FLOOD ASSESSMENT

FOR THE PROPOSED EXPANSION OF HEROES ACRE MEMORIAL PARK CEMETERY, MSUNDUZI LOCAL MUNICIPALITY, UMGUNGUNDLOVU DISTRICT MUNICIPALITY, KZN

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DRAFT 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.

Table 1 Specialist declaration

Document control					
Report title		Flood Assessment For The Proposed Expansion Of Heroes Acre Memorial Park Cemetery, Umsunduzi Local Municipality, Umgungundlovu District Municipality, KZN			
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1. INTRODUCTION

1.1 Project Background and Description of the Activity

The Msunduzi Local Municipality aims to expand the existing Heroes' Acre Cemetery, with EnviroPro leading the permitting process. The project will require a Floodline delineation as the proposed project lies adjacent to the Wilgerfontein River.

As part of the specialist requirements a flood assessment is required to determine high risk areas.

Sub Div	Farm No.	Town Name	Latitude	Longitude	Area (m^2)	SG Code	Deed
0	125	Pietermaritzburg	-29.64776	30.35991	160 680	N0FT02580000012500000	N/A

The key requirements for this study are as follows:
1. Desktop hydrological assessment.
2. Catchment analysis.
3. Design flood investigation.
4. Reporting (report & maps in pdf format).

The receiving environment as of May 2023 can be seen in Figure 1 with the layout of the site in Figure 2.

Figure 1 The receiving environment of the Heroes Park Memorial Acre – (a) existing gravesite, (b, c & d) Wilgerfontein River and (c) backdrop showing Edendale

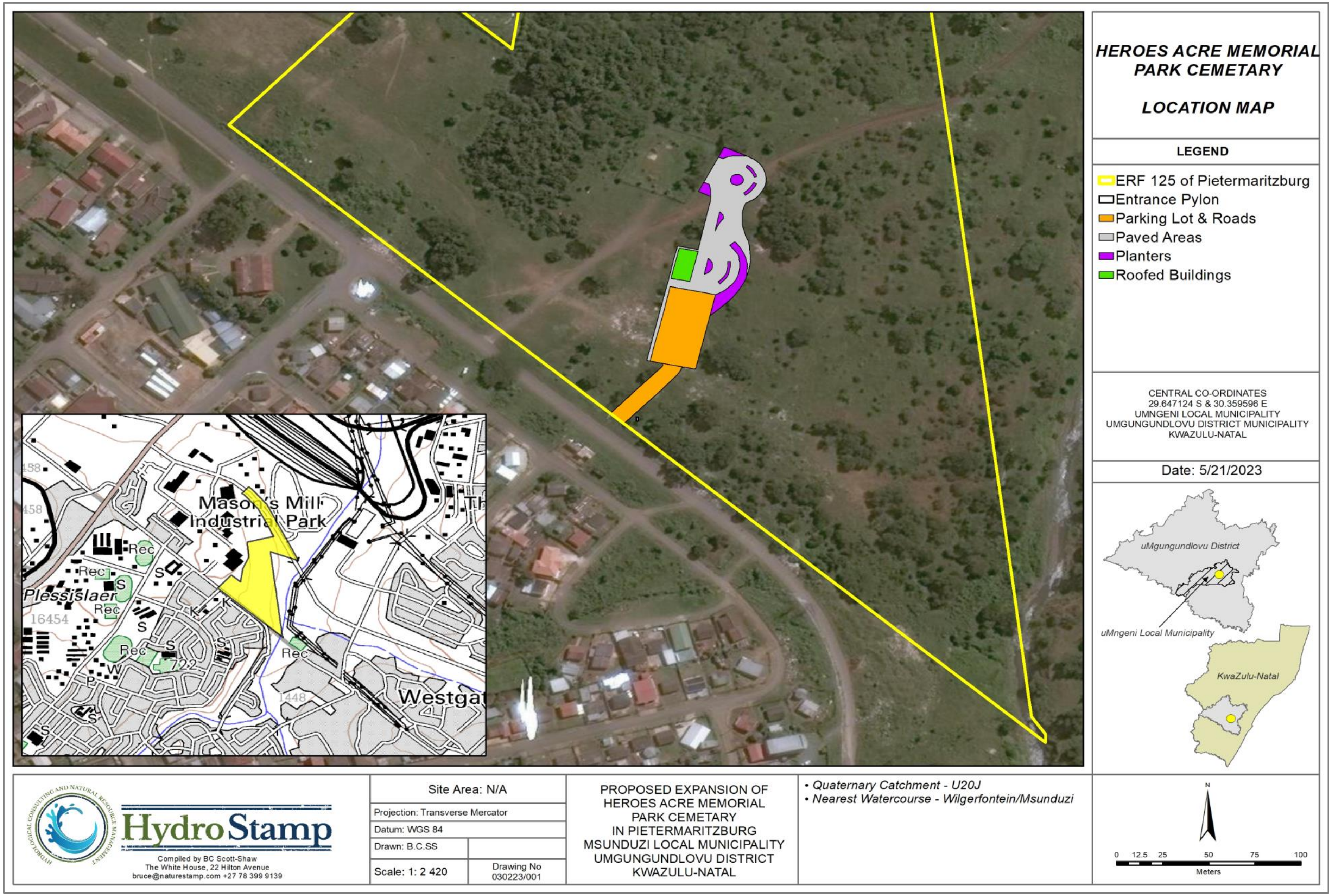

Figure 2 Locality map of the Heroes Park Acre Memorial

1.2 Terms of reference

i. Hydrological Assessment

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.

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 available. However, this data was of poor quality. 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 near Masons Mill industrial park and adjacent to the Wilgerfontein river. This system flows into the Msunduzi river near Camps Drift.

The Wilgerfontein 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 °C in summer and 13.8 °C in the winter months (Table 2). 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 2 Mean monthly rainfall and temperature observed at Heroes Park (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 (°C)	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 3 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 15th May 2023. 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 partial 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).

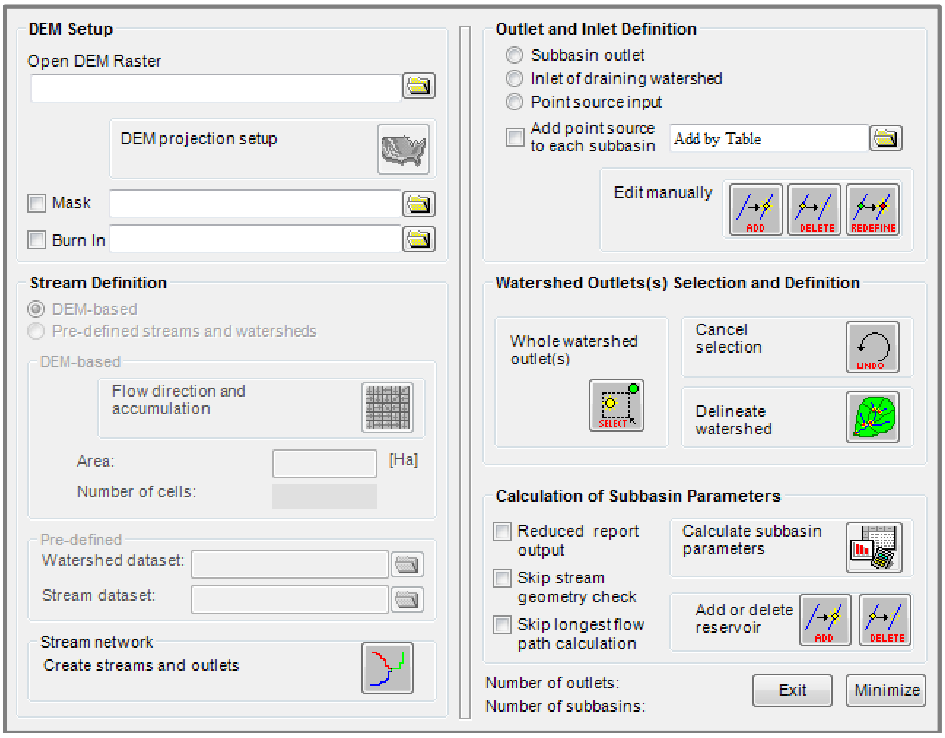

Figure 4 Soil Water Assessment Tool (*SWAT*) watershed delineation tool for sub-catchment delineation and stream network creation

3.3 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).

3.4 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).

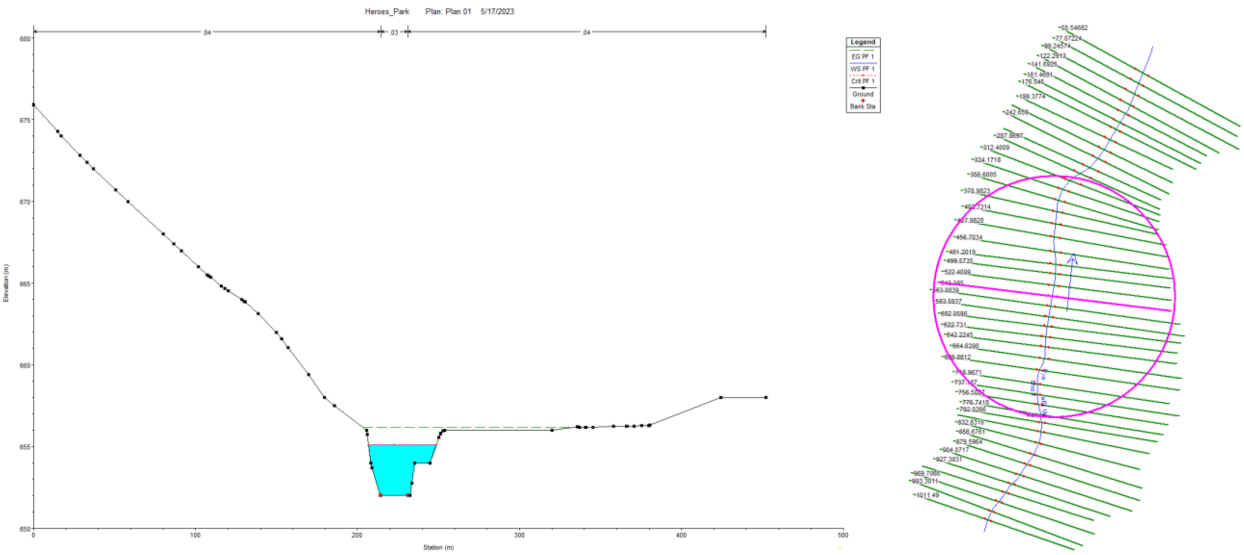

Figure 5 Longitudinal profile and channel cross sections developed for a section of the Wilgerfontein River

3.5 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.

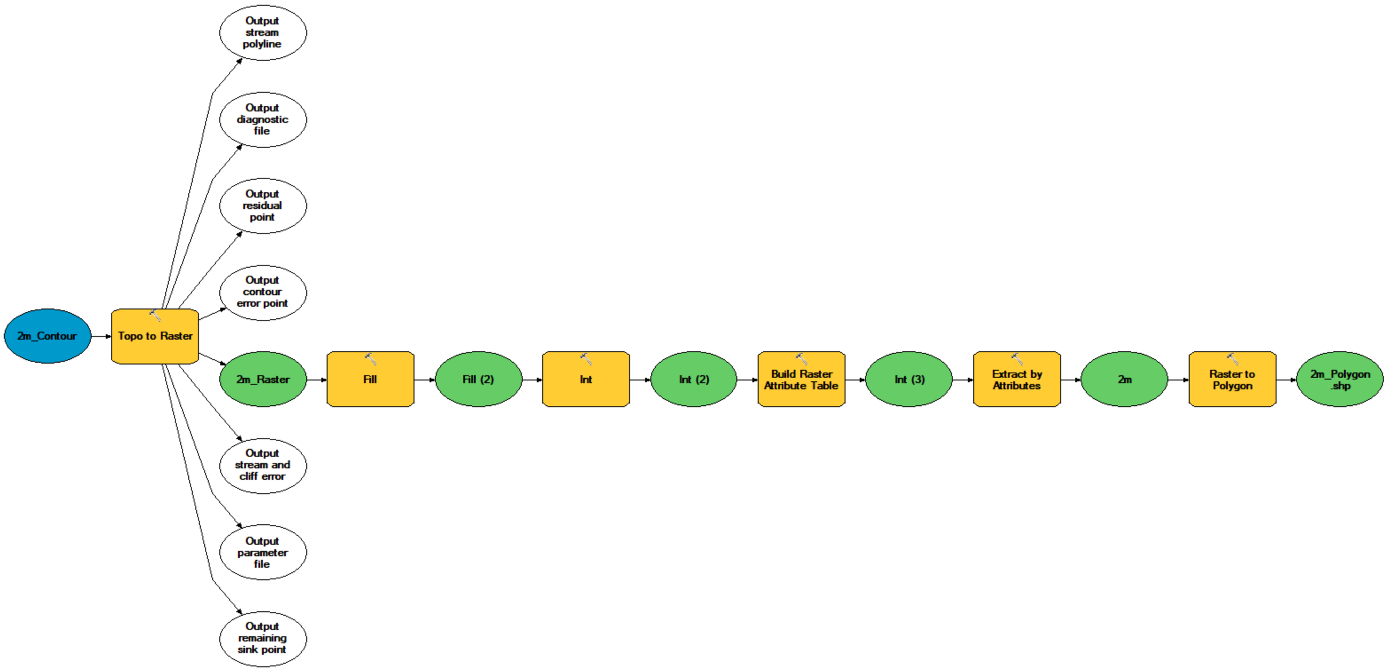

Figure 6 GIS model for flood generation in small channels

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.

- 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 5 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 moderately sized and the watercourse associated with the site has been transformed for settlements. In addition, boreholes nearby are used for small scale livestock drinking and are negligible.

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 4 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
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

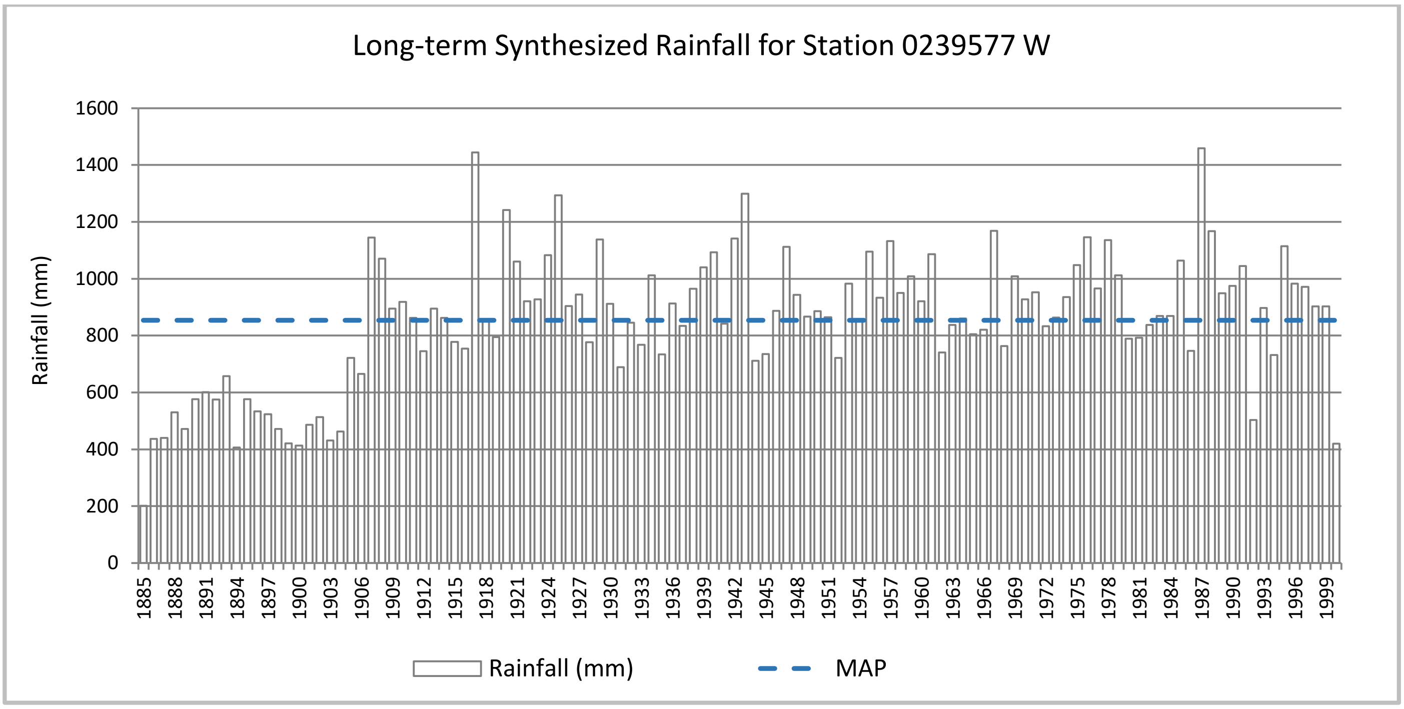

Figure 7 Long term synthesized annual rainfall values with the mean annual precipitation indicated in blue

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 would be representative of the site if it had good quality data.

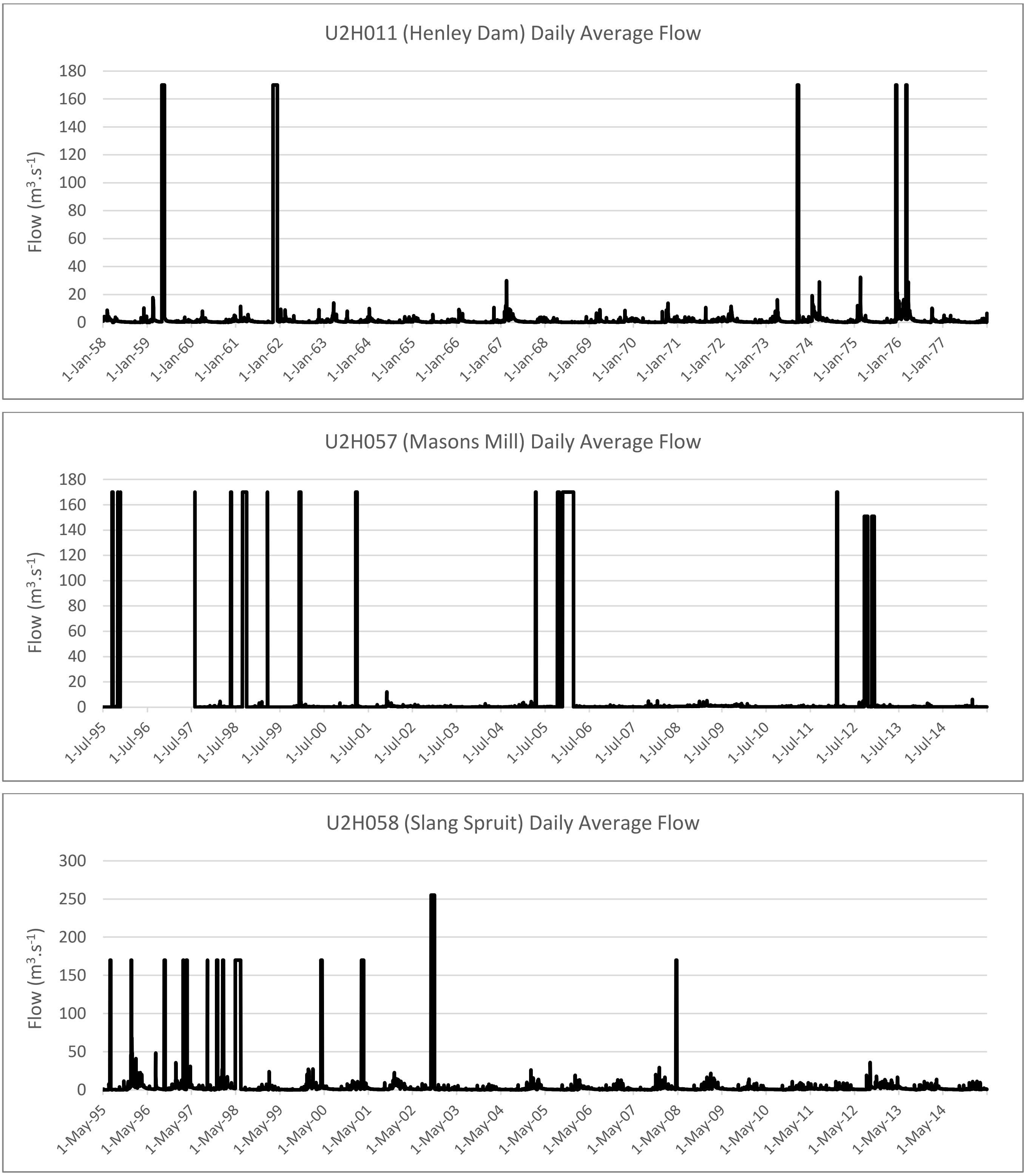

Figure 8 Historical streamflow from gauging stations within the catchment area of the Umsunduzi River

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 (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 dumping, surrounded by industry and infrastructure on the opposite banks.

Table 5 Proposed land cover area for the contributing catchment area

Land Cover	Area (ha)	Percentage
Cultivated commercial annual crops non-pivot	0.67	0.01
Cultivated subsistence crops	15.66	0.33
Degraded	1.45	0.03
Grasslands	**1890.35**	**39.93**
Indigenous Forest	1.44	0.03
Low shrubland	3.02	0.06
Mines	4.43	0.09
Plantations / Woodlots	231.93	4.90
Settlements	**2213.46**	**46.75**
Thicket /Dense bush	268.82	5.68
Waterbodies	0.18	0.00
Wetlands	66.40	1.40
Woodland/Open bush	36.70	0.78
Total	**4734.52**	**100**

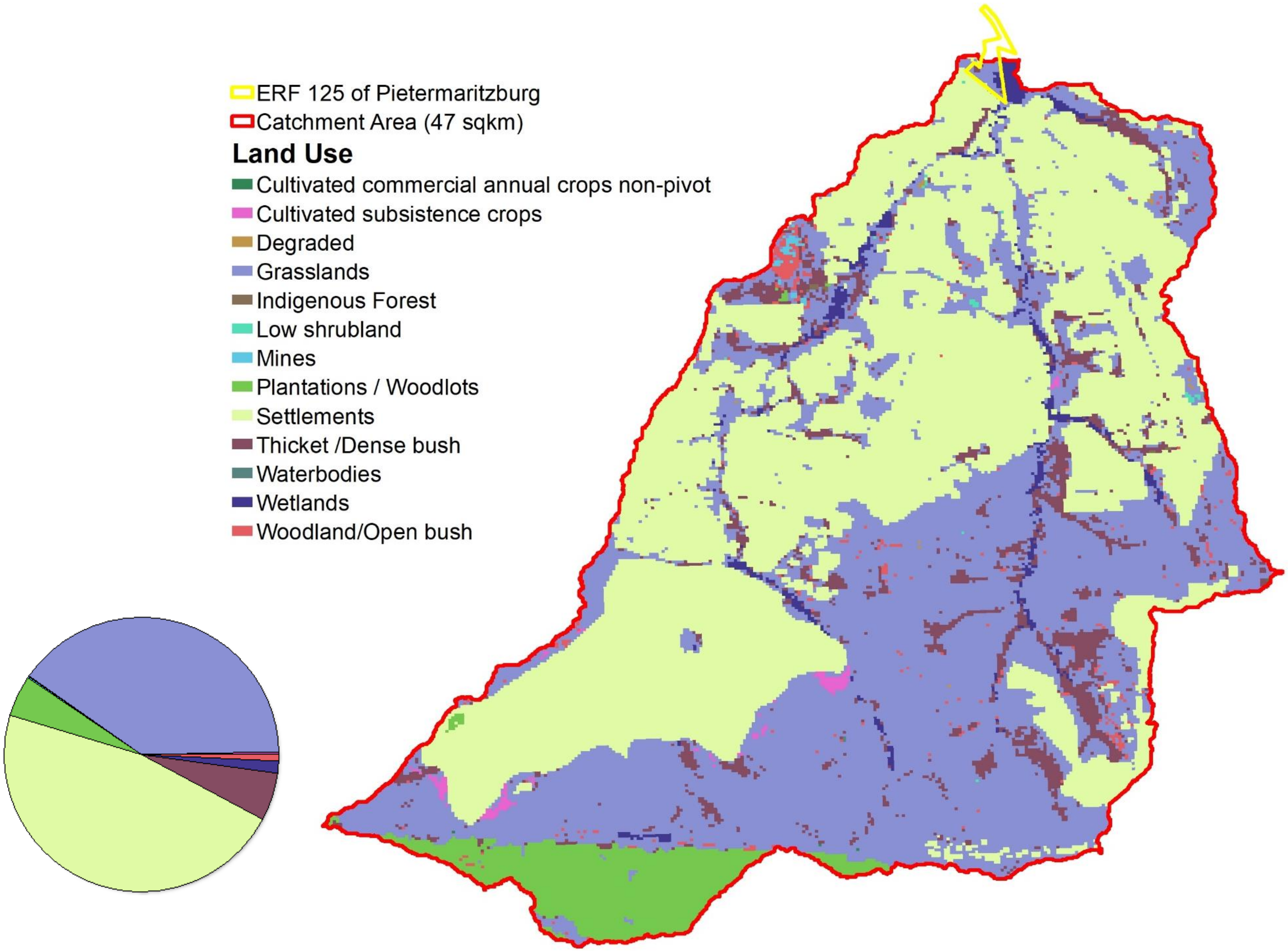

Figure 9 Existing land use for the catchment area of Heroes Park

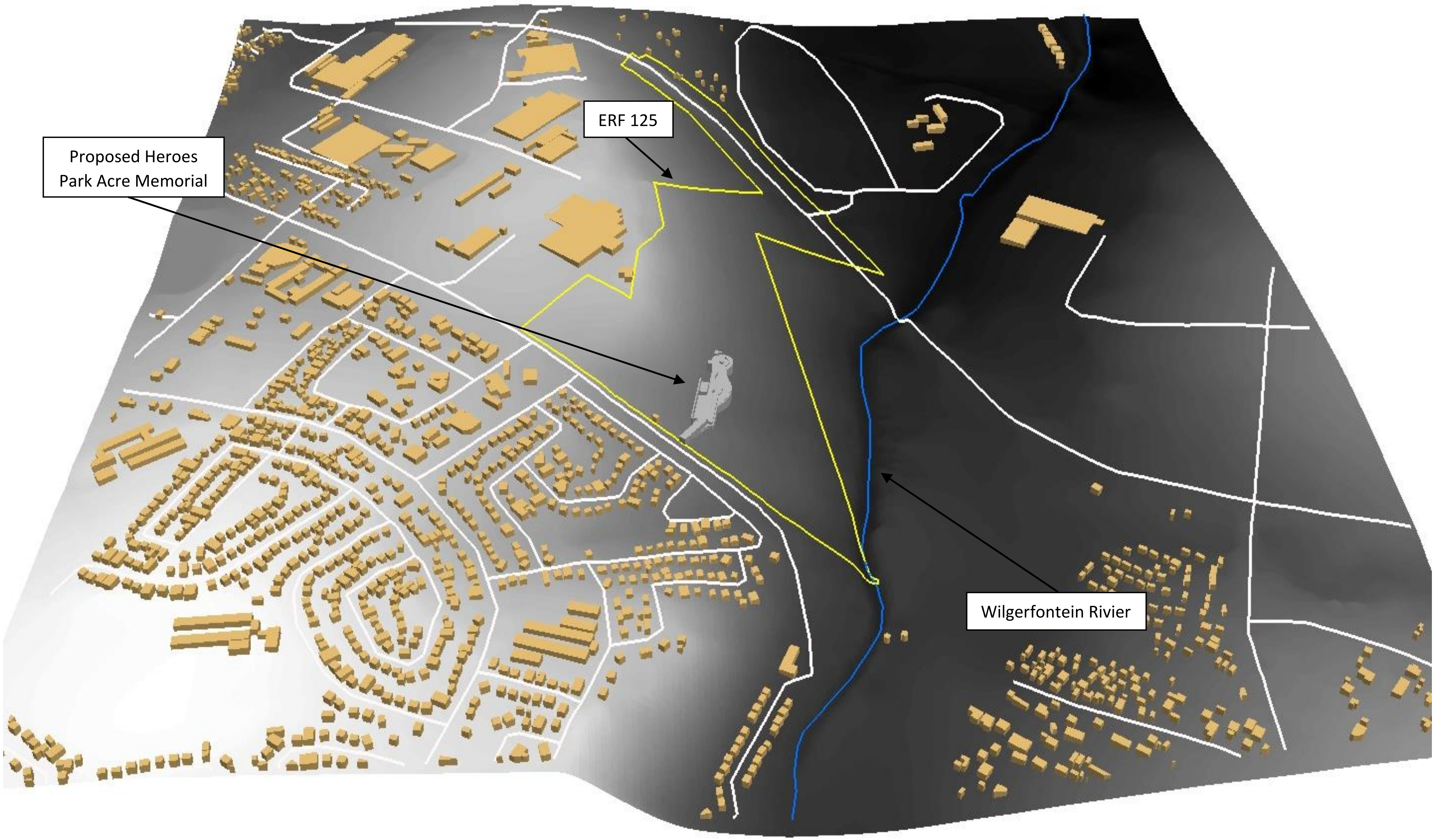

Figure 10 Exaggerated (x2) Digital Elevation Model (DEM) of the catchment surrounding Heroes Park

5.4 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 6 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	90	93.0
50 Year Return Period	94.82	123.2	134	160.0
100 Year Return Period	109.35	161.1	157	199.0

The design runoff results obtained for the 1:10, 1:50 and 1:100 year flood events for the various river reaches are summarised in Table 6.

5.5 Design Peak Discharge

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 11) for the current state indicated that the entire site is not within the flood extent. However, **given the likelihood of peak/intense storm events, stormwater should be managed on site**.

It is clear that the proposed development has already taken cognisance of likely flood areas such as that of the Wilgerfontein.

Table 7 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
SCS-SA	**47.9**	**92.8**	**137.3**	**189.2**	**271.2**	**348.3**

The 1:100 year event for the total catchment area of 47 km^2 using SCS-SA was 348.3 $m^3.s^{-1}$.

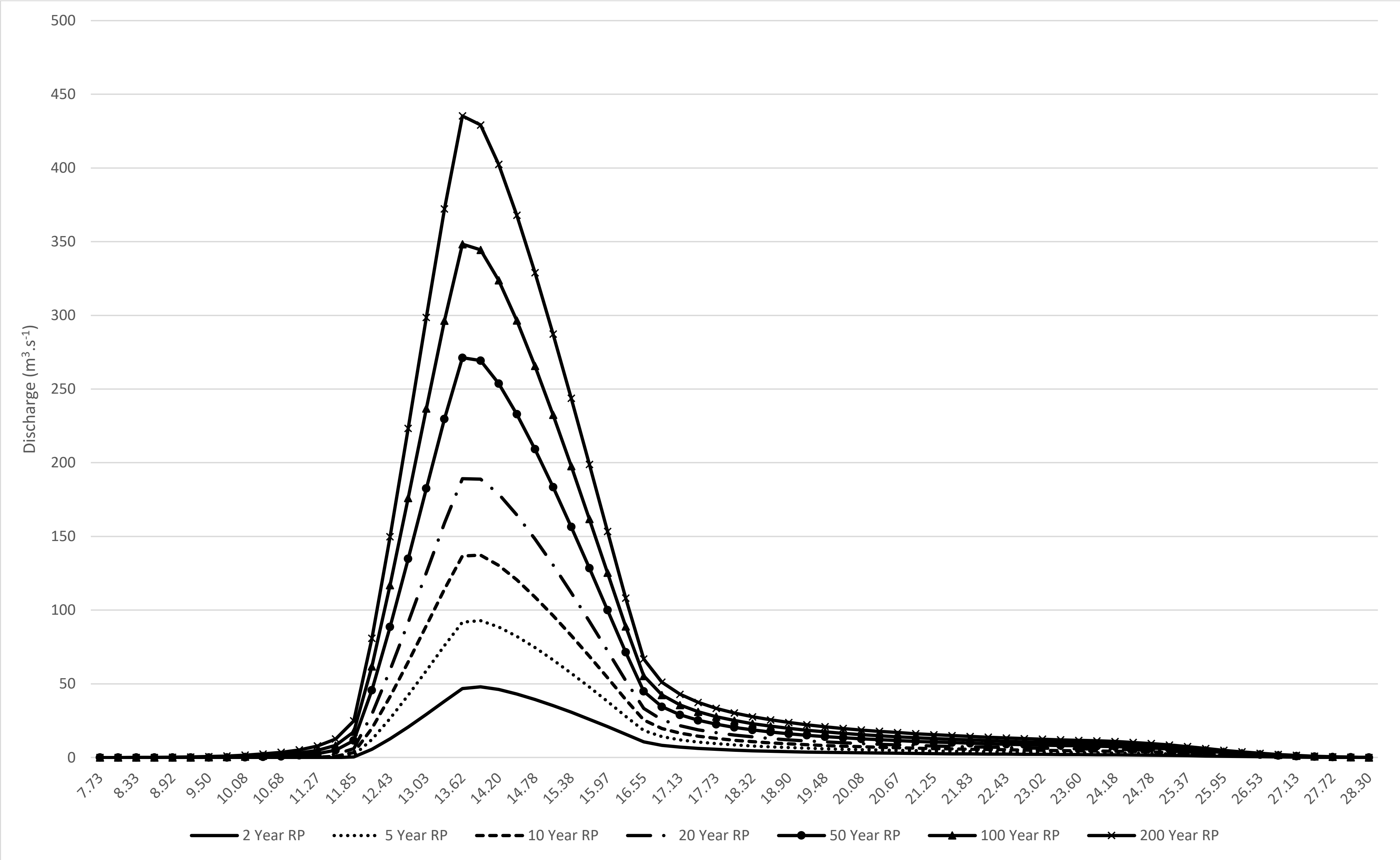

Figure 11 Flood hydrograph derived for Heroes Park Acre Memorial

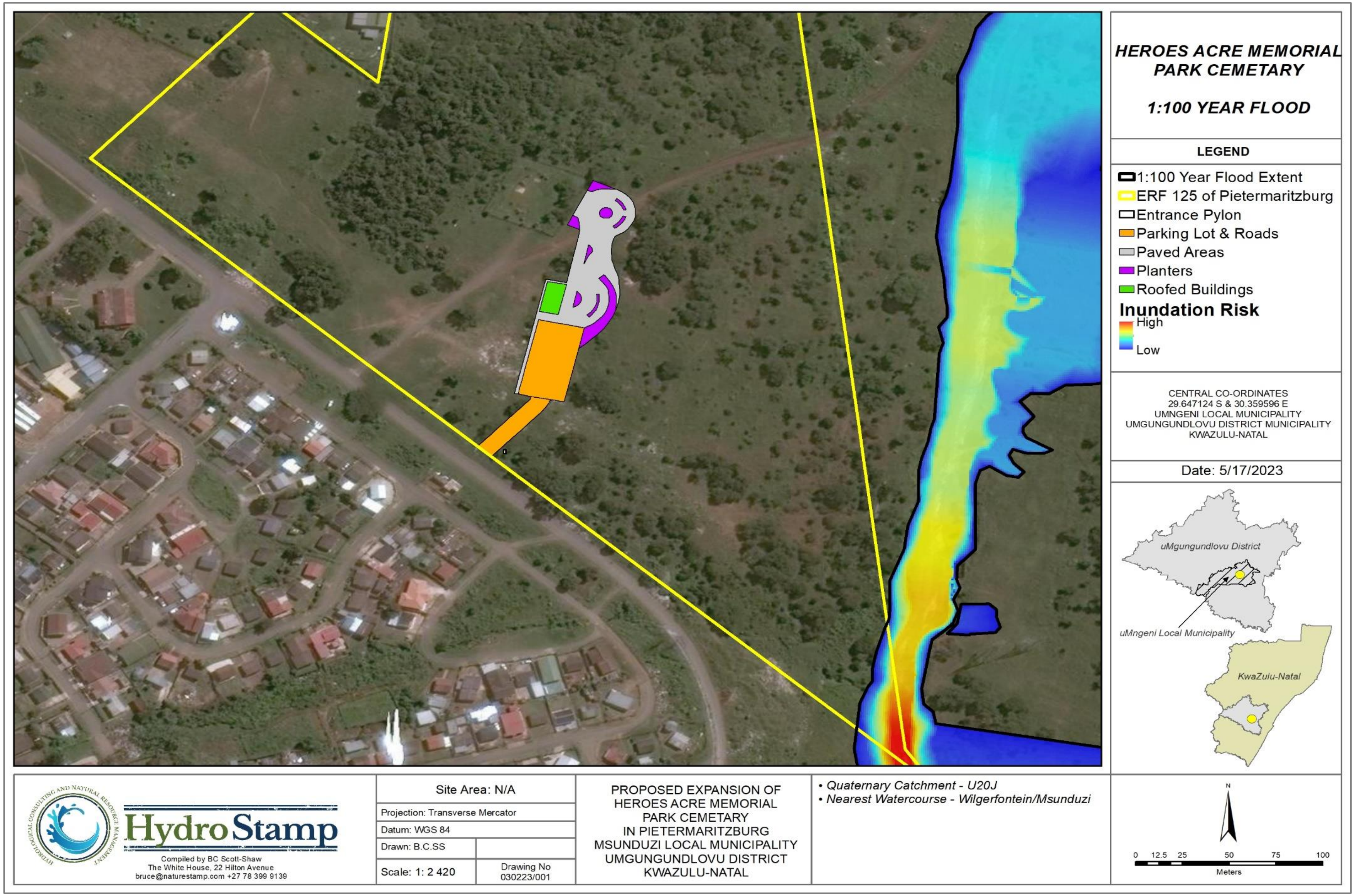

Figure 12 1:100 year flood extent and inundation risk for the Heroes Park Acre Memorial

5.6 Potential Impacts & Mitigation

The specialist recommendations need to address the following key questions:

- Will downstream water users be affected by potential spills/leaks from the development?
- Will the proposed land use result in a change in the surface water quality?
- Will the proposed land use result in a change in the surface water quantity?
- What actions can be taken to ensure no impact on surface water resources occurs?

From a **surface water quality** perspective, the downstream users **will not be** affected by the **proposed activities** at Heroes Park. However, mitigation measures should still be adopted:

- Storm water is managed on-site to that of the pre-development state;
- Any dirty water/wastewater is connected to municipal infrastructure or removed from the site;
- Rubbish bins are placed strategically and maintained;
- Assuming there are spill contingency plans in place; and
- Any spills would be contained if any spills were to occur.

From a **surface water quantity** perspective, the downstream users **will not be** affected by the **proposed activities** at Heroes Park. This is based on the following findings/reasons:

- The site would not use water from this system;
- Storm water is managed on-site to that of the pre-development state; and
- Water is not utilized out of the river.

5.7 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.

5.8 Mitigation Measures and Recommendations (Spill Management Plan)

The proposed Heroes Park 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 120% 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.

6. CONCLUSION

The results provided indicate that the proposed park is completely outside of the 1:100 year flood extent. A small section of ERF 125 is within the flood extent but this is a significant distance from the proposed footprint. The flood risk in this area is low primarily due to setting of the development area as it has avoided the watercourse. It is recommended that any future layout considers the low lying/watercourse areas as 'green space'. Furthermore, additional measures should be taken to ensure that flows are managed within this area. Vegetated areas are encouraged to promote infiltration.

The net discharge of water on the system would be higher than that of the pre-development state. As such, Stormwater needs to be 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 storm events within the site.
2. The site is entirely outside of the flood extent and are of low risk.
3. Strict adherence to best practice guidelines, spill management and erosion control must be throughout operation of the development.
4. Regular maintenance of culverts/drains/gutters must be undertaken to ensure that the flood risk is not increased due to blockages by debris.
5. 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.

5 REFERENCES

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4. SCHULZE, RE. (2011) Atlas of Climate Change and the South African Agricultural Sector: A 2010 Perspective. Department of Agriculture, Forestry and Fisheries, Pretoria, RSA. pp 387.
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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)	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	**Heroes Park**		
River detail	**Wilgerfontein**		
Calculated by	**BCSS**	**Date**	**16/05/2023**

Physical characteristics					
Size of catchment (A)	**47**	km²	Rainfall Region		
Longest Watercourse	**9.1**	km	**Area Distribution Factors**		
Average slope (S_{av})	**0.02**	m/m	Rural (α)	Urban (β)	Lakes(γ)
Dolomite Area ($D_{\%}$)	**2**	%	**0.5**	**0.5**	**0**
Mean Annual Rainfall (MAR)	**756**	mm			
Catchment Characteristics	**Flat/permeable**	%			
r - look up from Table 3C.3	**Thick grass cover**	0.8			

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%)		0.15	-
Total	100	-	0.180	Heavy soil, steep (>7%)		0.3	-
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very Permeable	**10**	0.05	0.005	Houses	**5**	0.4	0.020
Permeable	**50**	0.1	0.050	Flats	**10**	0.6	0.060
Semi-permeable	**30**	0.2	0.060	**Industry**			
Impermeable	**10**	0.3	0.030	Light industry	**15**	0.65	0.098
Total	100	-	0.145	Heavy Industry	**15**	0.75	0.113
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush and plantation	**20**	0.05	0.010	City Centre	**25**	0.825	0.206
Light bush and farm-lands	**50**	0.15	0.075	Suburban	**20**	0.6	0.120
Grasslands	**25**	0.25	0.063	Streets	**10**	0.825	0.083
No Vegetation	**5**	0.3	0.015	Maximum flood		1.00	-
Total	100	-	0.163	Total	100	-	0.699

Time of concentration (T_c)	**Defined Watercourse**	Notes:
Overland flow	Defined watercourse	*Pre-development Run-off*
		Latitude: *28°42'*
$$T_c = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$	$$T_c = \left(\frac{0,87L^2}{1000S_{av}}\right)^{0.385}$$	*Tc = 1.63787305* *Longitude:* *32°02'*
3.8 Hours	1.6 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} (= $C_1(1-D_{\%})+C_1D_{\%}(\Sigma(D_{factor} \times C_{s\%}))$)	0.4808213	0.4808213	0.48082125	0.48082125	0.48082125	0.48082125	0.48082125
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} (= $C_{1D} \times F_t$)	0.2404106	0.2644517	0.28849275	0.32215024	0.39908164	0.48082125	0.48082125
Combined run-off coeffiecient C_T (= $\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0.4695803	0.4816008	0.49362138	0.51045012	0.54891582	0.58978563	0.58978563

Rainfall							
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point Rainfall (mm), P_T	**48.1**	**65.0**	**70.0**	**109.5**	**143.2**	**163.0**	**210.0**
Point Intensity (mm/hour), P_{iT} (=P_T/T_C)	29.4	39.7	42.7	66.9	87.4	99.5	128.2
Area Reduction Factor (%), ARF_T	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Average Intensity (mm/hour), I_T (= P_{iT} x ARF_T)	29.4	39.7	42.7	66.9	87.4	99.5	128.2
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Peak flow (m^3/s),	180.040	249.526	275.427	445.536	626.562	766.297	987.253

ANNEXURE C **SDF Method**

Description of catchment	**Heroes Park**						
River detail	**Wilgerfontein**						
Calculated by	**BCSS**			**Date**	**16 May 2023**		
Physical characteristics							
Size of catchment (A)	**57**	km²	Time of Concentration (T_C)	$T_c = \left(\frac{0{,}87\,L^2}{1000\,S_{av}}\right)^{0,385}$		**1.64**	hours
Longest watercourse (L)	**9.1**	km					
Average slope (S_{av})	**0.02**	m/m					
SDF basin (0)#	**25**		Time of concentration, t (= 60 T_C)			**98**	minutes
2-year return period rainfall (M)	**55**	mm	Days of thunder per year (R)			**9**	days/year
TR102 n-day rainfall data							
Weather Service station		**Whitson**	Mean annual precipitation (MAP)			**830**	mm
Weather Service station number		**239 138**	Coordinates				
Duration (days)	Return period (years)						
	2	5	10	20	50	100	200
1	**55**	**71**	**83**	**95**	**113**	**127**	**143**
2	**71**	**94**	**111**	**129**	**155**	**176**	**199**
3	**80**	**108**	**129**	**150**	**181**	**207**	**235**
7	**104**	**138**	**162**	**187**	**221**	**250**	**279**
Rainfall							
Return period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	**27.78**	**46.86**	**61.30**	**75.73**	**94.82**	**109.25**	**123.69**
Area reduction factor (%), ARF (= (90000-12800lnA+9830lnt)$^{0.4}$)	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Average intensity (mm/hour), I_T (= $P_{t,T}$ x ARF / T_C)	**16.96**	**28.61**	**37.43**	**46.24**	**57.89**	**66.70**	**75.52**
Run-off coefficients							
Calibration factors	C_2 (2-year return period) (%)		**10**	C_{100} (100-year return period) (%)			**80**
Return period (years)	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient (C_T), $C_T = \frac{C_2}{100} + \left(\frac{Y_T}{2{,}33}\right)\left(\frac{C_{100}}{100} - \frac{C_2}{100}\right)$	**0.10**	**0.35**	**0.48**	**0.59**	**0.72**	**0.80**	**0.88**
Peak flow (m³/s), $Q_T = 0.278 \times C_T I_T A$	**26.85**	**159.62**	**287.13**	**433.93**	**656.18**	**844.93**	**1046.38**