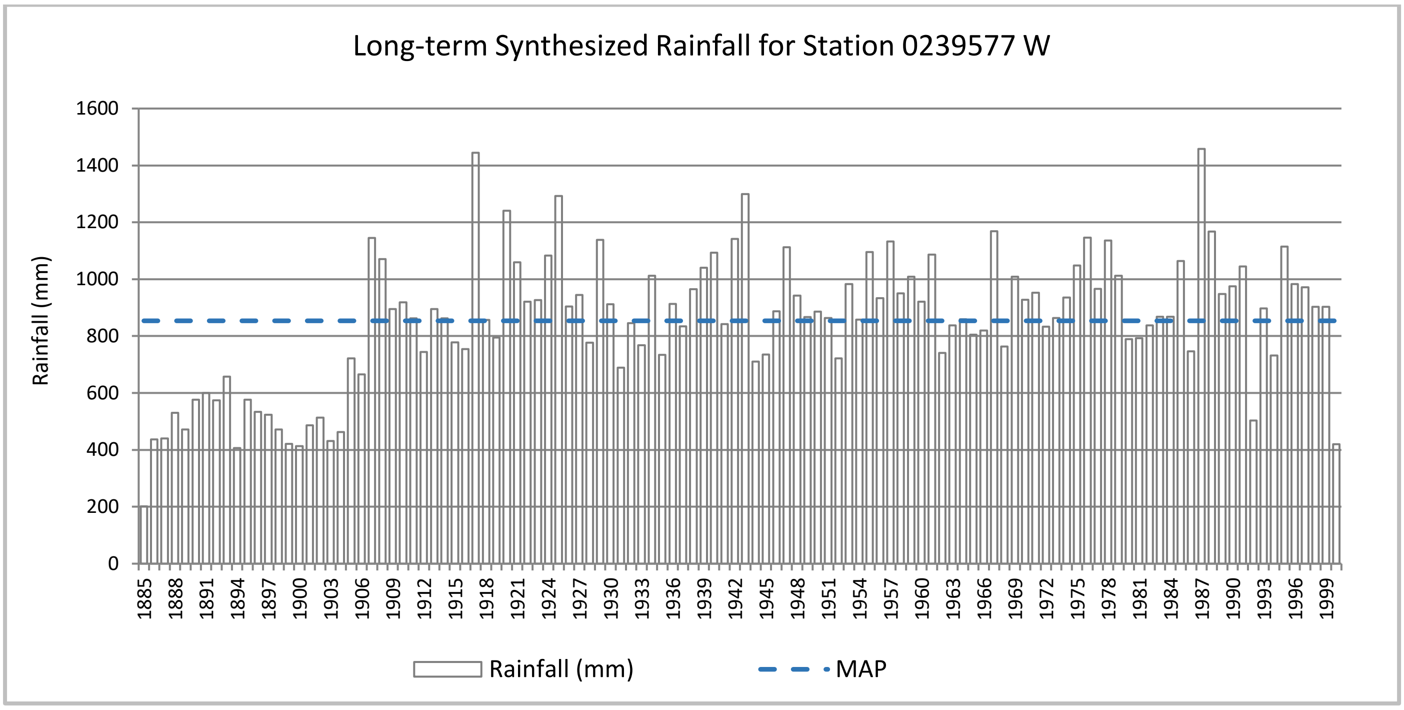


Figure 7 Long term synthesized annual rainfall values with the mean annual precipitation indicated in blue

The data obtained from the nearby gauging stations (as indicated in Figure 8) indicated that overtopping was present throughout all of the gauging stations analyzed. These stations would have been used to validate sections of the flood output. However, due to the poor quality of the observations, design rainfall was utilized.

Of importance to note, the key event in 1984 and 1987 were not captured by these gauges. Station U2H057 could be used as a paired comparison if it had good quality data.

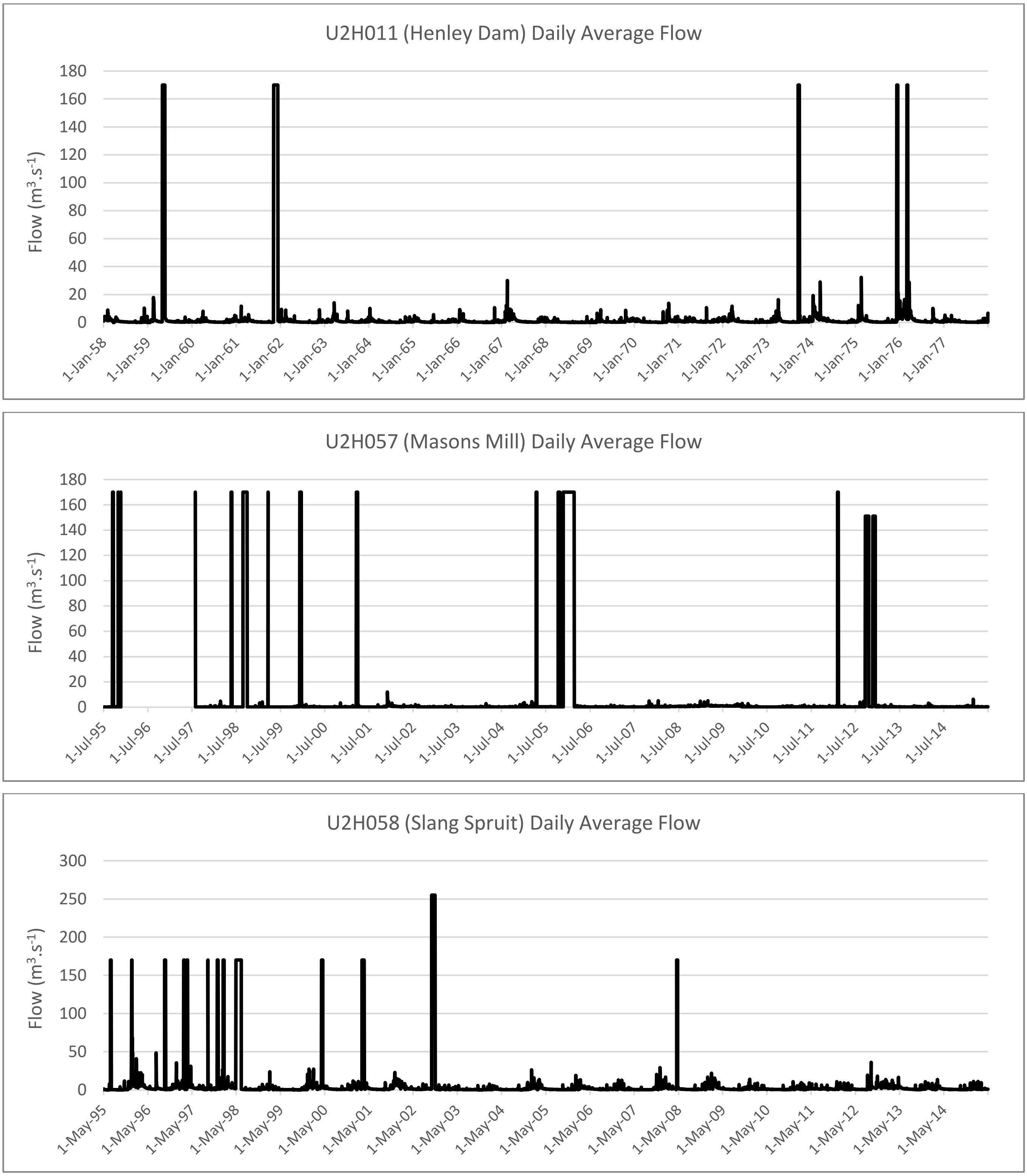


Figure 8 Historical streamflow from gauging stations within the catchment area of the Umsunduzi River

5.2 Allowable Abstractions and Water Registration

Quaternary Catchment (QC) site: U20J (uMgeni/uMsunduzi). According to GN 538 (2016), the General Authorization (GA) limits for this QC are as follows–

- Abstraction of surface water: 2 000 m^3 / year @ 1 l/s from throughout the year
- Storage of water: 2 000 m^3
- Groundwater abstraction: 275 m^3/ha/year (allowed under GA).

These limits show that this catchment area is water limited and restricted water use applies.

5.3 Catchment

Contour lines (0.5 & 2 meter) were used to calculate the slope of each of the banks. These were further improved through height measurements taken on-site. The soils and geology were obtained from GIS layers obtained from the Soil Science department at the University of KwaZulu-Natal (UKZN). Various vegetation databases were used to determine the likely or expected vegetation types (Mucina & Rutherford, 2006; Scott-Shaw & Escott, 2011). A number of recognized databases were utilized in achieving a comprehensive review, and allowing any regional or provincial conservation and biodiversity concerns to be highlighted.

This site is dominated by Ngongoni veld (SVs 4, Mucina and Rutherford, 2006). This occurs within the sub-escarpment savanna biome. The desktop analysis revealed that the area is largely transformed, with the possibility for some flagged fauna and flora (e.g. red data species and endangered wildlife) being found from the C-plan, SEA and MINSET databases. However, this does not necessarily mean that rare or endangered species will occur in the area of interest. The following information was collected for the vegetation unit SVs 4 (Mucina & Rutherford, 2006; Scott-Shaw & Escott, 2011):

- Undulating plains and hilly landscape mainly associated with drier coast hinterland valleys in the rain-shadow of the rain-bearing frontal weather systems from the east coast.
- Sour sparse wiry grassland dominated by unpalatable Ngongoni grass (*Aristida junciformis*) with this mono-dominance associated with low species diversity.
- In good condition dominated by *Themeda triandra* and *Tristachya leucothrix*.
- Wooded areas are found in valleys at lower altitudes, where this vegetation unit grades into KwaZulu-Natal Hinterland Thornveld and Bisho Thornveld.
- Termitaria support bush clumps with *Acacia* species, *Cussonia spicata*, *Ehretia rigida*, *Grewia occidentalis* and *Coddia rudis*.

Large patches of alien invaders were noted as well as subsistence farming, surrounded by industry and infrastructure on the opposite banks. Dumping was observed along the riparian banks.

Table 4 Proposed land cover area for the contributing catchment area

Land Cover	Pre-development Area (ha)	Pre-development Percentage	Post-development Area (ha)	Post-development Percentage
Buildings	68.35	6.80	70.2	6.99
Cultivated commercial annual crops non-pivot	4.30	0.43	4.30	0.43
Degraded	0.28	0.03	0.28	0.03
Grasslands	368.85	36.72	367	36.54
Indigenous Forest	0.18	0.02	0.18	0.02
Low shrubland	1.76	0.18	1.76	0.18
Plantations / Woodlots	3.28	0.33	3.28	0.33
Settlements	418.11	41.62	418.11	41.62
Thicket /Dense bush	118.31	11.78	118.31	11.78
Wetlands	17.60	1.75	17.60	1.75
Woodland/Open bush	3.48	0.35	3.48	0.35
Total	1004.51	100	1004.51	100

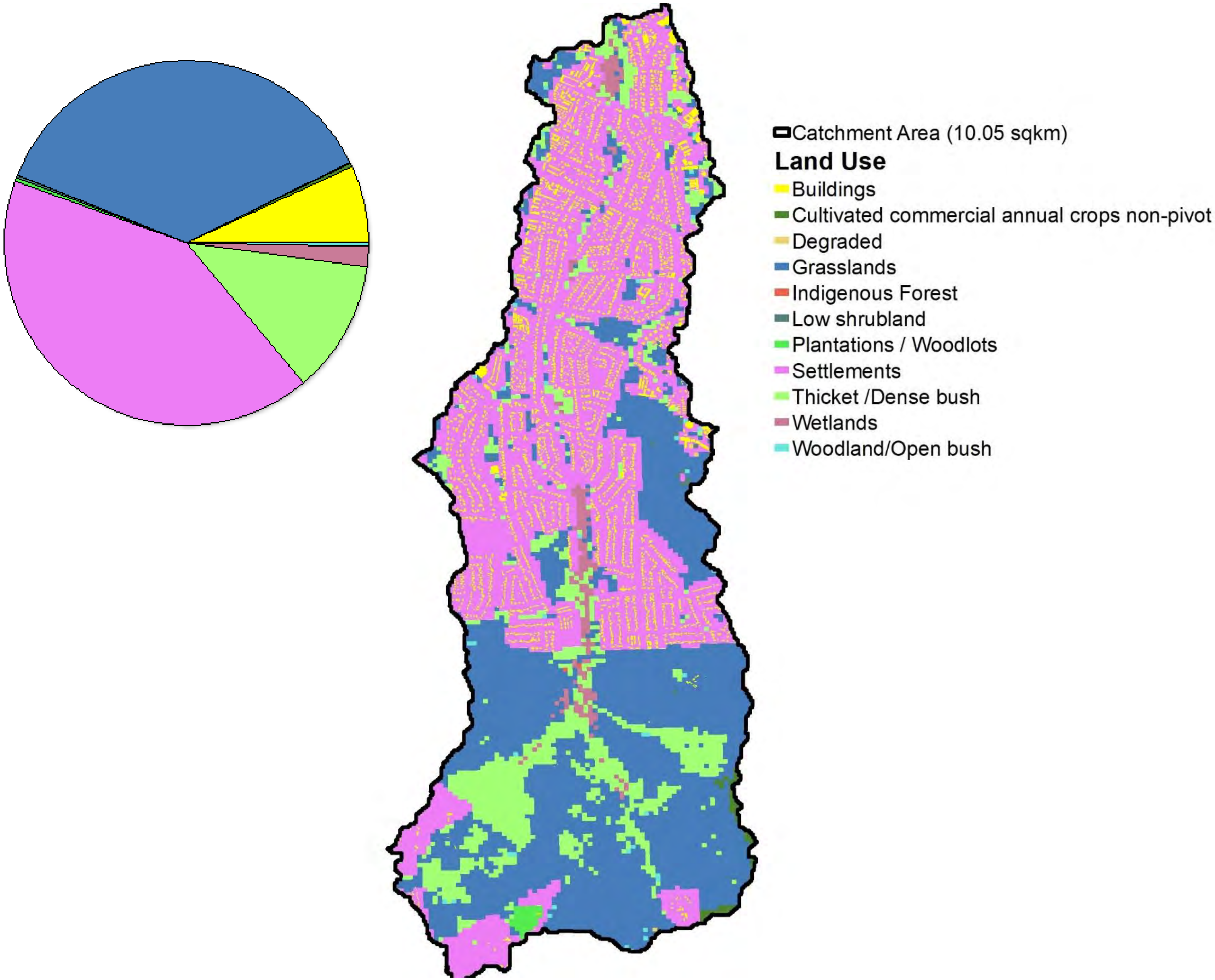


Figure 9 Existing land use for the catchment area of Woodburn Shopping Centre Expansion

Figure 10 Exaggerated (x3) Digital Elevation Model (DEM) of the catchment surrounding Woodburn Shopping Centre

5.4 Design Rainfall

Design rainfall differs from standard rainfall as it is rainfall associated with an events rainfall depth for a specified storm duration and a recurrence interval (frequency of occurrence). The design rainfall used is dependent on the method used to calculate the statistics. The Design Rainfall Estimation (DRE) tool which uses observed rainfall data was included for comparative purposes. The results of the design rainfall assessment have been provided in Annexure A. A summary of these results has been provided in Table 5.

Table 5 Design rainfall depth for the nearest reliable rainfall station

Station Name & ID	Obs MAP	Years	Altitude (m)	Design Rainfall (mm)						
				2	5	10	20	50	100	200
Allerton Vet - 0239604 W	1072	48	882	58.6	82.1	100.4	120.4	150.3	176.0	205.0

The data from SAWS rainfall station 0239604 W (Allerton Vet) was used to estimate Intensity-Duration Frequency (IDF) curves for the site and are used as design inputs to calculate sizes of stormwater management infrastructure. Probability distributions were derived from 70 annual maximum daily rainfall depths. The annual maximum daily rainfall depths based on hydrological years (October to September) were analysed using Log-normal, Gumbel, General Extreme Value (GEV) and Log Pearson 3 statistical distributions.

5.5 Design Storm Determination

5.5.1 Storm Water Volumes

The storm water volumes were calculated for the contributing catchment of the Woodburn extension site as well as for the sub-catchments.

Table 6 Calculated peak runoff for the pre- and post-development state sub-catchments for a 1:50 year return period using the SCS-SA method

RP	State	Area (m^2)	Peak Runoff ($m^3.s^{-1}$)	Discharge Depth (mm)	Attenuation Required (m^3)
50 Year	Pre-development	18 573	0.29	436	383
	Post-development	18 573	0.72	679	

For the minor sub-catchments, it was calculated that 383 m^3 of attenuation is required. It is assumed that the access roads that will be utilized will have open drains which are recessed into the ground. Dimensions were assumed as a typical road drain (1 meters in width and recessed below the level of the culvert / kerb by approximately 0.3 meters). Cut-off drains would be placed strategically and increased in high slope areas. Drains were assessed to determine if they could handle certain design events, the following calculation was used (SANRAL Drainage Manual 5th Edition).

5.5.2 Storm Water Management Structures

- All storm water discharge during construction is considered to be dirty water.
- As the development will be connected to municipal infrastructure, water from gutters and roads are considered to be clean water once the construction phase is complete and revegetation has occurred.
- All roofs must have gutters and downpipes.
- Storage tanks (JoJos) are encouraged to further attenuate peak events and recycle water on site.
- Sizing of drainage channels for each sub-catchment area was based on the South African SCS type 2 method (SANRAL, 2013).
- Cut-off drains as per the design recommendations must be installed to facilitate the control of surface water runoff velocities from roads.
- The lower lying areas on the property should be used to place the primary attenuation structure. The following is recommended:
  - 400 mm Ø pipe be used;
  - This would allow for 0.3 $m^3.s^{-1}$ to be discharged.
- All of the proposed structures have been designed separately by RFJ & Associate engineers (see Figure 11).
- Clean stormwater will be strategically attenuated and discharged into the Foxhillspruit.

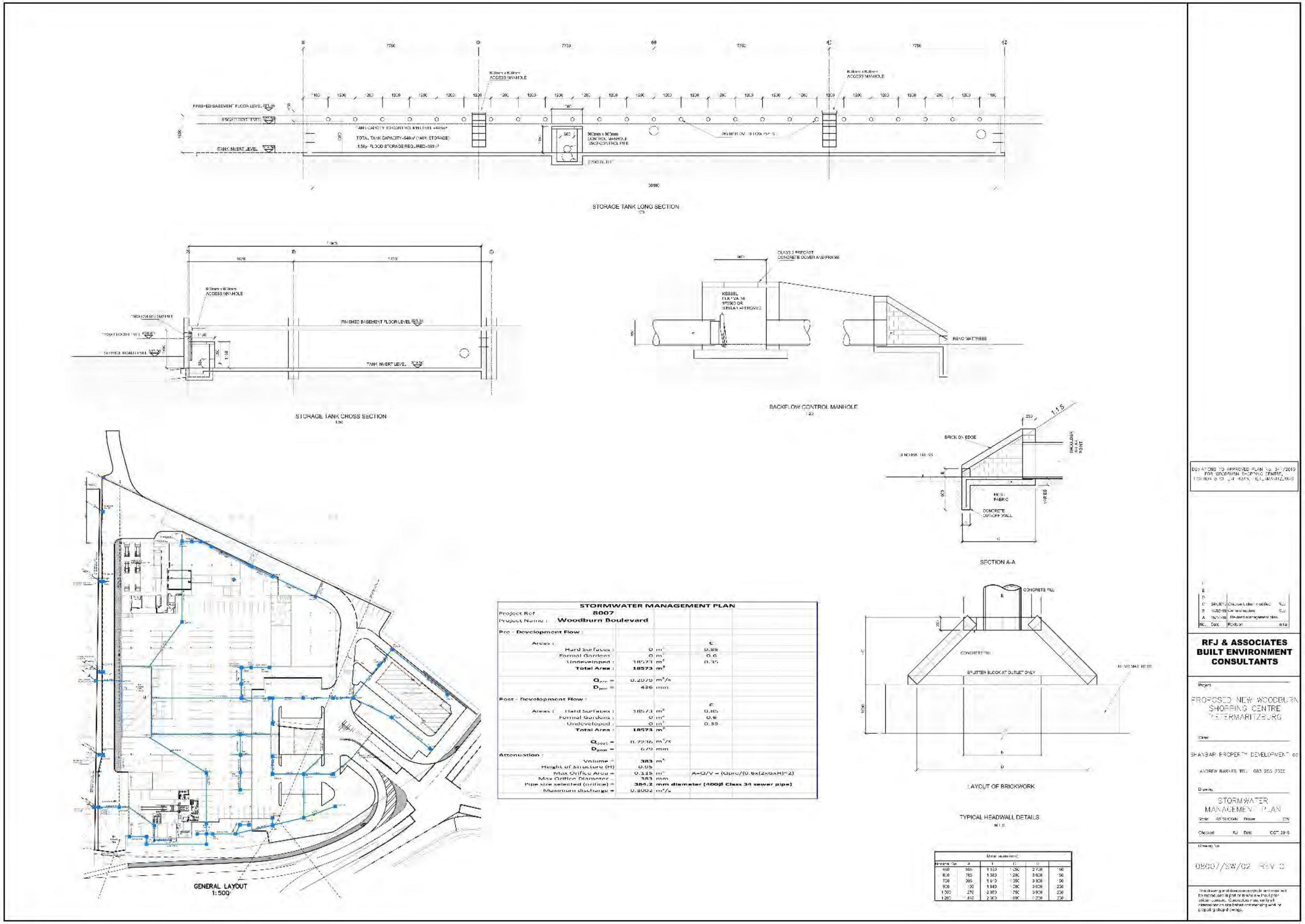


Figure 11 Storm water control infrastructure for the proposed Woodburn Mall expansion (RFJ & Associates)

5.6 Design Rainfall

Design rainfall differs from mean annual rainfall as it is rainfall associated with an events rainfall depth for a specified storm duration and a recurrence interval (frequency of occurrence). The design rainfall used is dependent on the method used to determine the peak discharge. The SCS-SA method use 1 day-rainfall for various return periods while the Rational and SDF Methods use rainfall intensity linked to the catchments Time of Concentration (Tc) and Storm Duration. The Design Rainfall Estimation (DRE) tool which uses observed rainfall data has been included for comparison.

The results of the design rainfall analysis are summarised below:

Table 7 Comparison between the various one-day design rainfall estimation techniques available for the study site

Return Period	Design Rainfall Depth (mm)			
	SDF	DRE	SCS-SA (using DRE)	Rational
10 Year Return Period	61.3	78.8	84	93.0
50 Year Return Period	94.82	123.2	123	160.0
100 Year Return Period	109.35	161.1	143	199.0

5.7 Design Peak Discharge

The design runoff results obtained for the 1:20, 1:50 and 1:100 year flood events for the various river reaches are summarized in Table 7. The populated calculation sheets for the Rational, SDF and SCS methods can be seen in Annexure B, C & D. The high contrast in values is due to the catchment size limitations of the design approaches. It is expected by the authors that the estimates from the SCS-SA and SDF are unrealistic. This is likely due to build up nature of the catchment areas and rainfall value that may not be representative of the entire catchment (the area is known for localised storm events). Furthermore, the lack of vegetation and the presence of roads has resulted in a much shorter time of concentration than what would have occurred in past decades. The design values indicate that the larger design events were vastly different between models whereas the smaller more frequent events were similar between models. This is likely due to the recommended catchment areas that these models are designed for. Given the results, the rational model was considered to be the most appropriate model if design rainfall were to be used, based on the small catchment area.

Table 8 Adopted design peak discharge values ($m^3.s$-1) run through HEC-RAS for the catchment area

Peak Discharge ($m^3.s^{-1}$)	Return Period						
	2	5	10	20	50	100	200
Rational	35.037	57.302	77.707	104.177	154.655	211.625	N/A
SCS-SA	13.6	24.8	34.0	45.5	63.0	79.0	N/A

5.8 Hydraulic Modelling

Various hydraulic models were produced in HEC-RAS and exported to HEC-geoRAS by importing river centreline, cross sections, water surfaces and flow data from GIS layers and the hydrologic model. This allowed for inundation mapping and flood line polygons to be generated. The water surface TIN was converted to a GRID, and then the actual elevation model was subtracted from the water surface grid. The area with positive results (meaning the water surface is higher than the terrain) illustrated the flood area, whereas the area with negative results illustrated the dry areas not inundated by the flood. Inundation can be seen at various locations such as around bends.

The 1:2, 1:5, 1:10, 1:20, 1:50, 1:100 and 1:200 year combined flood hydrograph showed a moderate time of concentration and a high combined peak. The 1:100 year flood extent (Figure 12) for the current state indicated that the low lying banks and some floodplain areas surrounding the site are within the flood extent. However, most of the erven area is not within the flood extent. The proposed development should take cognisance of likely flood areas. An additional risk assessment was undertaken. This shows that the flood extents that fall within the site boundary has a low velocity risk indicating minimal potential damage. As such, if a flood event were to occur, the site would be at low/minimal risk of damage but may be inundated with slow flowing water. This is largely due to the straight channel of the Foxhill Spruit and the artificial berm/retaining wall.

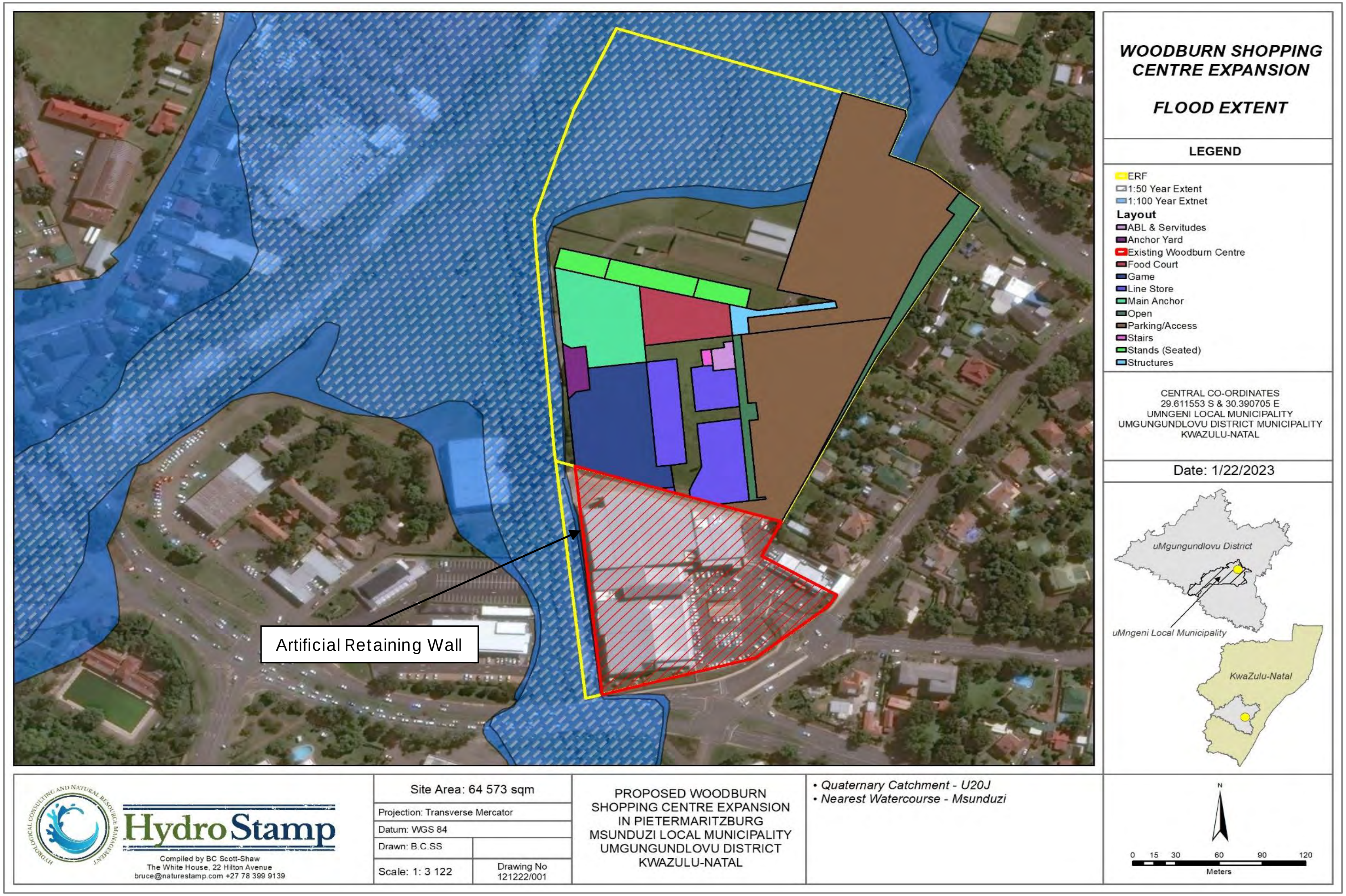
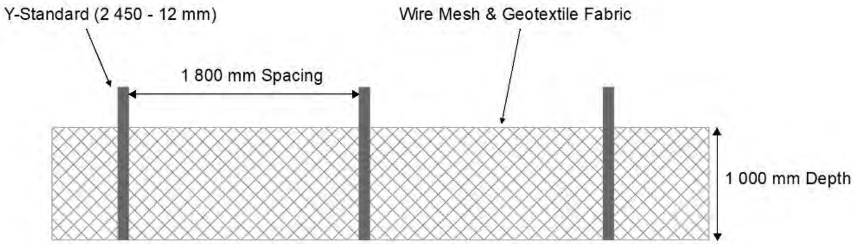
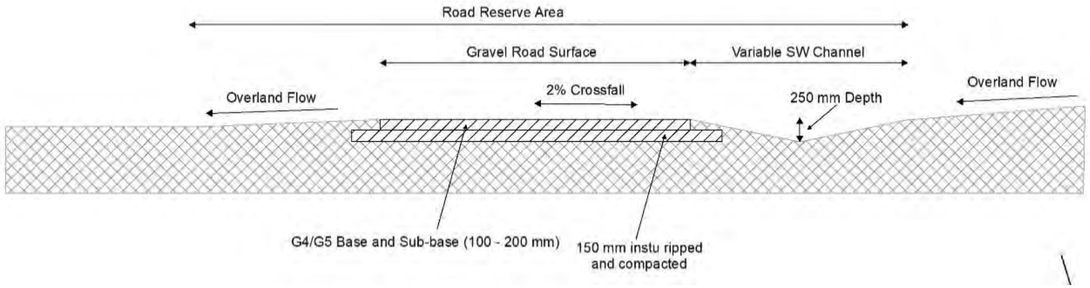


Figure 12 1:100 year flood extent for the Woodburn Shopping Centre Expansion site

Table 9 Intervention measures per activity at the proposed Woodburn Mall Extension

Unit	Activity/Risk	Severity	Intervention
Preliminary Stage			
Access Roads	Route planning	Low	• Ensure watercourse areas are not disturbed/traversed; • Ensure steep slopes are avoided where possible; • Ensure existing roads are used where possible.
Platform Areas	Site planning	Low	• Ensure sites are flat; • Ensure sites are away from watercourses; • Ensure the bed rock is stable to avoid collapse..
Dump/Spoil Site	Site planning	Low	• Ensure watercourse disturbance is kept to a minimum; • Ensure steep slopes are avoided where possible.
Construction Phase			
Access Roads	Formalization of roads. Risk of erosion and sedimentation	Low	• Temporary silt traps in any development areas where the slope exceeds 12°, installed along contour. • Silt traps should also be placed around the topsoil stockpiles to maintain the spoil for rehabilitation.  • Storm water runoff be directed to the lower side of the roads. At this point it should then be collected in side drains and disposed of in designated places by means of suitable outlet structures (cut-off drains and rockeries) and berms. • No dirty water must be directed into watercourses.  • Roads should be constructed at-grade to allow for continued flow (see example above); • Only include side drains where inundation or damage may occur otherwise the natural flow path would be interrupted; • Stormwater (clean) will be attenuated) and discharged at strategic points into the Foxhillspruit canal.

Infrastructure Areas/Platforms	Contamination from construction activities. Risk of erosion and sedimentation	Moderate	• No dirty water must be directed into watercourses (i.e. water containing sediments from the cleared area). • Dirty water must be directed into silt traps. • Temporary silt traps and berms should be constructed around the footprint in areas exceeding 12° (see above). • Regular maintenance of vehicles must be undertaken. • Any oil spills must be immediately cleaned up.
Spoil Sites	Potential oil spills from vehicles and equipment. Risk of erosion and sedimentation	Moderate	• Drains and berms at concentration points to manage and divert surface flow/ runoff from spoil sites during construction. • No dirty water must be directed into watercourses. • Flows must be attenuated and subsequently directed towards natural flow paths. • Effluent from construction staff must be treated on-site otherwise it should be removed from the site.
Operation Phase			
Access Roads	Operation of vehicles along roads. Potential erosion channels.	Low	• Undertake a periodic site inspection to verify and inspect the effectiveness and integrity of the storm water run-off control systems. • Immediate rehabilitation should erosion occur. • Temporary silt traps to continue for 1 year after closure in any areas where the slope exceeds 12° should vegetation not be fully established.
Infrastructure Areas/Platforms	Increased stormflow from surface Risk of erosion and sedimentation	Low	• Undertake a periodic site inspection to verify and inspect the effectiveness and integrity of the storm water run-off control systems. • Immediate rehabilitation should erosion occur.
Spoil Sites/Remnant platforms	Continued disturbance of soil and vegetation from footprint.	Low	• Undertake a periodic site inspection to verify and inspect the effectiveness and integrity of the storm water run-off control systems. • Immediate rehabilitation should erosion occur.

5.9 Potential Spill Scenarios

Due to the nature of the activities, there is a chance of potential spills occurring on site (equipment etc.). This is most likely during construction (building, cement mixing, machinery etc.). The potential spill scenarios are outlined as follows:

1. Spills and leaks from vehicles. Regular removal of spills and leaks should be undertaken on-site. Eco-friendly detergents should be used.

2. The potential for contamination from spoil sites, rubble and concrete.

3. A storm or flood event occurs during implementation, resulting in structures being exceeded. All activities should stop and a spill management plan be executed. Furthermore, erosion control actions should be initiated.

5.10 Mitigation Measures and Recommendations (Spill Management Plan)

The proposed Woodburn Shopping Centre Expansion development should employ best practise stormwater management practises, as outlined below –

- Implementation should take place during the dry season wherever possible. Activities should stop during heavy rains.
- Vegetation clearing should be limited as much as possible and plants rescued for rehabilitation.
- Directing clean stormwater towards natural drainage lines, contours and dispersing over grassed, flat areas (preferably the existing watercourses).
- Vehicles and equipment must be kept outside of watercourse buffers.
- Vehicles and equipment must be kept clean and serviced off site.
- Staff/workers on-site must be educated on identifying potential erosion areas and best practice guidelines.
- Energy dissipating measures with regards to stormwater management would be installed where necessary to prevent soil erosion.
- The engineer or contactor must ensure that only clean stormwater runoff enters the environment.
- Drainage should be controlled to ensure that runoff from the project area does not culminate in off-site pollution, flooding or result in any damage to properties downstream, of any stormwater discharge points.
- Infrastructure must have the following:
  - Completely lined storage infrastructure (concrete bunded area), with the capacity to contain 110% of the total amount of petrochemicals stored within a specific tank;
  - Spills must be completely removed from the site;
  - Valves / taps to contain or release any spillage collected from storage tanks; and
  - Fire extinguisher equipment installed within each facility.

Furthermore, as guided by the DWS, the following soil erosion measures should be put into place –

- Erosion control measures should be put in place to minimize erosion along the construction/implementation areas. Extra precautions must be taken in areas where the soils are deemed to be highly erodible.
- Soil erosion onsite should be prevented at all times, i.e. post- construction activities.
- Erosion measures should be implemented in areas prone to erosion such as near water supply points, edges of slopes etc. These measures could include the use of sand bags, hessian sheets, retention or replacement of vegetation if applicable and in accordance with the EMPR and the biodiversity impact assessment.
- Where the land has been disturbed during implementation, it must be rehabilitated and re-vegetated back to its original state after completion.
- Stockpiling of soil or any other material used during the construction phase must not be allowed on or near slopes, near a watercourse or water body. This is to prevent pollution of the impediment of surface runoff (further details are provided in the EMPr).

In order to reduce the potential impact of spills on site the following must be adhered to:

- Emergency numbers are provided on site – e.g. Spilltech, fire department, ambulance, etc.;
- Spill cleaning kits such as a Drizit kit are available on site;
- All chemicals on site are recorded in the inventory of hazardous substances;
- Equipment, machinery and vehicles are regularly checked and maintained in good order;
- Machinery and equipment maintenance is undertaken in designated areas;
- Drip trays are to be placed underneath machinery and equipment during maintenance;

In the instance of a spill on site the following procedure must be followed:

1. Locate the source of the spill;
2. Stop the spill and prevent further spreading;
3. The appropriate oil sponge, absorbent or spill kit (e.g. DriZit) can then be used to clean and remove the spilled substance(s);
4. Spills from trucks/tractors must be contained within a concreted site area and prevented from spreading;
5. Spilled petrochemicals can then be cleaned up and removed using the appropriate oil sponge, absorbent or spill kit (e.g. DriZit);
6. The spill must be reported to the site manager / supervisor and ECO;
7. Depending on the significance of the spill, the incident may also need to be reported to the DEDTEA and DWS.

5.11 Erosion Control Plan

There is an overlap between the storm water management and erosion control. The erosion control is particularly relevant during construction and at certain locations during operation. The removal of vegetation also leaves the site at a higher risk.

- Immediately rehabilitate eroded areas:
  - Install protective structures, e.g. geotextiles;
  - Plant indigenous grasses on any open areas;
  - Ensure the slope remains gentle and stable;
  - Use vegetation plugs, rock packs or gabions where erosion is visible;
  - Immediately revegetate the area.
- Ensure that steeper areas are avoided and that the vegetation remains at these sites.
- Continual erosion monitoring should occur by a trained staff member.

The site should take into account the following erosion control mechanisms:

- Geotextiles;
- Gabion baskets;
- Soil binding chemicals;
- Hydroseeding techniques;
- Vegetation plugs;
- mulch

To ensure rehabilitation is effective, it is vital that the working area is managed correctly during the implementation phase. An important part of this management will be that careful preservation and management of soil stockpiles should be implemented from the start of the site. The following points have been provided for use with the rehabilitation actions:

- Top- and subsoil stockpiles (used for road levelling and bank lifting) must not be stockpiled within 100m or within the 1:100 year floodplain of a watercourse.
- Naturally occurring vegetation removed by site clearance operations may be grubbed in with the topsoil for stockpiling.
- The topsoil shall not be buried or rendered in any other way inappropriate for rehabilitation use.
- Topsoil stripping (in widening and new development areas) shall not occur in wet weather and during stripping and stockpiling, the topsoil shall not be subject to a compaction force greater than 1 500kg/m² and shall not be pushed for more than 50m.

- Topsoil shall also only be handled twice, once to strip and stockpile, and secondly to replace, level, shape and scarify if necessary.
- Top soil stockpiles must be protected against erosion and a record kept of all top soil quantities and should there be shortfalls of topsoil required for rehabilitation, adequate replacement material from commercial sources should be obtained as approved by the Engineer (preferably from areas identified with sourced excess topsoil).
- Equally, excess topsoil shall be landscaped and stabilized in accordance to the requirements of the Engineer and in consultation with the Contractor's Land Rehabilitation Specialist.
- Topsoil stockpiles should not be stockpiled for longer than 6 months. If this can't be avoided, the stockpiles will need to be enriched or upgraded prior to rehabilitation. The Contractor shall consult with the Engineer with regards to matching preconstruction conditions or existing adjacent conditions.
- All stockpiles left for extended periods of time shall be stabilized using approved vegetation cover or other erosion control measures.
- Any excess subsoil must be removed from the road fringe once back filling is completed, and spoiled at an agreed spoil site (spoil sites to be agreed between landowner, ECO and Engineer).

6. CONCLUSION

The results provided indicate that most of the two erven areas are outside of the 1:100 year flood extent. However, some of the lower lying areas (rugby fields and some parking areas) are within the flood extent. The flood risk in this area is low primarily due to flood attenuation by the landscape and the flow direction at this point. Additional measures should be taken to ensure that flows are managed within this area. Vegetated areas are encouraged to promote infiltration. The existing shopping centre has operated well at attenuating peak events.

The net discharge of water on the system would be similar to that of the pre-development state if Stormwater is accommodated on-site. The risk on downstream users would be low assuming that the development adopts best practice measures and discussed in Section 5.8.

The findings and recommendations are:

1. The nearby watercourses are in a modified condition due to significant historical modification. The surrounding areas should be vegetated to increase the roughness and improve the aesthetics at the site. This would assist in attenuating the flood within this ERF.
2. Some parking areas are within the flood extent but are of low risk.
3. A catchment delineation was undertaken. However, there is no catchment area outside of the expansion footprint as flow is already directed into drains.
4. Strict adherence to best practice guidelines, spill management and erosion control must be throughout operation of the development.
5. Regular maintenance of culverts/drains/gutters must be undertaken to ensure that the flood risk is not increased due to blockages by debris.
6. Stormwater (clean) will be attenuated) and discharged at strategic points into the Foxhillspruit canal to the pre-development state (natural).
7. Dirty water is isolated on the site (sumps & separators) and connected to municipal infrastructure and subsequently discharged.
8. The risk of the proposed development is low assuming adherence to mitigation measures. However, the risk should still be managed through appropriate storm water management and general maintenance.

7. REFERENCES

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ANNEXURE A Design Rainfall Values

Design Rainfall in South Africa: Ver 3 (July 2012)

User selection has the following criteria:

Coordinates: Latitude: 29 degrees 43 minutes; Longitude: 30 degreess 24 minutes

Durations requested: 5 m, 10 m, 15 m, 30 m, 45 m, 1 h, 1.5 h, 2 h, 4 h, 6 h, 8 h, 10 h, 12 h, 16 h, 20 h, 24 h, 1 d, 2 d, 3 d, 4 d, 5 d, 6 d, 7 d

Return Periods requested: 2 yr, 5 yr, 10 yr, 20 yr, 50 yr, 100 yr, 200 yr

Block Size requested: 0 minutes

Data extracted from Daily Rainfall Estimate Database File

The six closest stations are listed

Station Name	SAWS Number	Distance (km)	Record (Years)	Latitude (°)	Latitude (')	Longitude (°)	Longitude (')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U	200	200L	200U
UKULINGA AGR RES STA	0239700_A	5.4	33	29	40	30	24	714	866	1 d	54.1	53.3	54.6	78.8	77.8	79.3	99.4	97.5	101.2	123.2	118.8	127.6	161.1	152.7	172.3	195.8	183.8	215.2	236.9	219.4	267.8
										2 d	69.8	68.6	71.1	101.4	100.1	102.2	127.9	124.7	130.9	158.7	151.9	166.2	207.9	192.5	226.0	253.3	228.2	285.4	307.3	267.2	360.1
										3 d	80.2	78.5	81.8	116.7	115.0	117.9	147.4	143.2	150.8	182.8	174.0	192.3	239.3	218.6	264.5	291.4	259.0	333.0	353.3	302.0	419.3
										4 d	86.7	85.0	88.5	125.1	123.2	126.3	156.9	152.5	161.2	193.4	184.3	203.6	251.4	230.1	276.3	304.3	270.5	345.9	366.8	313.5	434.1
										5 d	91.8	90.0	93.6	130.8	129.0	132.2	162.8	158.2	166.6	198.8	189.3	208.7	254.8	234.4	278.6	305.2	272.5	344.8	363.7	313.5	424.2
										6 d	95.7	94.1	97.3	135.2	133.3	136.5	166.9	162.6	170.9	202.6	193.9	212.2	257.7	237.4	280.1	306.6	274.9	344.4	363.2	314.4	420.6
										7 d	100.2	98.6	101.9	140.2	138.4	141.5	172.2	168.0	176.2	207.9	198.9	217.2	262.8	243.3	284.1	311.2	280.4	347.8	367.1	320.5	422.7
THORNVILLE	0239676_S	5.7	28	29	46	30	23	845	853	1 d	49.0	48.2	49.4	71.3	70.5	71.8	90.0	88.3	91.7	111.6	107.6	115.6	145.9	138.3	156.0	177.3	166.5	194.9	214.6	198.7	242.5
										2 d	61.3	60.2	62.4	89.0	87.8	89.7	112.3	109.4	114.9	139.2	133.2	145.8	182.4	168.9	198.3	222.2	200.2	250.4	269.6	234.5	316.0
										3 d	71.9	70.4	73.3	104.6	103.1	105.6	132.1	128.3	135.2	163.9	156.0	172.4	214.5	195.9	237.1	261.2	232.1	298.5	316.7	270.7	375.9
										4 d	76.3	74.8	77.9	110.1	108.5	111.1	138.1	134.2	141.9	170.3	162.2	179.3	221.3	202.6	243.2	267.9	238.1	304.5	322.9	276.0	382.1
										5 d	80.8	79.2	82.4	115.2	113.6	116.4	143.3	139.3	146.7	175.0	166.7	183.8	224.4	206.4	245.3	268.8	239.9	303.6	320.3	276.1	373.5
										6 d	86.3	84.9	87.8	121.9	120.3	123.1	150.6	146.7	154.1	182.8	174.9	191.4	232.4	214.2	252.6	276.6	248.0	310.7	327.6	283.6	379.4
										7 d	91.6	90.1	93.1	128.1	126.5	129.4	157.4	153.6	161.0	190.0	181.8	198.5	240.2	222.4	259.6	284.5	256.3	317.9	335.5	293.0	386.3
BAYNESFIELD ESTATES,	0239585_A	8.0	65	29	45	30	20	829	838	1 d	51.8	51.0	52.3	75.4	74.5	75.9	95.2	93.4	97.0	118.0	113.8	122.2	154.3	146.2	165.0	187.5	176.1	206.1	226.9	210.2	256.5
										2 d	64.9	63.7	66.1	94.2	93.0	95.0	118.9	115.8	121.7	147.4	141.1	154.4	193.2	178.8	210.0	235.3	212.0	265.2	285.5	248.3	334.6
										3 d	73.3	71.8	74.8	106.7	105.2	107.8	134.8	130.9	137.9	167.2	159.1	175.9	218.9	199.9	241.9	266.5	236.8	304.5	323.1	276.1	383.5
										4 d	78.4	76.9	80.0	113.1	111.4	114.2	141.8	137.8	145.7	174.9	166.6	184.1	227.3	208.1	249.8	275.2	244.6	312.7	331.7	283.5	392.5
										5 d	83.9	82.2	85.5	119.6	117.9	120.8	148.7	144.6	152.3	181.6	173.0	190.8	232.9	214.2	254.6	279.0	249.0	315.1	332.4	286.5	387.7
										6 d	89.1	87.6	90.6	125.9	124.2	127.1	155.4	151.4	159.1	188.7	180.6	197.6	239.9	221.1	260.8	285.5	256.0	320.7	338.1	292.8	391.6
										7 d	94.6	93.1	96.2	132.3	130.6	133.6	162.6	158.6	166.3	196.3	187.8	205.0	248.1	229.7	268.2	293.9	264.8	328.4	346.6	302.6	399.1
BAYNESFIELD ESTATE	0239585_W	9.7	71	29	45	30	19	917	841	1 d	51.8	51.0	52.3	75.4	74.5	75.9	95.2	93.4	96.9	118.0	113.7	122.2	154.2	146.2	164.9	187.4	176.0	206.0	226.8	210.1	256.3
										2 d	64.1	63.0	65.3	93.1	91.9	93.8	117.4	114.4	120.2	145.7	139.4	152.5	190.9	176.7	207.4	232.5	209.5	262.0	282.1	245.3	330.6
										3 d	72.5	71.0	73.9	105.5	104.0	106.5	133.2	129.4	136.3	165.2	157.3	173.8	216.3	197.6	239.1	263.4	234.1	301.0	319.3	272.9	379.0
										4 d	77.6	76.1	79.3	112.0	110.4	113.0	140.5	136.5	144.3	173.2	165.0	182.3	225.1	206.1	247.4	272.5	242.2	309.7	328.5	280.7	388.7
										5 d	82.9	81.3	84.5	118.1	116.5	119.4	147.0	142.9	150.5	179.5	171.0	188.5	230.1	211.6	251.6	275.6	246.1	311.4	328.5	283.1	383.1
										6 d	88.0	86.5	89.5	124.3	122.6	125.5	153.5	149.5	157.1	186.3	178.3	195.1	236.9	218.3	257.5	281.9	252.8	316.7	333.9	289.1	386.7
										7 d	93.5	92.0	95.1	130.8	129.1	132.1	160.7	156.8	164.4	194.0	185.7	202.7	245.2	227.1	265.1	290.5	261.7	324.6	342.6	299.1	394.4
COSMOORE, CATO RIDGE	0239855_A	9.7	33	29	45	30	29	769	777	1 d	60.2	59.3	60.7	87.6	86.6	88.2	110.6	108.5	112.7	137.1	132.2	142.0	179.3	169.9	191.7	217.9	204.6	239.5	263.6	244.2	298.0
										2 d	76.3	74.9	77.7	110.8	109.3	111.7	139.7	136.2	143.0	173.3	165.9	181.5	227.1	210.2	246.9	276.6	249.3	311.8	335.7	291.9	393.4
										3 d	84.4	82.6	86.0	122.8	121.0	124.0	155.0	150.6	158.7	192.3	183.1	202.3	251.8	230.0	278.2	306.6	272.4	350.3	371.6	317.7	441.2
										4 d	89.6	87.8	91.4	129.2	127.3	130.4	162.0	157.5	166.5	199.7	190.3	210.3	259.7	237.7	285.4	314.3	279.4	357.2	378.9	323.8	448.3

										5 d	94.0	92.1	95.8	133.9	132.1	135.3	166.6	162.0	170.6	203.5	193.8	213.7	260.9	239.9	285.2	312.5	279.0	353.0	372.4	321.0	434.3
										6 d	98.5	96.8	100.2	139.1	137.2	140.4	171.8	167.3	175.8	208.5	199.5	218.3	265.1	244.3	288.1	315.4	282.9	354.4	373.6	323.5	432.7
										7 d	102.8	101.1	104.5	143.8	141.9	145.2	176.6	172.3	180.7	213.2	204.0	222.7	269.5	249.6	291.4	319.2	287.7	356.8	376.5	328.8	433.5
UMLAAS ROAD	0240014_W	12.7	46	29	44	30	31	753	790	1 d	49.4	48.7	49.9	72.0	71.1	72.4	90.9	89.1	92.5	112.6	108.6	116.6	147.3	139.5	157.4	179.0	168.0	196.7	216.5	200.5	244.7
										2 d	63.7	62.5	64.8	92.4	91.3	93.2	116.6	113.7	119.4	144.7	138.4	151.5	189.6	175.5	206.0	230.9	208.0	260.2	280.2	243.7	328.3
										3 d	71.7	70.2	73.1	104.3	102.8	105.3	131.7	128.0	134.8	163.4	155.6	171.9	213.9	195.4	236.4	260.5	231.5	297.7	315.8	269.9	374.8
										4 d	76.6	75.1	78.2	110.5	108.9	111.5	138.6	134.7	142.4	170.9	162.8	179.9	222.1	203.3	244.1	268.8	239.0	305.5	324.1	277.0	383.5
										5 d	83.6	82.0	85.3	119.2	117.6	120.5	148.3	144.2	151.9	181.2	172.5	190.3	232.3	213.6	253.9	278.2	248.3	314.3	331.5	285.8	386.6
										6 d	88.5	87.0	90.0	125.0	123.3	126.2	154.3	150.3	157.9	187.3	179.2	196.1	238.2	219.5	258.9	283.4	254.1	318.4	335.7	290.6	388.8
										7 d	93.0	91.5	94.6	130.1	128.4	131.3	159.8	155.9	163.5	192.9	184.6	201.5	243.9	225.8	263.6	288.8	260.2	322.8	340.6	297.4	392.2

Gridded values of all points within the specified block

Latitude		Longitude		MAP	Altitude	Duration	Return Period (years)																				
(°)	(')	(°)	(')	(mm)	(m)	(m/h/d)	2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U	200	200L	200U
29	43	30	24	785	882	5 m	11.1	7.0	15.1	16.1	10.3	22.0	20.4	12.9	28.1	25.2	15.7	35.4	33.0	20.2	47.8	40.1	24.3	59.7	48.5	29.0	74.3
						10 m	14.9	10.3	19.6	21.8	15.0	28.4	27.5	18.8	36.3	34.0	23.0	45.8	44.5	29.5	61.8	54.1	35.5	77.2	65.5	42.4	96.1
						15 m	17.8	12.9	22.8	25.9	18.8	33.1	32.7	23.5	42.2	40.6	28.7	53.3	53.1	36.9	71.9	64.5	44.4	89.8	78.0	53.0	111.7
						30 m	22.4	16.6	28.3	32.7	24.3	41.0	41.3	30.4	52.4	51.1	37.1	66.1	66.9	47.6	89.2	81.3	57.4	111.4	98.3	68.5	138.6
						45 m	25.7	19.3	32.1	37.4	28.2	46.6	47.2	35.4	59.5	58.6	43.1	75.0	76.6	55.4	101.2	93.1	66.7	126.4	112.6	79.6	157.3
						1 h	28.3	21.5	35.1	41.2	31.4	50.9	52.0	39.3	65.0	64.5	47.9	82.0	84.3	61.6	110.7	102.4	74.2	138.2	123.9	88.5	172.0
						1.5 h	32.4	25.0	39.8	47.2	36.5	57.8	59.5	45.7	73.8	73.8	55.7	93.0	96.5	71.6	125.5	117.3	86.2	156.8	141.9	102.9	195.2
						2 h	35.7	27.8	43.5	51.9	40.6	63.2	65.5	50.9	80.7	81.2	62.0	101.7	106.2	79.6	137.3	129.1	95.9	171.5	156.2	114.4	213.4
						4 h	41.4	32.9	49.8	60.3	48.1	72.3	76.1	60.3	92.4	94.3	73.4	116.5	123.3	94.3	157.2	149.9	113.6	196.4	181.4	135.6	244.4
						6 h	45.2	36.3	53.9	65.8	53.1	78.3	83.1	66.5	100.0	102.9	81.0	126.1	134.6	104.2	170.2	163.6	125.4	212.6	197.9	149.7	264.5
						8 h	48.1	39.0	57.0	70.0	57.0	82.8	88.4	71.4	105.8	109.5	87.0	133.4	143.2	111.7	180.0	174.0	134.6	224.9	210.6	160.6	279.8
						10 h	50.4	41.2	59.6	73.5	60.1	86.5	92.7	75.4	110.5	114.9	91.8	139.3	150.3	118.0	188.0	182.6	142.1	234.9	221.0	169.6	292.3
						12 h	52.5	43.0	61.7	76.4	62.9	89.7	96.4	78.8	114.5	119.5	96.0	144.4	156.3	123.4	194.9	189.9	148.6	243.4	229.8	177.3	302.9
						16 h	55.8	46.2	65.3	81.3	67.5	94.9	102.6	84.6	121.1	127.2	103.0	152.7	166.3	132.4	206.1	202.1	159.4	257.5	244.5	190.2	320.4
						20 h	58.6	48.8	68.2	85.3	71.3	99.1	107.7	89.3	126.5	133.4	108.8	159.5	174.5	139.8	215.3	212.0	168.3	269.0	256.6	200.9	334.7
						24 h	60.9	51.0	70.7	88.7	74.5	102.7	112.0	93.4	131.1	138.8	113.7	165.3	181.5	146.2	223.1	220.5	176.0	278.7	266.8	210.1	346.8
						1 d	51.7	43.3	60.0	75.3	63.2	87.1	95.0	79.2	111.2	117.7	96.5	140.2	153.9	124.0	189.3	187.1	149.3	236.4	226.4	178.2	294.2
						2 d	65.6	58.6	72.2	95.5	85.6	104.9	120.6	107.3	134.0	149.4	130.7	168.9	195.4	167.9	227.9	237.5	202.2	284.8	287.3	241.3	354.3
						3 d	75.4	70.0	80.5	109.8	102.2	116.9	138.6	128.1	149.4	171.8	156.1	188.3	224.7	200.5	254.1	273.0	241.5	317.5	330.4	288.2	395.0
						4 d	81.6	74.5	88.3	118.8	108.8	128.2	149.9	136.4	163.8	185.8	166.1	206.4	243.0	213.5	278.6	295.3	257.1	348.1	357.3	306.8	433.1
						5 d	86.7	78.2	94.8	126.3	114.2	137.7	159.4	143.2	175.9	197.5	174.4	221.7	258.3	224.1	299.3	313.9	269.9	373.8	379.8	322.1	465.2
						6 d	91.1	81.4	100.5	132.7	118.9	146.0	167.5	149.0	186.4	207.6	181.5	235.0	271.5	233.2	317.2	329.9	280.8	396.3	399.2	335.2	493.1
						7 d	95.0	84.1	105.6	138.4	122.9	153.4	174.7	154.1	195.9	216.5	187.7	246.9	283.1	241.2	333.3	344.1	290.4	416.3	416.3	346.6	518.1

ANNEXURE B Rational Method

Description of Catchment	**Woodburn Shopping Centre Expansion**		
River detail	**Foxhill Spruit**		
Calculated by	**BCSS**	**Date**	**14/04/2022**

Physical characteristics

Size of catchment (A)	**10**	km²	Rainfall Region		
Longest Watercourse	**6**	km	**Area Distribution Factors**		
Average slope (S_{av})	**0.02**	m/m	Rural (α)	Urban (β)	Lakes(γ)
Dolomite Area ($D_{\%}$)	**0**	%	**0.5**	**0.5**	**0**
Mean Annual Rainfall (MAR)	**750**	mm			
Catchment Characteristics	**Flat/permeable**	%			
r - look up from Table 3C.3	**Medium grass cover**	0.4			

Rural (1)				**Urban** (2)			
Surface Slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C_2**
Vleis and Pans	**5**	0.05	0.003	**Lawns**			
Flat Areas	**25**	0.11	0.028	Sandy, flat (<2%)		0.075	-
Hilly	**60**	0.2	0.120	Sandy, steep (>7%)		0.175	-
Steep Areas	**10**	0.3	0.030	Heavy soil, flat (<2%)	**25**	0.15	0.038
Total	100	-	0.180	Heavy soil, steep (>7%)		0.3	-
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very Permeable	**10**	0.05	0.005	Houses	**55**	0.4	0.220
Permeable	**50**	0.1	0.050	Flats		0.6	-
Semi-permeable	**30**	0.2	0.060	**Industry**			
Impermeable	**10**	0.3	0.030	Light industry		0.65	-
Total	100	-	0.145	Heavy Industry		0.75	-
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush and plantation	**20**	0.05	0.010	City Centre		0.825	-
Light bush and farm-lands	**50**	0.15	0.075	Suburban		0.6	-
Grasslands	**25**	0.25	0.063	Streets	**20**	0.825	0.165
No Vegetation	**5**	0.3	0.015	Maximum flood		1.00	-
Total	100	-	0.163	Total	100	-	0.423

Time of concentration (T_c)	**Defined Watercourse**	Notes:	
Overland flow	Defined watercourse	*Pre-development Run-off*	
$$T_c = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$	$$T_c = \left(\frac{0{,}87L^2}{1000\,S_{av}}\right)^{0.385}$$		*Latitude:* *28°42'*
		Tc = *1.18848807*	*Longitude:* *32°02'*
2.3 Hours	1.2 Hours		

Run-off coefficient

Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 ($C_1 = C_s + C_p + C_v$)	0.488	0.488	0.488	0.488	0.488	0.488	0.4875
Adjusted for dolomitic areas, C_{1D} (= $C_1(1-D_{\%})+C_1D_{\%}(\Sigma(D_{factor} \times C_{s\%}))$)	0.4875	0.4875	0.4875	0.4875	0.4875	0.4875	0.4875
Adjustment factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1
Adjusted run-off coefficient, C_{1T}	0.24375	0.268125	0.2925	0.326625	0.404625	0.4875	0.4875

(= C_{1D} x F_t)							
Combined run-off coeffiecient C_T (= $\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0.3331 25	0.34531 25	0.3575	0.3745625	0.41356 25	0.455	0.455
Rainfall							
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point Rainfall (mm), P_T	**45.0**	**71.0**	**93.0**	**119.0**	**160.0**	**199.0**	
Point Intensity (mm/hour), P_{iT} (=P_T/T_C)	37.9	59.7	78.3	100.1	134.6	167.4	0.0
Area Reduction Factor (%), ARF_T	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Average Intensity (mm/hour), I_T (= P_{iT} x ARF_T)	37.9	59.7	78.3	100.1	134.6	167.4	0.0
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Peak flow (m³/s),	35.037	57.302	77.707	104.177	154.655	211.6 25	0.000

ANNEXURE C SDF Method

```
CATCHMENT NAME                     :  Foxhill
 PROJECT NO                        :  Woodburn Shopping Centre
 RUN NO                            :  1
 TOTAL CATCHMENT AREA (km^2)       :  10.00
 STORM INTENSITY DISTRIBUTION TYPE :  3
 CATCHMENT LAG TIME (h)            :  1.47
 COEFFICIENT OF INITIAL ABSTRACTION:  0.10

 CURVE NUMBERS:           Initial    Final
   Sub-catchment 1          80       80.0
   Sub-catchment 2          75       75.0
   Sub-catchment 3          68       68.0

 RETURN PERIOD (YEARS)                2      5     10     20     50    100    200

 DESIGN DAILY RAINFALL DEPTH (mm)    51     70     84    100    123    143    164

 DESIGN STORMFLOW DEPTH (mm)
   Sub-catchment 1                 18.4   31.9   42.7   55.8   75.5   93.3  112.4
   Sub-catchment 2                 14.2   25.9   35.6   47.6   65.9   82.6  100.7
   Sub-catchment 3                  9.6   19.0   27.1   37.3   53.5   68.5   85.1

 TOTAL RUNOFF DEPTH (mm)           15.6   27.7   37.7   50.0   68.6   85.6  104.0

 DESIGN STORMFLOW VOLUME
 (thousands m^3)
   Sub-catchment 1                 88.5  152.9  205.0  267.9  362.6  447.8  539.4
   Sub-catchment 2                 52.6   95.8  131.8  175.9  243.7  305.5  372.6
   Sub-catchment 3                 14.4   28.5   40.6   56.0   80.2  102.8  127.7

 TOTAL STORMFLOW VOLUME             0.2    0.3    0.4    0.5    0.7    0.9    1.0
 (millions m^3)

 COMPUTED CURVE NUMBER             76.7   76.6   76.6   76.5   76.5   76.4   76.4

 PEAK DISCHARGE (m^3/s)            13.6   24.8   34.0   45.5   63.0   79.0   96.3


 ******************************************************************
RETURN PERIOD (years)   =      2
DESIGN RAINFALL   (mm)  =     51
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.7
LAG TIME (h)            =    1.5
PEAK DISCHARGE (m^3/s)  =  13.63
 ******************************************************************
    TIME                       DISCHARGE
  (minutes)       (cubic metres/sec)      (litres/sec)

     680.              0.003                  3.
     696.              0.031                 31.
     712.              0.209                209.
     728.              1.740               1740.
     744.              3.805               3805.
     760.              6.110               6110.
     776.              8.553               8553.
     792.             11.052              11052.
     808.             13.392              13392.
     824.             13.631              13631.
     840.             13.060              13060.
     857.             12.160              12160.
     873.             11.070              11070.
     889.              9.855               9855.
     905.              8.548               8548.
     921.              7.170               7170.
     937.              5.737               5737.
     953.              4.270               4270.
     969.              2.853               2853.
     985.              2.213               2213.
    1001.              1.865               1865.
    1017.              1.630               1630.
    1033.              1.456               1456.
    1049.              1.320               1320.
    1065.              1.210               1210.
    1081.              1.118               1118.
    1097.              1.041               1041.
    1113.              0.975                975.
    1130.              0.917                917.
    1146.              0.866                866.
    1162.              0.821                821.
    1178.              0.781                781.
    1194.              0.745                745.
    1210.              0.712                712.
    1226.              0.683                683.
    1242.              0.655                655.
    1258.              0.631                631.
    1274.              0.608                608.
    1290.              0.586                586.
```

1306.	0.567	567.
1322.	0.548	548.
1338.	0.531	531.
1354.	0.515	515.
1370.	0.500	500.
1386.	0.486	486.
1403.	0.473	473.
1419.	0.460	460.
1435.	0.448	448.
1451.	0.432	432.
1467.	0.409	409.
1483.	0.378	378.
1499.	0.341	341.
1515.	0.297	297.
1531.	0.246	246.
1547.	0.197	197.
1563.	0.153	153.
1579.	0.116	116.
1595.	0.084	84.
1611.	0.057	57.
1627.	0.036	36.
1643.	0.019	19.
1659.	0.008	8.
1676.	0.002	2.

```
 ******************************************************************
RETURN PERIOD (years)   =      5
DESIGN RAINFALL   (mm)  =     70
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.6
LAG TIME (h)            =    1.5
PEAK DISCHARGE (m^3/s)  =  24.79
 ******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
632.	0.001	1.
648.	0.006	6.
664.	0.024	24.
680.	0.074	74.
696.	0.206	206.
712.	0.692	692.
728.	3.654	3654.
744.	7.511	7511.
760.	11.747	11747.
776.	16.171	16171.
792.	20.616	20616.
808.	24.634	24634.
824.	24.795	24795.
840.	23.580	23580.
857.	21.815	21815.
873.	19.737	19737.
889.	17.451	17451.
905.	15.016	15016.
921.	12.472	12472.
937.	9.853	9853.
953.	7.205	7205.
969.	4.703	4703.
985.	3.628	3628.
1001.	3.050	3050.
1017.	2.662	2662.
1033.	2.375	2375.
1049.	2.151	2151.
1065.	1.970	1970.
1081.	1.820	1820.
1097.	1.693	1693.
1113.	1.584	1584.
1130.	1.490	1490.
1146.	1.407	1407.
1162.	1.333	1333.
1178.	1.267	1267.
1194.	1.208	1208.
1210.	1.155	1155.
1226.	1.106	1106.
1242.	1.062	1062.
1258.	1.021	1021.
1274.	0.983	983.
1290.	0.949	949.
1306.	0.916	916.
1322.	0.887	887.
1338.	0.859	859.
1354.	0.833	833.
1370.	0.808	808.
1386.	0.785	785.
1403.	0.764	764.
1419.	0.743	743.
1435.	0.724	724.
1451.	0.697	697.
1467.	0.659	659.
1483.	0.610	610.

1499.	0.550	550.
1515.	0.478	478.
1531.	0.396	396.
1547.	0.317	317.
1563.	0.247	247.
1579.	0.187	187.
1595.	0.135	135.
1611.	0.092	92.
1627.	0.057	57.
1643.	0.031	31.
1659.	0.013	13.
1676.	0.003	3.

****
RETURN PERIOD (years)   =   10
DESIGN RAINFALL   (mm) =   84
STORM DISTRIBUTION TYPE =   3
CURVE NUMBER (computed) =   76.6
LAG TIME (h)   =   1.5
PEAK DISCHARGE (m^3/s) = 34.03
****

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
600.	0.001	1.
616.	0.005	5.
632.	0.017	17.
648.	0.045	45.
664.	0.102	102.
680.	0.217	217.
696.	0.471	471.
712.	1.254	1254.
728.	5.429	5429.
744.	10.772	10772.
760.	16.595	16595.
776.	22.635	22635.
792.	28.653	28653.
808.	33.995	33995.
824.	34.029	34029.
840.	32.241	32241.
857.	29.730	29730.
873.	26.811	26811.
889.	23.624	23624.
905.	20.249	20249.
921.	16.738	16738.
937.	13.140	13140.
953.	9.524	9524.
969.	6.142	6142.
985.	4.725	4725.
1001.	3.968	3968.
1017.	3.460	3460.
1033.	3.085	3085.
1049.	2.793	2793.
1065.	2.557	2557.
1081.	2.361	2361.
1097.	2.196	2196.
1113.	2.054	2054.
1130.	1.931	1931.
1146.	1.823	1823.
1162.	1.727	1727.
1178.	1.642	1642.
1194.	1.565	1565.
1210.	1.495	1495.
1226.	1.432	1432.
1242.	1.374	1374.
1258.	1.321	1321.
1274.	1.272	1272.
1290.	1.227	1227.
1306.	1.186	1186.
1322.	1.147	1147.
1338.	1.110	1110.
1354.	1.077	1077.
1370.	1.045	1045.
1386.	1.015	1015.
1403.	0.987	987.
1419.	0.961	961.
1435.	0.936	936.
1451.	0.901	901.
1467.	0.852	852.
1483.	0.788	788.
1499.	0.710	710.
1515.	0.618	618.
1531.	0.512	512.
1547.	0.410	410.
1563.	0.320	320.
1579.	0.241	241.
1595.	0.174	174.
1611.	0.119	119.
1627.	0.074	74.
1643.	0.040	40.

1659.	0.017	17.
1676.	0.003	3.

****
RETURN PERIOD (years) = 20
DESIGN RAINFALL (mm) = 100
STORM DISTRIBUTION TYPE = 3
CURVE NUMBER (computed) = 76.5
LAG TIME (h) = 1.5
PEAK DISCHARGE (m^3/s) = 45.48
****

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
551.	0.000	0.
567.	0.001	1.
583.	0.006	6.
600.	0.018	18.
616.	0.042	42.
632.	0.084	84.
648.	0.157	157.
664.	0.279	279.
680.	0.492	492.
696.	0.910	910.
712.	2.077	2077.
728.	7.751	7751.
744.	14.913	14913.
760.	22.667	22667.
776.	30.664	30664.
792.	38.572	38572.
808.	45.480	45480.
824.	45.308	45308.
840.	42.788	42788.
857.	39.344	39344.
873.	35.383	35383.
889.	31.085	31085.
905.	26.554	26554.
921.	21.859	21859.
937.	17.065	17065.
953.	12.272	12272.
969.	7.829	7829.
985.	6.010	6010.
1001.	5.042	5042.
1017.	4.393	4393.
1033.	3.915	3915.
1049.	3.543	3543.
1065.	3.242	3242.
1081.	2.993	2993.
1097.	2.783	2783.
1113.	2.603	2603.
1130.	2.446	2446.
1146.	2.309	2309.
1162.	2.187	2187.
1178.	2.078	2078.
1194.	1.980	1980.
1210.	1.892	1892.
1226.	1.812	1812.
1242.	1.738	1738.
1258.	1.671	1671.
1274.	1.609	1609.
1290.	1.552	1552.
1306.	1.499	1499.
1322.	1.450	1450.
1338.	1.404	1404.
1354.	1.361	1361.
1370.	1.321	1321.
1386.	1.283	1283.
1403.	1.247	1247.
1419.	1.214	1214.
1435.	1.182	1182.
1451.	1.138	1138.
1467.	1.076	1076.
1483.	0.996	996.
1499.	0.897	897.
1515.	0.781	781.
1531.	0.647	647.
1547.	0.517	517.
1563.	0.404	404.
1579.	0.305	305.
1595.	0.220	220.
1611.	0.150	150.
1627.	0.094	94.
1643.	0.051	51.
1659.	0.021	21.
1676.	0.004	4.

****
RETURN PERIOD (years) = 50
DESIGN RAINFALL (mm) = 123

```
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.5
LAG TIME (h)            =    1.5
PEAK DISCHARGE (m^3/s)  =  63.04
 *******************************************************************
    TIME                       DISCHARGE
  (minutes)       (cubic metres/sec)      (litres/sec)

     503.               0.000                  0.
     519.               0.002                  2.
     535.               0.006                  6.
     551.               0.016                 16.
     567.               0.035                 35.
     583.               0.067                 67.
     600.               0.116                116.
     616.               0.190                190.
     632.               0.296                296.
     648.               0.452                452.
     664.               0.685                685.
     680.               1.059               1059.
     696.               1.744               1744.
     712.               3.533               3533.
     728.              11.515              11515.
     744.              21.451              21451.
     760.              32.133              32133.
     776.              43.081              43081.
     792.              53.822              53822.
     808.              63.038              63038.
     824.              62.483              62483.
     840.              58.804              58804.
     857.              53.909              53909.
     873.              48.338              48338.
     889.              42.332              42332.
     905.              36.029              36029.
     921.              29.524              29524.
     937.              22.912              22912.
     953.              16.333              16333.
     969.              10.298              10298.
     985.               7.886               7886.
    1001.               6.608               6608.
    1017.               5.754               5754.
    1033.               5.125               5125.
    1049.               4.636               4636.
    1065.               4.241               4241.
    1081.               3.914               3914.
    1097.               3.638               3638.
    1113.               3.402               3402.
    1130.               3.196               3196.
    1146.               3.016               3016.
    1162.               2.856               2856.
    1178.               2.714               2714.
    1194.               2.586               2586.
    1210.               2.470               2470.
    1226.               2.365               2365.
    1242.               2.269               2269.
    1258.               2.181               2181.
    1274.               2.099               2099.
    1290.               2.025               2025.
    1306.               1.955               1955.
    1322.               1.891               1891.
    1338.               1.830               1830.
    1354.               1.774               1774.
    1370.               1.722               1722.
    1386.               1.672               1672.
    1403.               1.626               1626.
    1419.               1.582               1582.
    1435.               1.540               1540.
    1451.               1.483               1483.
    1467.               1.402               1402.
    1483.               1.297               1297.
    1499.               1.168               1168.
    1515.               1.017               1017.
    1531.               0.842                842.
    1547.               0.674                674.
    1563.               0.526                526.
    1579.               0.397                397.
    1595.               0.287                287.
    1611.               0.195                195.
    1627.               0.122                122.
    1643.               0.066                 66.
    1659.               0.027                 27.
    1676.               0.005                  5.


 *******************************************************************
RETURN PERIOD (years)   =    100
DESIGN RAINFALL   (mm)  =    143
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.4
LAG TIME (h)            =    1.5
PEAK DISCHARGE (m^3/s)  =  79.02
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 *******************************************************************
    TIME                        DISCHARGE
  (minutes)       (cubic metres/sec)      (litres/sec)

     471.               0.000                 0.
     487.               0.003                 3.
     503.               0.009                 9.
     519.               0.021                21.
     535.               0.041                41.
     551.               0.074                74.
     567.               0.122               122.
     583.               0.190               190.
     600.               0.282               282.
     616.               0.407               407.
     632.               0.576               576.
     648.               0.811               811.
     664.               1.152              1152.
     680.               1.681              1681.
     696.               2.626              2626.
     712.               5.006              5006.
     728.              15.101             15101.
     744.              27.555             27555.
     760.              40.886             40886.
     776.              54.494             54494.
     792.              67.771             67771.
     808.              79.019             79019.
     824.              78.065             78065.
     840.              73.302             73302.
     857.              67.067             67067.
     873.              60.018             60018.
     889.              52.449             52449.
     905.              44.530             44530.
     921.              36.380             36380.
     937.              28.117             28117.
     953.              19.927             19927.
     969.              12.464             12464.
     985.               9.530              9530.
    1001.               7.981              7981.
    1017.               6.946              6946.
    1033.               6.185              6185.
    1049.               5.593              5593.
    1065.               5.115              5115.
    1081.               4.720              4720.
    1097.               4.386              4386.
    1113.               4.100              4100.
    1130.               3.852              3852.
    1146.               3.634              3634.
    1162.               3.441              3441.
    1178.               3.269              3269.
    1194.               3.115              3115.
    1210.               2.975              2975.
    1226.               2.848              2848.
    1242.               2.732              2732.
    1258.               2.626              2626.
    1274.               2.528              2528.
    1290.               2.437              2437.
    1306.               2.354              2354.
    1322.               2.276              2276.
    1338.               2.203              2203.
    1354.               2.135              2135.
    1370.               2.072              2072.
    1386.               2.012              2012.
    1403.               1.956              1956.
    1419.               1.903              1903.
    1435.               1.853              1853.
    1451.               1.785              1785.
    1467.               1.687              1687.
    1483.               1.560              1560.
    1499.               1.406              1406.
    1515.               1.223              1223.
    1531.               1.013              1013.
    1547.               0.811               811.
    1563.               0.632               632.
    1579.               0.477               477.
    1595.               0.345               345.
    1611.               0.235               235.
    1627.               0.146               146.
    1643.               0.079                79.
    1659.               0.033                33.
    1676.               0.006                 6.


 *******************************************************************
RETURN PERIOD (years)   =    200
DESIGN RAINFALL   (mm)  =    164
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.4
LAG TIME (h)            =    1.5
PEAK DISCHARGE (m^3/s)  =  96.30
 *******************************************************************
    TIME                        DISCHARGE
```

(minutes)	(cubic metres/sec)	(litres/sec)
423.	0.000	0.
439.	0.001	1.
455.	0.004	4.
471.	0.011	11.
487.	0.023	23.
503.	0.045	45.
519.	0.078	78.
535.	0.126	126.
551.	0.190	190.
567.	0.275	275.
583.	0.384	384.
600.	0.524	524.
616.	0.706	706.
632.	0.946	946.
648.	1.272	1272.
664.	1.733	1733.
680.	2.440	2440.
696.	3.678	3678.
712.	6.721	6721.
728.	19.111	19111.
744.	34.287	34287.
760.	50.470	50470.
776.	66.930	66930.
792.	82.914	82914.
808.	96.305	96305.
824.	94.878	94878.
840.	88.919	88919.
857.	81.219	81219.
873.	72.562	72562.
889.	63.297	63297.
905.	53.628	53628.
921.	43.699	43699.
937.	33.658	33658.
953.	23.735	23735.
969.	14.747	14747.
985.	11.261	11261.
1001.	9.425	9425.
1017.	8.200	8200.
1033.	7.299	7299.
1049.	6.599	6599.
1065.	6.034	6034.
1081.	5.567	5567.
1097.	5.173	5173.
1113.	4.835	4835.
1130.	4.542	4542.
1146.	4.284	4284.
1162.	4.057	4057.
1178.	3.853	3853.
1194.	3.671	3671.
1210.	3.506	3506.
1226.	3.356	3356.
1242.	3.219	3219.
1258.	3.093	3093.
1274.	2.978	2978.
1290.	2.871	2871.
1306.	2.772	2772.
1322.	2.681	2681.
1338.	2.595	2595.
1354.	2.515	2515.
1370.	2.440	2440.
1386.	2.370	2370.
1403.	2.303	2303.
1419.	2.241	2241.
1435.	2.182	2182.
1451.	2.101	2101.
1467.	1.986	1986.
1483.	1.837	1837.
1499.	1.655	1655.
1515.	1.440	1440.
1531.	1.193	1193.
1547.	0.954	954.
1563.	0.744	744.
1579.	0.562	562.
1595.	0.406	406.
1611.	0.276	276.
1627.	0.172	172.
1643.	0.093	93.
1659.	0.039	39.
1676.	0.008	8.