PROPOSED TOWNSHIP ESTABLISHMENT OF GREATER SEVILLE EXT 3 ON THE REMAINDER OF PORTION 1 AND PORTION 2 OF THE FARM SEVILLE 224 KU, BUSHBUCKRIDGE, MPUMALANGA

STORMWATER MANAGEMENT PLAN

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1.0 INTRODUCTION

1.1 Introduction

This report scope is Stormwater Management Plan for the proposed township development of Greater Seville Ext 3 on the Remainder of Portion 1 and Portion 2 of the Farm Seville 224 KU, Mpumalanga Province.

The proposal intends developing a 25.50 hectare of land comprising of housing units, business, education, church, and municipal purposes.

Several notable features on the site are as follows –

- An existing nearby housing developments.
- Areas of forest.

1.2 Impact of development on existing catchments

The impacts of the proposed housing development on the environments in the affected catchments will range from negative to positive depending on the degree of planning and design and methods of implementation that contribute to the mitigation of the naturally negative impacts of development.

Expected consequences of unmitigated development include an increase in hardened areas, reduced infiltration areas, loss of vegetation and reduced evapo-transpiration potential. There will be an overall increase in surface runoff, an increase in the speed of runoff and peak flow rates in the watercourses.

1.3 Mitigation of development consequences

The recommendations in the specialist studies highlight the importance of adequate attention to the following key issues:

- Protection of the natural watercourses to prevent pollution, erosion and retain runoff.

- Promotion of subsoil infiltration where possible

- Provision of indigenous vegetation along watercourses and stabilisation of banks

- Provision of in-stream installations at selected sites to trap first-flush pollution and non-soluble trash and litter entering the stormwater system.

- Attention to development of on-site use rainfall attenuation and provisions for reducing runoff by in-catchment and on-site evaporation and evapo-transpiration.

- Local flood risk reduction by selection of appropriate design standards for culverts and stormwater attenuation facilities

- Implementation of adequate on-site and localised stormwater management practices

- Attenuation of flood peaks to predevelopment levels at the 2% (50-year) and the 10% (100-year) risk level

- Matching of new impermeable areas with sufficient flood attenuation.

The Stormwater Management Plan described below lists many practical on-site controls to address these fundamentals issues. However, this does not exclude any technology that can be shown to be effective in controlling runoff while supporting the proposed spatial development intensity levels and contributing positively to the environment.

To fully mitigate the negative impacts of development the following will need to be adhered to: -

- The potential increase in catchment runoff must be balanced against the combined effects of evapo-transpiration from catchment vegetation, evaporation from water bodies plus the retention and re-use of both storm runoff and treated wastewater.

- The potential increase in flood peaks must be mitigated to at least predevelopment levels by the provision of sufficient stormwater detention facilities at micro and macro levels.

- The potential increase in flood volumes must be mitigated where possible by subsoil infiltration, retention of runoff in on-site facilities and unsaturated wetland areas where evaporation and infiltration can help to reduce flood runoff rates.

- Installations must be provided to contain pollution as close to source as possible and in a practical location for servicing by Department of Solid Wastes.

1.4 Objectives

This stormwater management plan for the housing development has the following objectives:

1. To protect all life and property from damage by stormwater and floods
2. To prevent erosion of soil by wind and water
3. To conserve the flora and fauna of the natural environment
4. To protect and enhance water resources in the catchments from pollution and siltation.
5. To protect and enhance the local and downstream water courses.

1.5 Major Risks

1.5.1 Erosion

The topsoil is generally highly erodible and pose a constant and significant threat to the stability of the natural landforms. On the steeper slopes, erosion can take place extremely quickly once initiated, resulting in dongas and undermining structures.

The damage to the watercourse will seriously impact not only on the site of the erosion but could damage neighbouring properties and wetlands located in the downstream valleys where the eroded sediment will be deposited. The cost of correcting the damages will be substantially more than the precautions required to avoid them.

1.5.2 Flooding

The proposed development will tend to reduce the natural rainfall infiltration and increase storm runoff. Downstream flood damage risks will therefore increase unless adequate attenuation of flood runoff is provided collectively in the watercourses and on individual sites if necessary. The design of the major stormwater system must address this issue as far as possible and must be designed such that the downstream post-development flood risks are no greater than the pre-development flood risks.

1.6. Stormwater Management Philosophy

Among the major stormwater system consists of all-natural water ways, including streams and rivers. It includes swales, energy dissipators and other devices constructed to control stormwater. Roadways and their associated drainage structures are also part of the major stormwater system if they result in a significant deflection of stormwater from its natural overland flow path.

The minor stormwater system consists of any measures provided to accommodate stormwater runoff within sites and road reserves and convey the runoff to the major stormwater system. These measures include gutters, conduits, berms, channels, road verges, small watercourses, and infiltration constructions.

Stormwater runoff should not be concentrated to an extent that would result in any damage to the environment during storms with a probability frequency more than 1 in 10 years and would result in only minor, repairable damage in storms with a probability frequency of more than 1 in 50 years. All elements of the built and natural environment must be able to withstand a 1 in 50-year storm event without significant consequential loss and risk to property and life. Note that a “storm frequency” equates to a “probability of occurrence” of a storm event that should be used to assess the annual budget or insurance provision for remedial works, should the event occur.

In all catchments, the water courses and built stormwater infrastructure must be maintained in a clean state, free of any rubbish, debris and matter likely to pose any pollution threat to the lower reaches of the water courses.

The Stormwater Management Philosophy for the housing development encourages developers, their professional teams, contractors, and property owners to do the following:

- Always maintain adequate ground cover at all places and to negate the erosive forces of wind, water and all forms of traffic.

- Prevent concentration of stormwater flow at any point where the ground is susceptible to erosion.

- Reduce stormwater flows as much as possible by the effective use of attenuating devices.

- Ensure that development does not increase the rate of stormwater flow above that which the natural ground can safely accommodate at any point in the sub-catchments.

- Ensure that all stormwater control works are constructed in a safe and aesthetic manner in keeping with the overall development.

- Prevent pollution of water ways and water features by suspended solids and dissolved solids in stormwater discharges.

- Contain soil erosion, whether induced by wind or water forces, by constructing protective works to trap sediment at appropriate locations. This applies particularly during construction.

- Avoid situations where natural or artificial slopes may become saturated and unstable, both during and after the construction process.

1.7. Stormwater Management Policy

The following rules are to be observed by all developers, property owners, their professional teams, contractors, and sub-contractors:

1. Designs for the buildings and site development in general must avoid concentration of stormwater runoff both spatially and in time and may be required to provide for on-site attenuation of stormwater runoff to limit peak flows to pre-development levels.

2. Detailed plans to control and prevent erosion by water must be agreed prior to the commencement of any works, including site clearance, on any portion of the site.

3. Removal of vegetation cover must be carried out with care and attention to the effect, whether temporary or long term, that this removal will have an erosion potential.

4. Precautions shall be always taken on building sites to contain soil erosion and prevent any eroded material from being removed from the site.

5. Landscaping and re-vegetation of areas not occupied by buildings or paving shall be programmed to proceed immediately after building works have been completed or have reached a stage where newly established ground cover is not at risk from the construction works.

6. On-site stormwater control systems, such as swales, berms, soil fences and detention ponds are to be constructed before any construction commences on the site. As construction progresses, the stormwater control measures are to be monitored and adjusted to always ensure complete erosion and pollution control.

7. Earthworks on sites are to be kept to a minimum. Where embankments must be formed, stabilization and erosion control measures shall be implemented immediately.

8. Stormwater must not be allowed to pond near existing building foundations.

9. Prior to any physical work proceeding on any site, stormwater control plans (SCPs) detailing the proposed stormwater control measures are to be formulated. No work is to be undertaken without an approved SCP.

10. Stormwater Control Plans must describe what control measures are to be implemented before and during the construction period, as well as the final stormwater control measures required for the site on completion of site development. Plans must indicate who is responsible for the design of the control measures and who is, or will be, designated as the responsible person on site during each stage of the implementation of the control measures.

11. Stormwater Control Plans must show that all the provisions, regulations and guidelines contained in this document have been considered.

12. In the event of a failure to adequately implement the approved stormwater control plan, the owner/developer shall be responsible for making good all consequential environmental damage at his own cost. Owner/developers are therefore advised to ensure that all members of their professional teams and their contractors are competent to undertake the development work and are adequately insured.

1.8 Major Stormwater Systems

A plan indicating the sub-catchment delineation for this project is attached as an appendix with details and possible stormwater impacts indicated to advise the planning process and highlight critical areas for attention during the design phase.

In due course, the stormwater systems in each drainage basin have been identified and analysed to determine the requirements for new stormwater infrastructure to meet the objectives of this stormwater management plan. The results have been documented that advises designers on the hydraulic capacities of the major system and provides parameters for further detailed design at specific locations within the overall development.

The parameters should include:

- Allowable ranges for the percentage impervious for commercial areas

- Average depression storage values for pervious and impervious areas

- Initial and final infiltration rates and the appropriate Horton’s decay constant

- Geotechnical data on infiltration rates for infiltration galleries

- Equivalent Rational Method coefficients and unit area runoffs for developments

- It is important that all building designs provide for maximum on-site stormwater attenuation and that the developers instruct their professional teams accordingly. It is important that level and near-level areas, such as building roofs and parking areas, are used to best advantage to attenuate storm runoff.

1.9 Critical Aspects

1. Stormwater drainage is a crucial aspect in the development of the housing development and will require careful planning, designing, and managing.

2. The stormwater detention ponds should be designed for the 50-year storm event and should be located at appropriately selected sites. Site selection must take account of the necessary geotechnical, environmental, and topographical conditions, including wetland conservation.

3. In addition to macro stormwater measures, micro-stormwater measures should be implemented on individual sites. The form of this attenuation will be dependent on several factors such as topography (natural and artificial slopes), the zoning of the site and soil conditions present. It is envisaged that in the steeper regions on-site attenuation tanks will be the most suitable form of attenuation with outlets to the municipal pipe network, where provided, or appropriate flow spreaders.

4. In the flatter areas (a large portion of the site) where soil conditions are favorable, infiltration measures will be the preferred form of on-site stormwater control and disposal. In certain instances, infiltration devices may need to be supplemented with attenuation tanks with outlets to the municipal pipe network.

5. A limited stormwater pipe network should be provided for stormwater reticulation to safely convey minor stormwater runoff from properties and roads to and between the attenuation facilities.

6. To ensure that water quality is not compromised, silt and trash traps will need to be provided within the system. Where conditions permit, open ditches, drains and channels should be used instead of pipes. Attention must be given to the erodibility of channels where flow velocities are high and appropriate lining provided. Forms of lining will vary from natural vegetation to stone pitching and reinforced concrete linings.

7. While the stormwater management objective of the development should be to minimize the concentration of stormwater and attenuate flows as much as possible, roads and driveways cut into steeper slopes will cause storm runoff to be channeled and focused. Exit points should be located over flat ground, where sheet flow can be re-established or into culverts that convey the flow to a water body, or an energy-dissipating device.

8. In preparing the sub-catchment boundaries, account has been taken of the natural watersheds and the probable impact of proposed roads on the flow of stormwater runoff. Certain sub-catchment boundaries will be defined by proposed roadways

that are likely to concentrate stormwater runoff in a formalized system. Within the development area, stormwater servitudes of adequate width will be required over properties straddling a natural watercourse, or where runoff is diverted for a specific reason. Lined conduits, either open channels or pipes, with outfall energy dissipaters must be provided wherever there is an assessed risk of erosion on slopes steeper than 2%.

9. The proposed development should not adversely impact on the environments of the development node and surrounding areas in terms of erosion and sediment deposition, but the frequency of flooding and the total runoff volume will increase unless adequate provision can be made to maintain the current natural rate of stormwater retention and infiltration in the sub-catchments.

10. An overall stormwater systems model should be developed to determine peak flood flow rates and flood levels for the main watercourses and assess the collective impacts of developments on runoff patterns. The outputs from the modelling will provide the input data required for the design of culverts, channels and other stormwater infrastructure associated with the proposed developments.

11. Detailed hydraulic analysis will be required during the design stage to assess storm runoff and flood levels at specific locations, such as bridges, road culverts and where properties are affected by the 100-year flood. It is important to note that although a structure may be designed for a return period less than 1 in 100 years, the design analysis must still assess the consequences resulting from a 100-year storm event.

12. For sub-catchments flowing into the development area, potential future development in these sub-catchments should be considered and any requirements for stormwater detention should be identified. Similarly, for sub-catchments flowing out of the development area the impact on the downstream watercourse must be considered and measures taken to ensure any upstream development does not result in an increased flood damage risk downstream.

13. Sites within the proposed development that bound on stormwater detention areas, near road crossings, watercourse confluences and water features could be subject to flooding. In these situations, no development should take place below the outfall levels of water detention areas, plus an appropriate freeboard allowance.

14. The proposed development layouts will impact on storm runoff to varying degrees. Adequate provision will have to be made for the management and disposal of stormwater runoff from the various internal developments as they are planned, and this must be done in an integrated and coordinated process to avoid stormwater damage in the future.

15. Overland flow may be encouraged where possible but should be avoided in the specific areas identified. These are typically where roads will capture and concentrate cross flows at the local low points in the roads. Plans must consider probable impact of flow from these points of concentration on the downstream environment.

16. Steeper watercourses will require protection from erosion using appropriate channel lining, detention dams, or controlled drops to dissipate flow energy.

17. All natural and unlined channels should be inspected for adequate binding of soil by sustainable ground cover. Stone pitching should be used to reinforce channel inverts on steep slopes. Existing wetlands and stormwater detention areas should be protected from encroachment by the development.

1.1 Locality

The proposed township is situated 145km north of Mbombela along the R40, in Mpumalanga Province, South Africa. The area is administered by Bushbuckridge Local Municipality under Ehlanzeni District Municipality. GPS coordinates of site are 24°39'30.99"S 31°24'34.87"E.

The locality map is shown on the figures below.

Figure 1 Location of development site

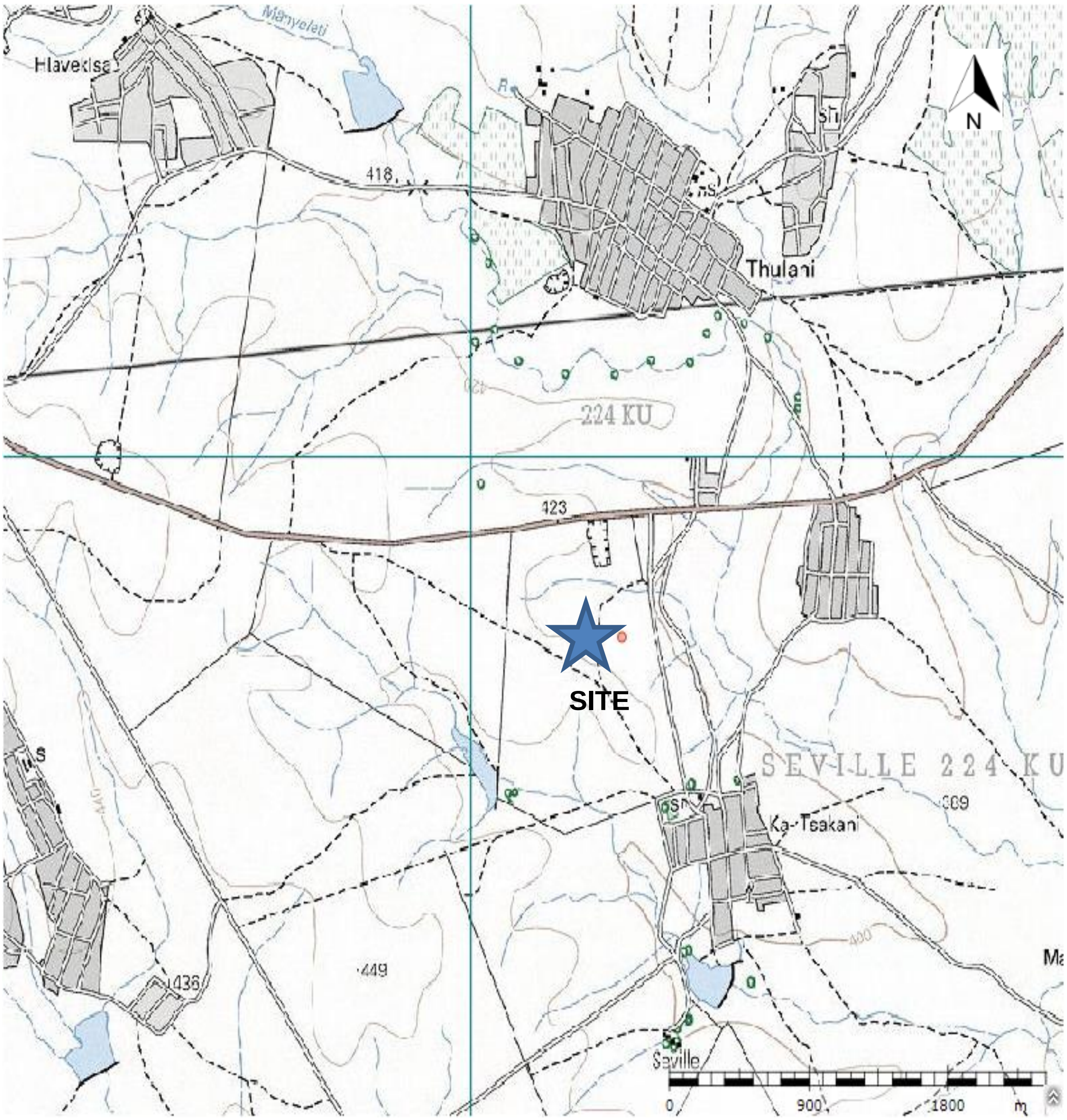


Figure 2 Project site

2.0 STORMWATER MANAGEMENT

2.1 Storm water Management

The objective of a storm water management plan should be to manage the storm water of the collective watersheds to:

- Prevent flood damage or concentration of run-off.
- Divert storm water and surface run-off from buildings, roads and parking areas into rainwater harvesting tanks, swales or a piped system flowing into a stormwater attenuation pond.
- Protect the stream and keep all construction outside the 1:100-year flood line
- Preserve the natural and beneficial functions of the natural drainage system downstream.
- Preserve and enhance storm water quality.
- Attenuate the difference between pre and post development flows.

The proposed storm water management system has been designed to be self-regulating with no external control. It will aim to collect run-off into rainwater harvesting tank, swales, underground pipes with an attenuation pond to attenuate and manage the increase in flow between the pre and post development stages from the transformed areas.

The run-off from the roofs, gutters and downpipes shall be collected in rainwater harvesting tanks considering any overflows being dispersed overland into swales and ultimately collected into underground stormwater systems and contained in two stormwater attenuation ponds. Hardened areas, like roads and parking areas will be routed overland, collected in kerbs and channels and into grid inlets or catchpits where it is collected in concrete stormwater pipes and diverted into the two stormwater attenuation ponds along the lower boundary of the site where increased flow will be attenuated, whilst silt is deposited. The stormwater attenuation ponds should be located along the lower end of the site, but outside the mainstream area to encourage the infiltration of stormwater, whilst silt is collected. The outlet or discharge from the attenuation pond will be protected with gabion mattresses and other energy dissipaters from where it will be released into the natural drainage areas and stream in a controlled manner.

2.2 Stormwater runoff

Current storm water runoff volumes are based on the following information and assumptions:

- Site Development Plan provided by the architect.
- Internal roads areas calculated from layout.
- The hardened transformed area for the proposed housing development.
- The use of grid inlets and storm water pipe network to collect, transport and divert run-off into the two attenuation ponds.
- Constructing two stormwater attenuation ponds along the lower portion of the site

2.3 Methods for design flood estimation

2.3.1. Rational Method

The Rational Method is widely used throughout the world for both small rural and urban catchments (Pilgrim and Cordery, 1993; Alexander, 2001) and is the most widely used method of estimating design flood peak discharges using design rainfall as input as it is easy to understand and simple to use (Parak and Pegram, 2006).The method is an approximate deterministic method and a major weakness is the judgement required to determine the appropriate runoff coefficient and the variability of the coefficients between different hydrological regimes (Pilgrim and Cordery, 1993).

The Rational Method computes only flood peaks and is sensitive to the input design rainfall intensity and the selection of the runoff coefficient which is based on the experience of the user. The method assumes that the peak discharge occurs when the duration of the rainfall event is equal to the time of concentration of the catchment and that the rainfall intensity does not vary and is distributed uniformly over the catchment. Because of these assumptions, the Rational Method is recommended to be applied on catchments with areas < 15 km^2 in South Africa (HRU, 1972).

The storm water run-off has been calculated using the accepted “Rational Method” that considers the drainage area, nature of the soil surface and the storm intensity.

The Rational Method is still probably the quickest and most used method of estimating the peak runoff value of stormwater run-off generated from urban and rural areas despite its limitations in application and accuracy.

The formula used in this method is: -

$Q = ft \times C \times I \times A/360$ cumecs
Where
Q = the maximum/peak rate of run-off in cumecs (m^3/s)
ft = an adjustment factor for the recurrence interval storm considered.
C= run-off coefficient (see applicable tables for determination)
I = the rainfall intensity (mm/hr.)
A = area of catchment in hectares (1 ha = 10 000m^2)

2.3.1.1 Area of catchment (A)

The area of catchment is the total area made up of 17 sub basins that will contribute to the run-off at that point, either from naturally occurring stream flow and from overland flow of the proposed development comprising of housing retail shops, secondary school and church.

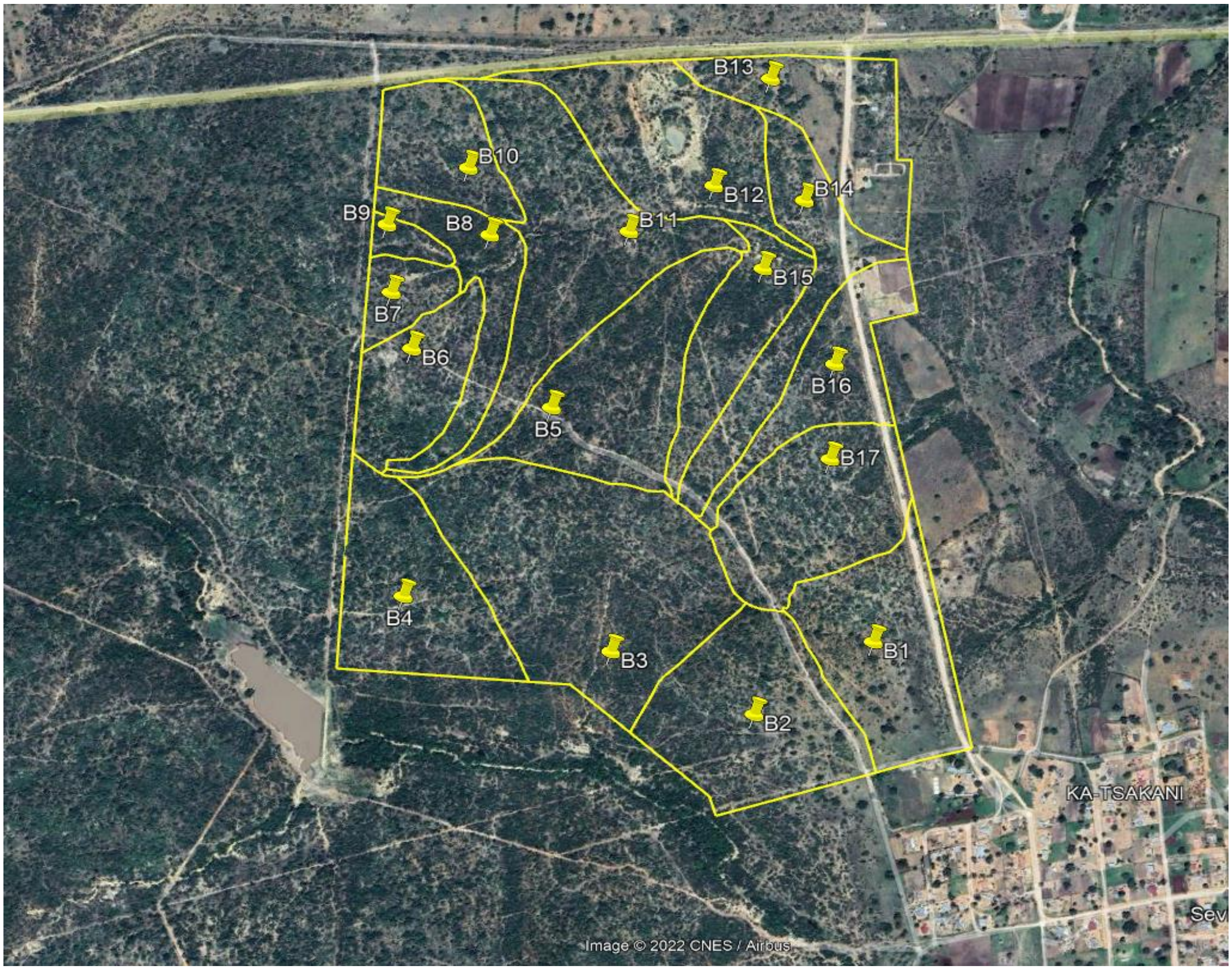


Figure 3: Sub catchment Areas

Catchment Characteristics

The catchment characteristics are shown the following tables below.

Table 1 Catchment Characteristic

Characteristic	Rural Distribution	Urban Distribution	Lakes Distribution	Total
Catchment	**%**	**%**	**%**	**(%)**
B1	100	0	0	100
B2	100	0	0	100
B3	100	0	0	100
B4	100	0	0	100
B5	100	0	0	100
B6	100	0	0	100
B7	100	0	0	100
B8	100	0	0	100
B9	100	0	0	100
B10	100	0	0	100
B11	100	0	0	100
B12	100	0	0	100
B13	100	0	0	100
B14	100	0	0	100
B15	100	0	0	100
B16	100	0	0	100
B17	100	0	0	100

Table 2 Rural area - Surface slope

Surface slope	Lakes and pans (<3%) Distribution	Flat area (3 to 10%) Distribution	Hilly (10 to 30%) Distribution	Steep areas (>30%) Distribution	Total
Catchment	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
B1	16%	77%	7%	0%	100%
B2	18%	80%	2%	0%	100%
B3	16%	83%	1%	0%	100%
B4	25%	61%	12%	2%	100%
B5	11%	89%	0%	0%	100%
B6	18%	81%	1%	0%	100%
B7	25%	74%	1%	0%	100%
B8	11%	87%	2%	0%	100%
B9	6%	92%	2%	0%	100%
B10	10%	88%	2%	0%	100%
B11	20%	79%	1%	0%	100%
B12	27%	73%	0%	0%	100%
B13	28%	72%	0%	0%	100%
B14	9%	88%	3%	0%	100%
B15	9%	88%	3%	0%	100%
B16	9%	88%	3%	0%	100%
B17	16%	83%	1%	0%	100%

Table 3 Rural area – Permeability

Rural area - Permeability	**Very permeable**	**Permeable**	**Semi-permeable**	**Impermeable**	**Total**
	Distribution	**Distribution**	**Distribution**	**Distribution**	
Catchment	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
B1	0%	0%	100%	0%	100%
B2	0%	0%	100%	0%	100%
B3	0%	0%	100%	0%	100%
B4	0%	0%	100%	0%	100%
B5	0%	0%	100%	0%	100%
B6	0%	0%	100%	0%	100%
B7	0%	0%	100%	0%	100%
B8	0%	0%	100%	0%	100%
B9	0%	0%	100%	0%	100%
B10	0%	0%	100%	0%	100%
B11	0%	0%	100%	0%	100%
B12	0%	0%	100%	0%	100%
B13	0%	0%	100%	0%	100%
B14	0%	0%	100%	0%	100%
B15	0%	0%	100%	0%	100%
B16	0%	0%	100%	0%	100%
B17	0%	0%	100%	0%	100%

Table 4 Rural area - Vegetation

Rural area - Vegetation	**Thick bush & forests**	**Light bush & cultivated land**	**Grasslands**	**Bare**	**Total**
	Distribution	**Distribution**	**Distribution**	**Distribution**	
Catchment			(%)		
B1	100%	0%	0%	0%	100%
B2	100%	0%	0%	0%	100%
B3	100%	0%	0%	0%	100%
B4	100%	0%	0%	0%	100%
B5	100%	0%	0%	0%	100%
B6	100%	0%	0%	0%	100%
B7	100%	0%	0%	0%	100%
B8	100%	0%	0%	0%	100%
B9	100%	0%	0%	0%	100%
B10	100%	0%	0%	0%	100%
B11	100%	0%	0%	0%	100%
B12	100%	0%	0%	0%	100%
B13	100%	0%	0%	0%	100%
B14	100%	0%	0%	0%	100%
B15	100%	0%	0%	0%	100%
B16	100%	0%	0%	0%	100%
B17	100%	0%	0%	0%	100%

2.3.1.2 Time of concentration (Tc)

The time of concentration can be regarded as the time it takes for the excess rainfall resulting in run-off from the furthest significant part of a natural catchment to reach the point being considered. The shape of the catchment has significant implications on assessing the length of the flow path.

Since the development in the area the catchments are relatively small (< 1 km square) we advocate using a minimum time of concentration of 15 minutes for all undeveloped/rural/residential type sites. In other words, if the calculated time of concentration for a residential site is less than 15 minutes use 15 minutes, and where a site is predominantly hardened i.e., fully developed commercial/industrial sites) a minimum of 10 mins if the calculated time of concentration is less.

Each of the fourteen (17) sub catchment have areas less that 1km^2, therefore the adopted time of concentration are 15minutes and 10 minutes for predevelopment area and post development respectively as outlined in the table 5 below.

Table 5: Time of Concentration Values

Catchment	Zoning		Slope (%)	Time of Concentration	
	(ha)	Km^2		Predevelopment	Post development
B1	10.42	0.104	5.54	15	10
B2	12.21	0.122	2.66	15	10
B3	20.40	0.204	3.06	15	10
B4	9.95	0.0995	3.40	15	10
B5	11.16	0.112	3.07	15	10
B6	5.75	0.0575	3.17	15	10
B7	2.33	0.0233	3.68	15	10
B8	5.38	0.0538	4.49	15	10
B9	1.02	0.0102	5.02	15	10
B10	5.31	0.0531	4.90	15	10
B11	14.34	0.143	1.95	15	10
B12	10.44	0.104	1.41	15	10
B13	8.11	0.081	1.57	15	10
B14	7.81	0.0781	3.27	15	10
B15	5.94	0.0594	3.78	15	10
B16	6.49	0.065	4.14	15	10
B17	10.12	0.101	5.28	15	10

2.3.1.3 Run-off coefficient (C)

The run-off coefficient is a factor ranging between 0 and 1 which compensates for variations in rainfall over the catchment, infiltration and overland flow velocity during a storm, the shape of the catchment, ground slope, etc. Because of various indeterminate factors including ground moisture content, vegetation, permeability of soils, varying slopes, rainfall intensity etcetera, the coefficient 'C' is difficult to assess and a widely diverging range of estimated runoff coefficients can result. To minimize widely disparate results and allow for uniformity and consistency in approach, the table method used by the Dept of Water Affairs & Sanitation (DWS) will be used.

C can be derived from applicable tables for determination. Where several catchments or sub-catchments contribute runoff to the point under consideration then unless C is uniform for all (i.e., the same slopes and vegetation etc. exist) then a modified C applies which must be calculated as follows:

Coverall = (Sum of Ci x Ai)/(Sum of Ai) for all of the differing sub-catchments "i".

For undeveloped sites, the value for 'C' must be derived from the sum of the contributions of the ground slope Cs, the vegetative cover Cv and the permeability or soil type Cp. In urban/industrial areas a combination of the percentage area contribution of the hardened areas and the balance of the site area assessed in terms of Cs, Cy and Cp above is logical/appropriate:

Ci for the catchment "i" = C_{si} + C_{vi} + Cpi

Ci may be considered to remain constant during any storm for smaller catchments (<5 km^2). However, we do advocate using a modification factor ft to reduce the runoff for lower order storms.

Table 6 : Modification factors for Runoff Coefficient

RI Storm year	**Reduction Factor f_t**
2 year	0.5
5 year	0.55
10 year	0.6
20year	0.67
50 year	0.83
100 year	1

Table 7: Reduction Factors for Runoff Coefficient

Catchment	Zoning		Slope (%)	Reduction Factor f_t			
	(ha)	Km^2		1-5yr	1-10yr	1-50yr	1-100yr
B1	10.42	0.104	5.54	0.55	0.6	0.83	1
B2	12.21	0.122	2.66	0.55	0.6	0.83	1
B3	20.40	0.204	3.06	0.55	0.6	0.83	1
B4	9.95	0.0995	3.40	0.55	0.6	0.83	1
B5	11.16	0.112	3.07	0.55	0.6	0.83	1
B6	5.75	0.0575	3.17	0.55	0.6	0.83	1
B7	2.33	0.0233	3.68	0.55	0.6	0.83	1
B8	5.38	0.0538	4.49	0.55	0.6	0.83	1
B9	1.02	0.0102	5.02	0.55	0.6	0.83	1
B10	5.31	0.0531	4.90	0.55	0.6	0.83	1
B11	14.34	0.143	1.95	0.55	0.6	0.83	1
B12	10.44	0.104	1.41	0.55	0.6	0.83	1
B13	8.11	0.081	1.57	0.55	0.6	0.83	1
B14	7.81	0.0781	3.27	0.55	0.6	0.83	1
B15	5.94	0.0594	3.78	0.55	0.6	0.83	1
B16	6.49	0.065	4.14	0.55	0.6	0.83	1
B17	10.12	0.101	5.28	0.55	0.6	0.83	1

Table 8: DWS Predevelopment and Post development runoff coefficients

PRE-RUNOFF COEFFICIENT			POST RUNOFF COEFFICIENT		
RURAL			**URBAN**	%	
Steepness/Slope Cs	**%** **C**	> 900mm	Lawn sandy<2%	0	0.08
< 3%	9	0.05	Lawn sandy<7%	0	0.18
3-10 %	100	0.11	Lawn heavy<2%	0	0.15
10 - 30 %	0	0.2	Public open space	2.88	0.3
> 30 %	0	0.3	Residential single	62.47	0.4
Cs	**100**	**0.11**	Flats/church/creche/Primary school	8.14	0.6
			Industry, light	0	0.65
Permeability Cp	**%** **C**		Industry, heavy	0	0.7
Very perm (Dunes)	0	0.05	Business local	0.92	0.6
Perm (light soil)	0	0.1	Business CBD	0	0.85
Semi (most soils)	100	0.2	Streets/roofs	25.59	0.95
Imperm (rock, paving)	0	0.3			
Cp	**100**	**0.2**		100	0.95
Vegetal growth Cv	**%** **C**				0.6
			AREA WEIGHTING FACTORS		
Dense bush, forest	100	0.05		%	DWA
Cult land, sparse bush	0	0.15	RURAL	0	0.57
Grassland	0	0.25	URBAN	100	0.95

Bare Surface	0	0.3	LAKES	0	0.00
Cv	**100**	0.05	C post/design	100	0.95
Ct = Cs + Cp + Cv =		**0.36**			

Table 9: Overall Runoff coefficients (C) for Predevelopment and Post development

Catchment	**Zoning**		**Slope (%)**	**PRE-RUNOFF COEFFICIENT**					**POST RUNOFF COEFFICIENT**					
	(ha)	**Km²**		**Cs**	**Cp**	**Cv**	**Ct**	**Residential**	**shops**	**Streets**	**Secondary school**	**Church**	**Open Space**	**Coverall**
B1	10.42	0.104	5.54	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0.6	0.6	0.3	**0.61**
B2	12.21	0.122	2.66	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0	0	0.3	**0.61**
B3	20.40	0.204	3.06	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0	0.6	0.3	**0.61**
B4	9.95	0.0995	3.40	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0.6	0	0	**0.69**
B5	11.16	0.112	3.07	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0.3	**0.62**
B6	5.75	0.0575	3.17	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0.6	0.6	0.3	**0.61**
B7	2.33	0.0233	3.68	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0.3	**0.62**
B8	5.38	0.0538	4.49	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0	0	0.3	**0.61**
B9	1.02	0.0102	5.02	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0	**0.78**
B10	5.31	0.0531	4.90	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0	**0.78**
B11	14.34	0.143	1.95	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0.3	**0.62**
B12	10.44	0.104	1.41	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0.3	**0.62**
B13	8.11	0.081	1.57	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0	0	0	**0.72**
B14	7.81	0.0781	3.27	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0.6	0	0	**0.69**
B15	5.94	0.0594	3.78	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0	0	**0.78**
B16	6.49	0.065	4.14	0.11	0.2	0.05	**0.36**	0.6	0.6	0.95	0.6	0	0.3	**0.61**
B17	10.12	0.101	5.28	0.11	0.2	0.05	**0.36**	0.6	0	0.95	0	0.6	0	**0.72**

2.3.1.4 Rainfall figures

The rainfall figures in mm for the project area for the design are given in the table 10 below.

Table 10: Rainfall data of the project site

Duration		RETURN PERIOD(YEARS) DESIGN RAINFALL DEPTH(mm)					
		1:2	**1:5**	**1:10**	**1:20**	**1:50**	**1:100**
5	min	8.2	11.4	13.9	16.5	20.3	23.6
10	min	13.4	18.6	22.6	26.9	33.2	38.5
15	min	17.9	24.8	30.2	35.9	44.2	51.3
30	min	25	34.8	42.3	50.3	62	71.9
45	min	30.5	42.4	51.5	61.2	75.5	87.6
1	hr	35.1	48.8	59.3	70.5	86.9	100.7
1.5	hr	42.8	59.5	72.2	85.9	105.8	122.8
2	hr	49.2	68.4	83.1	98.8	121.8	141.3
4	hr	57.8	80.3	97.5	115.9	142.9	165.7
6	hr	63.4	88.2	107	127.3	156.9	181.9
8	hr	67.8	94.2	114.4	136	167.6	194.4
10	hr	71.3	99.2	120.4	143.2	176.4	204.7
12	hr	74.4	103.4	125.6	149.3	184	213.4
16	hr	79.5	110.5	134.2	159.5	196.6	228.1
20	hr	83.7	116.3	141.3	167.9	207	240.1
24	hr	87.3	121.3	147.3	175.1	215.9	250.4
1	day	72.4	100.6	122.2	145.3	179.1	207.7
2	days	91.1	126.6	153.7	182.8	225.3	261.3
3	days	104.2	144.8	175.8	209	257.6	298.8
4	days	114.1	158.6	192.6	229	282.2	327.4
5	days	122.5	170.3	206.7	245.8	303	351.4
6	days	129.8	180.4	219.1	260.4	321	372.3
7	days	136.3	189.4	230	273.5	337.1	391

2.3.1.4 Rainfall Intensity 'I'

The rainfall intensity is the average rainfall in mm/hr for a design storm of a given frequency having a duration equal to the Time of Concentration Tc. The intensity duration figures for the project area are given in the table 11 below.

Table 11: Design Rainfall Intensity values for the site

Tc		Return Period (Years) Design Rainfall Intensity (mm/hr)					
		1:2	**1:5**	**1:10**	**1:20**	**1:50**	**1:100**
10	min	80.4	112	136	161	199	231
15	min	71.6	99.2	121	144	177	205

2.3.1.4.1 Determination of Intensity duration in mm/hr.

The intensity duration in mm/hr. given in the table below for the predevelopment and post development was determined using the rainfall data given in the above table for

15minutes and 10minutes rainfall intensities for 1-2yr,1-5 yr,1-10yr,1-20yr,1-50yr and 1-100yr.

2.3.1.4.2 Calculation of stormwater volumes and flow rates

Table 12: 1:2 Year RP Generated Storms

Catchment	PRE-DEVELOPMENT						POST DEVELOPMENT					
	C=C x ft	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)	C	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)
B1	0.18	71.6	10.42	0.37	15	336	0.61	80.4	10.42	1.42	10	852
B2	0.18	71.6	12.21	0.44	15	393	0.61	80.4	12.21	1.66	10	998
B3	0.18	71.6	20.4	0.73	15	657	0.61	80.4	20.4	2.78	10	1667
B4	0.18	71.6	9.95	0.36	15	321	0.69	80.4	9.95	1.53	10	920
B5	0.18	71.6	11.16	0.40	15	360	0.62	80.4	11.16	1.55	10	927
B6	0.18	71.6	5.75	0.21	15	185	0.61	80.4	5.75	0.78	10	470
B7	0.18	71.6	2.33	0.08	15	75	0.62	80.4	2.33	0.32	10	194
B8	0.18	71.6	5.38	0.19	15	173	0.61	80.4	5.38	0.73	10	440
B9	0.18	71.6	1.02	0.04	15	33	0.78	80.4	1.02	0.18	10	107
B10	0.18	71.6	5.31	0.19	15	171	0.78	80.4	5.31	0.93	10	555
B11	0.18	71.6	14.34	0.51	15	462	0.62	80.4	14.34	1.99	10	1191
B12	0.18	71.6	10.44	0.37	15	336	0.62	80.4	10.44	1.45	10	867
B13	0.18	71.6	8.11	0.29	15	261	0.72	80.4	8.11	1.30	10	782
B14	0.18	71.6	7.81	0.28	15	252	0.69	80.4	7.81	1.20	10	722
B15	0.18	71.6	5.94	0.21	15	191	0.78	80.4	5.94	1.03	10	621
B16	0.18	71.6	6.49	0.23	15	209	0.61	80.4	6.49	0.88	10	530
B17	0.18	71.6	10.12	0.36	15	326	0.72	80.4	10.12	1.63	10	976

Table 13: 1:5 YEAR RP Generated Storms

Catchment	PRE-DEVELOPMENT						POST DEVELOPMENT					
	C=C x ft	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)	C	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)
B1	0.198	99.2	10.42	0.57	15	512	0.61	112	10.42	1.98	10	1186
B2	0.198	99.2	12.21	0.67	15	600	0.61	112	12.21	2.32	10	1390
B3	0.198	99.2	20.4	1.11	15	1002	0.61	112	20.4	3.87	10	2323
B4	0.198	99.2	9.95	0.54	15	489	0.69	112	9.95	2.14	10	1282
B5	0.198	99.2	11.16	0.61	15	548	0.62	112	11.16	2.15	10	1292
B6	0.198	99.2	5.75	0.31	15	282	0.61	112	5.75	1.09	10	655
B7	0.198	99.2	2.33	0.13	15	114	0.62	112	2.33	0.45	10	270
B8	0.198	99.2	5.38	0.29	15	264	0.61	112	5.38	1.02	10	613
B9	0.198	99.2	1.02	0.06	15	50	0.78	112	1.02	0.25	10	149
B10	0.198	99.2	5.31	0.29	15	261	0.78	112	5.31	1.29	10	773
B11	0.198	99.2	14.34	0.78	15	704	0.62	112	14.34	2.77	10	1660
B12	0.198	99.2	10.44	0.57	15	513	0.62	112	10.44	2.01	10	1208
B13	0.198	99.2	8.11	0.44	15	398	0.72	112	8.11	1.82	10	1090
B14	0.198	99.2	7.81	0.43	15	384	0.69	112	7.81	1.68	10	1006
B15	0.198	99.2	5.94	0.32	15	292	0.78	112	5.94	1.44	10	865
B16	0.198	99.2	6.49	0.35	15	319	0.61	112	6.49	1.23	10	739
B17	0.198	99.2	10.12	0.55	15	497	0.72	112	10.12	2.27	10	1360

Table 14: 1:10 YEAR RP Generated Storms

Catchment	PRE-DEVELOPMENT						POST DEVELOPMENT					
	C=C x ft	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)	C	I (mm/hr.)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)
B1	0.216	121	10.42	0.76	15	681	0.61	136	10.42	2.40	10	1441
B2	0.216	121	12.21	0.89	15	798	0.61	136	12.21	2.81	10	1688
B3	0.216	121	20.4	1.48	15	1333	0.61	136	20.4	4.70	10	2821
B4	0.216	121	9.95	0.72	15	650	0.69	136	9.95	2.59	10	1556
B5	0.216	121	11.16	0.81	15	729	0.62	136	11.16	2.61	10	1568
B6	0.216	121	5.75	0.42	15	376	0.61	136	5.75	1.33	10	795
B7	0.216	121	2.33	0.17	15	152	0.62	136	2.33	0.55	10	327
B8	0.216	121	5.38	0.39	15	352	0.61	136	5.38	1.24	10	744
B9	0.216	121	1.02	0.07	15	67	0.78	136	1.02	0.30	10	180
B10	0.216	121	5.31	0.39	15	347	0.78	136	5.31	1.56	10	939
B11	0.216	121	14.34	1.04	15	937	0.62	136	14.34	3.36	10	2015
B12	0.216	121	10.44	0.76	15	682	0.62	136	10.44	2.45	10	1467
B13	0.216	121	8.11	0.59	15	530	0.72	136	8.11	2.21	10	1324
B14	0.216	121	7.81	0.57	15	510	0.69	136	7.81	2.04	10	1221
B15	0.216	121	5.94	0.43	15	388	0.78	136	5.94	1.75	10	1050
B16	0.216	121	6.49	0.47	15	424	0.61	136	6.49	1.50	10	897
B17	0.216	121	10.12	0.73	15	661	0.72	136	10.12	2.75	10	1652

Table 15: 1:20 YEAR RP Generated Storms

Catchment	PRE-DEVELOPMENT						POST DEVELOPMENT					
	C=C x ft	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)	C	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)
B1	0.2412	144	10.42	1.01	15	905	0.61	161	10.42	2.84	10	1706
B2	0.2412	144	12.21	1.18	15	1060	0.61	161	12.21	3.33	10	1999
B3	0.2412	144	20.4	1.97	15	1771	0.61	161	20.4	5.57	10	3339
B4	0.2412	144	9.95	0.96	15	864	0.69	161	9.95	3.07	10	1842
B5	0.2412	144	11.16	1.08	15	969	0.62	161	11.16	3.09	10	1857
B6	0.2412	144	5.75	0.55	15	499	0.61	161	5.75	1.57	10	941
B7	0.2412	144	2.33	0.22	15	202	0.62	161	2.33	0.65	10	388
B8	0.2412	144	5.38	0.52	15	467	0.61	161	5.38	1.47	10	881
B9	0.2412	144	1.02	0.10	15	89	0.78	161	1.02	0.36	10	213
B10	0.2412	144	5.31	0.51	15	461	0.78	161	5.31	1.85	10	1111
B11	0.2412	144	14.34	1.38	15	1245	0.62	161	14.34	3.98	10	2386
B12	0.2412	144	10.44	1.01	15	907	0.62	161	10.44	2.89	10	1737
B13	0.2412	144	8.11	0.78	15	704	0.72	161	8.11	2.61	10	1567
B14	0.2412	144	7.81	0.75	15	678	0.69	161	7.81	2.41	10	1446
B15	0.2412	144	5.94	0.57	15	516	0.78	161	5.94	2.07	10	1243
B16	0.2412	144	6.49	0.63	15	564	0.61	161	6.49	1.77	10	1062
B17	0.2412	144	10.12	0.98	15	879	0.72	161	10.12	3.26	10	1955

Table 16: 1:50 YEAR RP Generated Storms

Catchment	PRE-DEVELOPMENT						POST DEVELOPMENT					
	C=C x ft	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)	C	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)
B1	0.2988	177	10.42	1.53	15	1378	0.61	199	10.42	3.51	10	2108
B2	0.2988	177	12.21	1.79	15	1614	0.61	199	12.21	4.12	10	2470
B3	0.2988	177	20.4	3.00	15	2697	0.61	199	20.4	6.88	10	4127
B4	0.2988	177	9.95	1.46	15	1316	0.69	199	9.95	3.80	10	2277
B5	0.2988	177	11.16	1.64	15	1476	0.62	199	11.16	3.82	10	2295
B6	0.2988	177	5.75	0.84	15	760	0.61	199	5.75	1.94	10	1163
B7	0.2988	177	2.33	0.34	15	308	0.62	199	2.33	0.80	10	479
B8	0.2988	177	5.38	0.79	15	711	0.61	199	5.38	1.81	10	1088
B9	0.2988	177	1.02	0.15	15	135	0.78	199	1.02	0.44	10	264
B10	0.2988	177	5.31	0.78	15	702	0.78	199	5.31	2.29	10	1374
B11	0.2988	177	14.34	2.11	15	1896	0.62	199	14.34	4.91	10	2949
B12	0.2988	177	10.44	1.53	15	1380	0.62	199	10.44	3.58	10	2147
B13	0.2988	177	8.11	1.19	15	1072	0.72	199	8.11	3.23	10	1937
B14	0.2988	177	7.81	1.15	15	1033	0.69	199	7.81	2.98	10	1787
B15	0.2988	177	5.94	0.87	15	785	0.78	199	5.94	2.56	10	1537
B16	0.2988	177	6.49	0.95	15	858	0.61	199	6.49	2.19	10	1313
B17	0.2988	177	10.12	1.49	15	1338	0.72	199	10.12	4.03	10	2417

Table 17: 1:100 YEAR RP Generated Storms

Catchment	PRE-DEVELOPMENT						POST DEVELOPMENT					
	C	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)	C	I (mm/hr)	A (ha)	Q (m^3/s)	Tc (min.)	Volume (m^3)
B1	0.36	205	10.42	2.14	15	1922	0.61	231	10.42	4.08	10	2447
B2	0.36	205	12.21	2.50	15	2253	0.61	231	12.21	4.78	10	2868
B3	0.36	205	20.4	4.18	15	3764	0.61	231	20.4	7.98	10	4791
B4	0.36	205	9.95	2.04	15	1836	0.69	231	9.95	4.41	10	2643
B5	0.36	205	11.16	2.29	15	2059	0.62	231	11.16	4.44	10	2664
B6	0.36	205	5.75	1.18	15	1061	0.61	231	5.75	2.25	10	1350
B7	0.36	205	2.33	0.48	15	430	0.62	231	2.33	0.93	10	556
B8	0.36	205	5.38	1.10	15	993	0.61	231	5.38	2.11	10	1263
B9	0.36	205	1.02	0.21	15	188	0.78	231	1.02	0.51	10	306
B10	0.36	205	5.31	1.09	15	980	0.78	231	5.31	2.66	10	1595
B11	0.36	205	14.34	2.94	15	2646	0.62	231	14.34	5.70	10	3423
B12	0.36	205	10.44	2.14	15	1926	0.62	231	10.44	4.15	10	2492
B13	0.36	205	8.11	1.66	15	1496	0.72	231	8.11	3.75	10	2248
B14	0.36	205	7.81	1.60	15	1441	0.69	231	7.81	3.46	10	2075
B15	0.36	205	5.94	1.22	15	1096	0.78	231	5.94	2.97	10	1784
B16	0.36	205	6.49	1.33	15	1197	0.61	231	6.49	2.54	10	1524
B17	0.36	205	10.12	2.07	15	1867	0.72	231	10.12	4.68	10	2805

2.4 Proposed Storm Attenuation Measures for protection of streams and nearby community

2.4.1 Attenuation measures per sub catchment area

The design storm flows for the project area of the housing development are given in table 18 and 19 below and layout details of the proposed attenuation measures within the sub catchment basins are in the attached layout drawing in annexure 2.

Table 18: Design Flow of stormwater attenuation structures for 1-50yr Return Period

Swale Reference No	Catchment	DESIGN FLOW 1-50YR Storm Flow (m^3/s)	Total Storm Flow(m^3/s)	Total Attenuation Volume(m^3)	Total Attenuation Volume(m^3)
S1	50% B17	2.015	2.015	1209	1209
S2	50% B17	2.015	2.015	1209	1209
S3	50% B1	1.755	1.755	1054	1054
S4	50% B1	1.755	1.755	1054	1054
S5	50% B2	2.06	2.06	12.35	12.35
S6	50% B2	2.06	2.06	12.35	12.35
S7	B4	3.8	3.8	2277	2277
S8	B3	6.88	6.88	4127	4127
S9	B6	1.94	1.94	1163	1163
S10	B7	0.8	2.61	479	1567
	B8	1.81		1088	
S11	B9	0.44	0.44	264	264
S12	B10	2.29	2.29	1374	1374
S13	B5	3.82	3.82	2295	2295
S14	B6	1.94	7.28	1163	4368
	B7	0.8		479	
	B8	1.81		1088	
	B9	0.44		264	
	B10	2.29		1374	
S15	B12	3.58	3.58	2147	2147
S16	50% B13	1.095	1.095	968.5	968.5
S17	S13	3.82	20.22	2295	12134
	S14	7.28		4368	
	S15	3.58		2147	
	B14	2.98		1787	
	B15	2.56		1537	
S18	50% B13	1.615	1.615	968.5	968.5
S19	B16	2.19	2.19	1313	1313

Table 19: Design Flow of stormwater attenuation structures for 1-100yr Return Period

Swale Reference No	Catchment	DESIGN FLOW 1-100YR Storm Flow (m^3/s)	Total Storm Flow(m^3/s)	Total Attenuation Volume(m^3)	Total Attenuation Volume(m^3)
S1	50% B17	2.34	2.34	1403	1403
S2	50% B17	2.34	2.34	1403	1403
S3	50% B1	2.04	2.04	1224	1224
S4	50% B1	2.04	2.04	1224	1224
S5	50% B2	2.39	2.39	1434	1434
S6	50% B2	2.39	2.39	1434	1434
S7	B4	4.41	4.41	2643	2643
S8	B3	7.98	7.98	4791	4791
S9	B6	2.25	2.25	1350	1350
S10	B7	0.93	3.04	556	1819
	B8	2.11		1263	
S11	B9	0.51	0.51	306	306
S12	B10	2.66	2.66	1595	1595
S13	B5	4.44	4.44	2664	2664
S14	B6	2.25	8.46	1350	5070
	B7	0.93		556	
	B8	2.11		1263	
	B9	0.51		306	
	B10	2.66		1595	
S15	B12	4.15	4.15	2492	2492
S16	50% B13	1.875	1.875	1124	1124
S17	S13	4.44	23.48	2664	14085
	S14	8.46		5070	
	S15	4.15		2492	
	B14	3.46		2075	
	B15	2.97		1784	
S18	50% B13	1.875	1.875	1124	1124
S19	B16	2.54	2.54	1524	1524

2.4.2 Attenuation measures at discharge points

The design storm flows for the project area of the housing development are given in table 20 and 21 below and layout details of the proposed attenuation measures at discharge points are in the attached layout drawing in annexure 2.

Table 20 : Recommended Attenuation Measures at discharge points for 1-50yr storm

Stream	**Catchment**	**POST DEVELOPMENT ESTIMATED STORM**				
		1-50YR				
		Storm Flow rate(m^3/s)	**Total storm flow(m^3/s)**	**Attenuation Storm Volume (m^3)**	**Total Attenuation Storm Volume (m^3)**	**Attenuation Measure before the Stream Reach**
1	B2	4.12	4.12	24.70	24.7	Swale and Energy dissipator
2	B3	6.88	10.68	4127	6404	Swale and Energy dissipator
	B4	3.80		2277		
3	B1	3.51	3.51	2108	2108	Swale and Energy dissipator
4	B16	2.19	6.22	1313	3730	Swale and Energy dissipator
	B17	4.03		2417		
5	B5	3.82	25.13	2295	15083	Swale and Energy dissipator
	B6	1.94		1163		
	B7	0.80		479		
	B8	1.81		1088		
	B9	0.44		264		
	B10	2.29		1374		
	B11	4.91		2949		
	B12	3.58		2147		
	B14	2.98		1787		
	B15	2.56		1537		
6	B13	3.23	3.23	1937	1937	Swale and Energy dissipator

Table 21 : Recommended Attenuation Measures at discharge points for 1-100yr Storm

Stream	**Catchment**	**POST DEVELOPMENT ESTIMATED STORM 1-100YR**				
		Storm Flow rate(m^3/s)	**Total storm flow(m^3/s)**	**Attenuation Storm Volume (m^3)**	**Total Attenuation Storm Volume (m^3)**	**Attenuation Measure before the Stream Reach**
1	B2	4.78	4.78	2868	2868	Swale and Energy dissipator
2	B3	7.98	12.39	4791	7434	Swale and Energy dissipator
	B4	4.41		2643		
3	B1	4.08	4.08	2447	2447	Swale and Energy dissipator
4	B16	2.54	7.22	1524	4329	Swale and Energy dissipator
	B17	4.68		2805		
5	B5	4.44	29.18	2664	17508	Swale and Energy dissipator
	B6	2.25		1350		
	B7	0.93		556		
	B8	2.11		1263		
	B9	0.51		306		
	B10	2.66		1595		
	B11	5.70		3423		
	B12	4.15		2492		
	B14	3.46		2075		
	B15	2.97		1784		
6	B13	3.75	3.75	2248	2248	Swale and Energy dissipator

3.0. GUIDELINES FOR OWNERS AND DEVELOPERS

All sub-developments within the housing development will be required to control stormwater runoff in accordance with the stormwater management philosophy and policies of the Municipality.

The following guidelines are intended to assist developers, owners, and their professional teams with the planning of site layouts, the design of the major and minor stormwater systems infrastructure and to ensure that the objectives of this Stormwater Management Plan are met during the planning, design, construction and operational phases of all developments.

Where prescriptive wording is adopted, the guideline shall be accepted and implemented as a rule.

3.1 Stormwater Runoff Control

Formal surface and underground stormwater systems are provided in the overall development for the acceptance of stormwater drainage from industrial sites, but it is important that the peak runoff rate from sites does not exceed the hydraulic capacities of the elements in the major stormwater system. The following are general guidelines for stormwater control from sites.

3.1.1 Buildings

a) Any building will inevitably result in some degree of flow concentration, or deflection of flow around the building.

b) The developer/owner shall ensure that the flow path of the stormwater on his site is adequately protected against erosion and is sufficiently roughened to retard stormwater flow to the same degree, or more, as that found in the natural predevelopment state of the site.

c) Where the construction of a building causes a change in the natural flora of the site that might result in soil erosion, the risk of soil erosion by stormwater must be eliminated by the provision of approved artificial soil stabilisation devices, or alternative flora suited to the changed conditions on the site.

d) No building works, earthworks, walls or fences may obstruct or encroach on a watercourse inside or outside the site without approved plans that do not compromise the objectives of the Stormwater Management Plan.

3.1.2 Roof Drainage

a) Building designs must ensure that rainfall runoff from roofing and other areas, not subjected to excessive pollution, must be efficiently captured for re-use where possible for on-site irrigation and non-potable water uses.

b) Where ground conditions permit, rainwater runoff that is not stored and utilised on site must be connected to infiltration galleries or trenches designed to maximise groundwater recharge. Infiltration facilities must be large enough to contain at least the first hour of a minor storm's runoff without overflowing.

c) Infiltration trenches must be aligned along the contour on the downstream side of the property such that any spillage during major storms results in sheet overland flow.

d) Where a piped stormwater system has been provided to a property, surplus runoff should be connected to this system. Garden and other debris must be trapped on screens or gratings before entering the local development's stormwater system.

3.1.3 Parking Areas and Yards

a) Any external parking area, yard or other paved area must be designed to attenuate stormwater runoff from a major storm to an acceptable degree.

b) Any area described in (a) must discharge rainwater flowing over, or falling onto its surface, in a controlled manner either overland as sheet flow, or into a detention facility, or infiltration gallery suitably sized to accommodate minor storm runoff.

3.1.4 Driveways

a) Driveways shall not be constructed to deflect or channel runoff onto a roadway, or to concentrate runoff along a particular path that is not a natural water course, without prior consent.

b) Driveways and paths should be designed and constructed such that the rate of flow of stormwater across and along the driveway or path is not increased when compared with the pre-development state.

c) Where the driveway joins the road, the driveway must not obstruct the flow in any open channel, whether lined or unlined, found along the road verge.

3.1.5 Roads

a) The principle of overland flow should apply to roadways where possible and roads should be designed and graded to avoid concentration of flow along and off the road.

b) Where flow concentration is unavoidable, measures to incorporate the road into the major stormwater system should be taken, with the provision of detention storage facilities at suitable points.

c) Inlet structures at culverts must be designed to ensure that the capacity of the culvert does not exceed the pre-development stormwater flow at that point and detention storage should be provided on the road and/or upstream of the stormwater culvert.

d) Outlet structures at a road culvert or a natural watercourse must be designed to dissipate flow energy and any unlined downstream channel must be adequately protected against soil erosion.

3.1.6 Stormwater Storage Facilities

a) The sufficiency and effectiveness of on-site detention storage to meet stormwater attenuation requirements within the minor and major stormwater systems is the responsibility of the property owner.

b) Any detention pond shall be integrated with the landscape on the site.

c) Detention ponds shall be maintained in good condition and shall not be permitted to become a health hazard or nuisance.

d) The Municipality shall have the right to inspect any stormwater drainage control facility at any time and issue instructions for repair and maintenance works deemed to be necessary, which instructions must be carried out within the prescribed period.

3.1.7 Subsurface Disposal of Stormwater

a) Any construction providing for the subsurface disposal of stormwater should be designed to ensure that such disposal does not cause slope instability, or areas of concentrated saturation or inundation.

b) Infiltration structures should be integrated into the terrain so as to be unobtrusive and in keeping with the natural surroundings.

3.1.8 Channels

a) Lined and unlined channels may be constructed to convey stormwater to a natural watercourse where deemed necessary and unavoidable.

b) Channels must be constructed with rough artificial surfaces, or lined with suitable, hardy vegetation, to be non-erodible and to provide maximum possible energy dissipation to the flow.

3.1.9 Energy Dissipaters

a) Measures should be taken to dissipate flow energy wherever concentrated stormwater flow is discharged down an embankment or erodible slope and the resulting supercritical flow poses a significant risk to the stability of the waterway.

b) Attenuation dams should be provided at the head of the energy dissipating structure if possible.

c) A means of dissipating energy must be provided at the outfall of any drop structure to ensure stormwater flow is returned to a safe sub-critical state, or to disperse the flow.

3.1.10 Flow Retarders

a) Stormwater flow should be retarded wherever possible using surface roughening or other flow restricting devices, provided these are designed and built to avoid blockages that could result in environmental and structural damage.

b) All such constructions must be regularly maintained by the owner and may be inspected at any time by the Municipality or their appointed representatives.

3.2 Stormwater Pollution Control

a) All property owners and developers shall ensure that no materials, fluids or substances are allowed to enter the stormwater system that could have a detrimental effect on the flora, fauna and aquatic life in the water courses, wetlands and dams.

b) Regular monitoring of sites within the catchment should be undertaken by the Municipality or their appointed representatives.

c) The owner of any site that is required to store any substances that could be regarded as hazardous in terms of water pollution shall notify the Municipality and shall take measures to ensure spillages of the substance(s) can be adequately contained to prevent contamination of the water resources within the development area.

d) No stormwater, wash water, or wastewater may be directed towards any permanent water body or wetland without the installation of a suitable filtration system to prevent pollution, including silt, from entering such water body.

3.3 Stormwater Erosion Control

The Municipality may, at its discretion, inspect the individual properties within the housing development on a regular basis to:

a) determine the effectiveness of the stormwater management policies and amend policy as and when necessary, to meet the objectives of the Stormwater Management Plan.

b) advise property owners of any repair, maintenance and improvement works required on the stormwater system control elements within their jurisdiction.

3.4 Safety

3.4.1 Inundation of Property and Buildings

a) No new buildings are to be constructed below the 1:100-year flood line.

b) The 1:100-year flood line may not be altered by the development of the site, landfarming or other means, without the approval of the Municipality, in case this interferes with the performance of existing stormwater management facilities.

c) All risk of inundation by flood water is carried by the owner of the property.

d) No flood water may be diverted or concentrated such that a risk of flooding or inundation of any property or building is created.

3.4.2 Structural Damage

a) The diversion or concentration of stormwater, whether on the surface or underground, must not increase the risk of structural damage to any development within the housing development.

b) The above includes the undermining of structures due to erosion of soil by stormwater.

4.0 DESIGN OF A MINOR SYSTEM

4.1 Critical Points

The effectiveness of stormwater design depends largely on the identification in a catchment area of those areas or points where flooding cannot be tolerated more than once in 10 years due to the likelihood of heavy economic losses or social inconvenience. Such points are termed critical points, and while they can sometimes be pinpointed on a topo cadastral map, they should always be identified during a field inspection.

Critical points may occur:

a) at low points in a road (where ponding will occur) and ponding water may overflow the verge on the fill side, thus eroding fill embankments and flooding low-lying property.

b) at the intersection of a steep road with a flat road where water flowing down the steep road could flood the intersection or overshoot the opposite verge.

c) at the site of an important drainage structure e.g. The confluence of a road with a major stream. Where potential flooding of a development may cause high economic losses.

4.2 Rainfall Intensity at Critical Points

At critical points, both sufficient inlet capacity and pipe capacity must be provided to cope with the 10-year storm event. At all other points in a catchment, except for certain cases discussed below, design generally is only for the 3-year storm.

In special cases e.g., in areas where uncontained stormwater resulting from the use of a 3 year design storm would cause severe wash-a-ways in soft ground, the Stormwater/Catchment Manager may require that the design be based on a storm frequency of 5 years for non-critical points, and of 20 years for critical points.

4.3 Minimum Diameter

Note that downstream pipes should never be smaller in diameter than the upstream pipe notwithstanding that hydraulic considerations (such as steeper hydraulic grade lines or slopes) may support/allow this. Downstream pipes will obviously tend to be blocked by any debris/objects transported down larger upstream pipes. The minimum diameter of pipe shall be as follows:

300 mm in a servitude; and 375 mm in a road reserve.

4.4 Minimum Velocity and Gradient

The desirable minimum full flow velocity shall be 1,5 m/sec and the absolute minimum full flow velocity should be 0,9 m/sec which is acceptable only in unusual circumstances.

Desirable and absolute minimum gradients are shown in the following table 22 below:

Table 22: Minimum velocity and Gradient

Diameter	**Desirable Gradient 1/**
300	80
375	110
450	140
525	170
600	200
675	240
750	280
825	320
900	350
1050	440
1200	520

4.5 Materials

In general, stormwater pipes shall have rubber ring joints, be spigot and socket spun concrete pipes complying with S.A.B.S. 677 but fiber reinforced cement pipes are permissible provided they comply with S.A.B.S. 819. Ogee type pipes are NOT acceptable.

Other acceptable/suitable pipe types are: “Weholite” and “Ribloc” type pipes for use where steep grades or to maximise the use of labour but their use is NOT recommended in road reserves and road crossings .

4.6 Anchor Blocks

20 mPa concrete anchor blocks should be provided as follows:

Table 23: Anchor blocks specifications

Grade (%)	**Spacing for 2,44 m pipe lengths**
Over 50	every joint
30 to 50 inc.	alternate joints
20	every 4th joint
10	every 8th joint

Spacing for intermediate grades can be interpolated.

4.7 Curved Alignment

In normal circumstances straight alignment between manholes should be used, but curved horizontal alignment is acceptable subject to the following limitations:

a) the minimum radius of curvature for an effective pipe length of 2,44 m is as follows:

Table 24: Curved alignment specifications

Pipe diameter (mm)	**Radius of curvature (m)**
300	70
375	70
450	93
525	93
600	112
675 to 900	140
1050	186
1200	186
1350	278
1500	278

b) curved alignment is only permissible with pipes having approved flexible joints.

4.8 Servitudes

The width of sewer and drainage servitudes is dependent upon the diameters of pipes to be laid within the servitude area and should not normally be less than 2m.

4.9 Position of Stormwater Sewers in Servitudes

Stormwater sewers in servitudes should be positioned as follows: in 3 m servitudes - 1,0 m from a property boundary.
in 2 m servitudes - in the center of the servitude.

4.10 Position of Stormwater Sewers in Road Reserves

Recommended layout of services in road reserves are shown in the Appendices for various road widths. In existing roads already containing services, a stormwater sewer should be laid in the verge at least 1 m clear in a horizontal direction from the water main.

4.11 Manholes
Manholes should be placed at every change in horizontal and/or vertical direction or at a maximum spacing of:

100 m for pipes up to and including 900 mm diameter.

150 m for pipes over 900 mm up to and including 1 200 mm diameter.

200 m for pipes over 1 200 mm in diameter.

4.12 Manhole Covers.

Where manholes occur in roadways, standard D.C. heavy-duty cast-iron covers and frames in accordance with SABS. 558 Type 2B

Where manhole covers are to be sloped to suit road gradients, they should be laid on shaped brickwork or in-situ concrete.

4.13 Benching in Manholes

All manholes should be benched with a smooth concrete channel formed to the soffit of the pipe and every attempt should be made to streamline the "inlet to outlet" flow of water.

4.14 Channels
The minimum roadway cross fall on any black top surface should be 2,5% and the minimum longitudinal gradient should be 0,5% for concrete channels and 1% for asphalt channels.

4.15 Minimum Cover

The minimum allowable depth of cover to the outside of the barrel of the pipe for stormwater sewers is as follows:

a) in servitudes 0,8 m

b) in footways and verges 1,0 m below final kerb level

c) in roadways 1,2 m below final constructed road level

4.16 Bedding

Bedding shall generally be in accordance with the requirements of Standard Engineering Specification Part "DB": Earthworks for Pipe Trenches.

4.17 Invert Levels at Manholes

Special Conditions

In the following circumstances conditions within a manhole warrant detailed examination:

a) where the velocity head from the inlet pipe is destroyed e.g. at a drop manhole;

b) where a relatively large inflow enters a manhole from an inlet or from one or more subsidiary lines.

When considering (a) and (b) above, the following criteria should be considered in calculating the required invert level of the outlet pipe:

i. full pipe flow at entry to outlet pipe.

ii. the water level in the manhole is not to be above crown level of the pipe carrying the major incoming flow and the crown of other incoming pipes should not be lower than this level.

Bend Losses

Bend losses should be considered where there is a change in horizontal direction greater than 4° and although opinions vary on the extent of such losses in manholes, a loss of 50% of the velocity head of the inlet pipe is considered reasonable.

4.18 Selection of Class of Pipe

The class of pipe to be used can be obtained from the "Concrete Pipe and Portal Culvert Handbook" issued by the Concrete Manufacturers Association.

4.19 Subsoil drains

A subsoil drain should consist of either of the following:

a) for small volumes of seepage water, 19 mm, or 25 mm grade single size stone as per SABS 1083 wrapped in drainage grade filter fabric with a 200 mm overlap at the top of the drain to form a nominal 200 mm by 200 mm square section with a 100 mm layer of coarse clean sand placed on either side of the 200 mm x 200 mm section.

b) for regular and high seepage flows, subsoil pipes wrapped in drainage grade filter fabric with a minimum overlap of 100 mm situated at the top of the pipe and covered with a clean coarse clean sand compacted to 95% Mod AASHTO.

Where subsoil drainage is required to cut off seepage, e.g., under a road, it may be connected into a conveniently situated stormwater manhole or catchpit by means of a no-fines concrete block built into the side wall of the brick chamber instead of bricks.

4.20 Large Storage Ponds

A major drainage system may consist of natural and artificial watercourses, large conduits, stormwater storage facilities, servitudes, and floodplains. Should such a system be intended to cope with storms of 100-year frequency, the severity of the storm and consequent disruption of certain activities may allow playing fields, carparks, open spaces and similar areas to be used for on-site storage of stormwater.

5.0 MONITORING AND MAINTENANCE

5.1 Monitoring

The storm water system must be monitored during construction at regular intervals by the Environmental Control Officer (ECO) in terms of the Environmental Management Programme (EMPr).

During the construction phase of the development, the construction process should be monitored against the EMPr, but should pay attention to the following aspects:

- Implementing temporary attenuation measures, such as earth berms to retain surface run-off until the attenuation areas are complete and functional.
- Providing a silt screen at all grid inlets to collect debris and silt during times of heavy rain.
- Controlling dust, especially during the construction of roads and house platforms.
- Placing topsoil and grass sods onto cut/fill embankments to reduce runoff and velocity, including the use of Soil saver where embankments are steep.
- Construction of the stormwater attenuation pond as soon as possible.
- Planting of grass and other vegetation as soon as open areas are complete to prevent scouring and erosion of the low cohesion soils found on site.
- Fencing off the construction area and keeping all construction vehicles off the undeveloped portions of vegetation and buffer areas.

On completion of the construction, the Homeowners Association will be responsible to monitor their internal storm water system and attenuation facilities to identify improvements / maintenance. The factors to be monitored include the functionality and impact of the rainwater harvesting tanks on the properties, internal roads, stormwater pipes and attenuation ponds and how they are functioning and if they are adequate.
The post development monitoring process should be done at regular intervals (suggested 6 monthly) to include the following activities:

- ❖ Product (catchpits, headwalls, concrete pipes, attenuation ponds and rainwater harvesting tanks)
- ❖ Type of maintenance (rehabilitation, improvement, new)
- ❖ Urgency (immediate, next 6 months, next 12 months) and description of work to be carried out

5.2 Operation and Maintenance

The system as designed requires no manual operation and is self-regulating. Maintenance work should be undertaken as required to restore and maintain the system to its original design, especially to repair and maintain scouring and erosion, especially at the outlets from the stormwater attenuation ponds.

The operation and maintenance of the storm water system is essential to ensure it functions properly to prevent damages or failures and must receive high priority from the Homeowners Association.

During the construction period, it is important that surface runoff is monitored, controlled and temporary measures be implemented until the construction is complete and the system can function independently. This is therefore an important aspect to be monitored by the ECO during the construction stage.

Routine maintenance will be the responsibility of the Homeowners Association and should include:

- Clearing of kerb and channels, catchpits, stormwater pipes and attenuation ponds (rainwater harvesting tanks will be maintained by homeowners)
- Removal of silt from collection points and attenuation pond
- Plant/weed control.
- Cutting grass on embankments

It is however recommended that specialist service providers implement more technical works like the replacement of storm water pipes and remedial work to the stormwater attenuation ponds, if required.

6.0 RECOMMENDATIONS

The following recommendations are made for the proposed housing development:

1) That the storm water design parameters used in the design of the storm water management system are accepted and approved.

2) The detail design of the storm water system includes recommendations of this plan.

3) Rainwater harvesting should be encouraged at all residential dwellings.

4) Rainwater harvesting tanks should be included in building plans submitted to the municipality for building plan approval.

5) The stormwater attenuation ponds should be constructed off-channel before draining into the stream.

6) The storm water system must be kept separate from the sewerage system.

7) All chemicals, cement, fuel and other hazardous material used during construction should be stored in controlled areas and not lower than the internal road.

8) Concentration of storm water should be prevented where possible, but energy dissipaters should be provided in areas of concentration.

9) On completion of every construction phase within the development, comprising the construction of buildings, roads and parking areas, all remaining exposed embankments and open areas must be vegetated as soon as possible, including the use of “Soil saver”, where necessary.

10) During the construction phase, the following aspects shall be closely monitored by the ECO to ensure the contractor complies:

    - Temporary berms and cut-off drains must be provided on site to collect run-off, especially until the stormwater attenuation pond is complete and functional.

    - Silt screens must be provided at the catchpits during road/stormwater construction.

    - Topsoil must be conserved on site and prevented from entering the stormwater system.

- Exposed embankments, cut/fill slopes and open areas must be vegetated as soon as possible to reduce runoff.

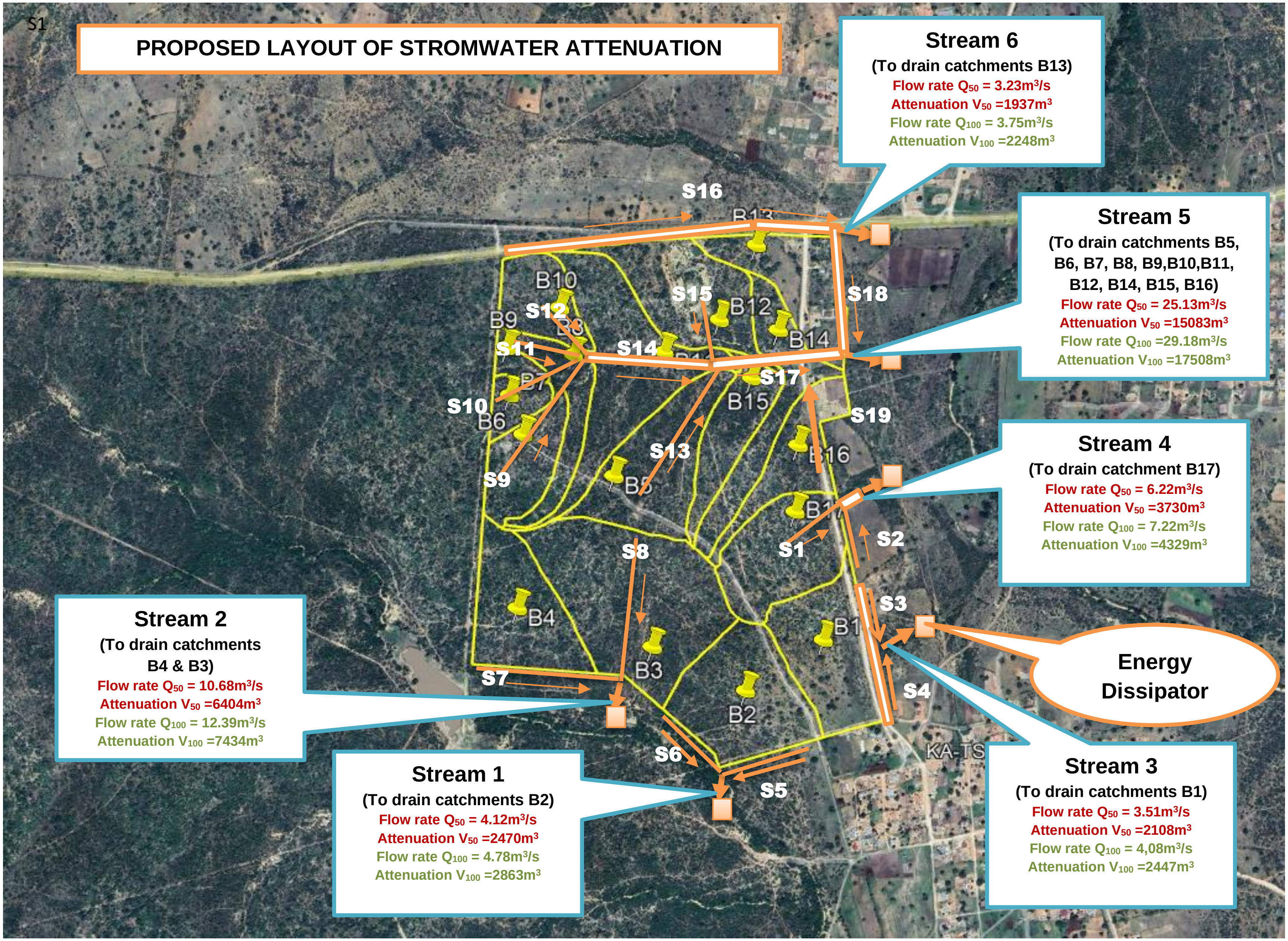
- Dust control during construction must be always applied.

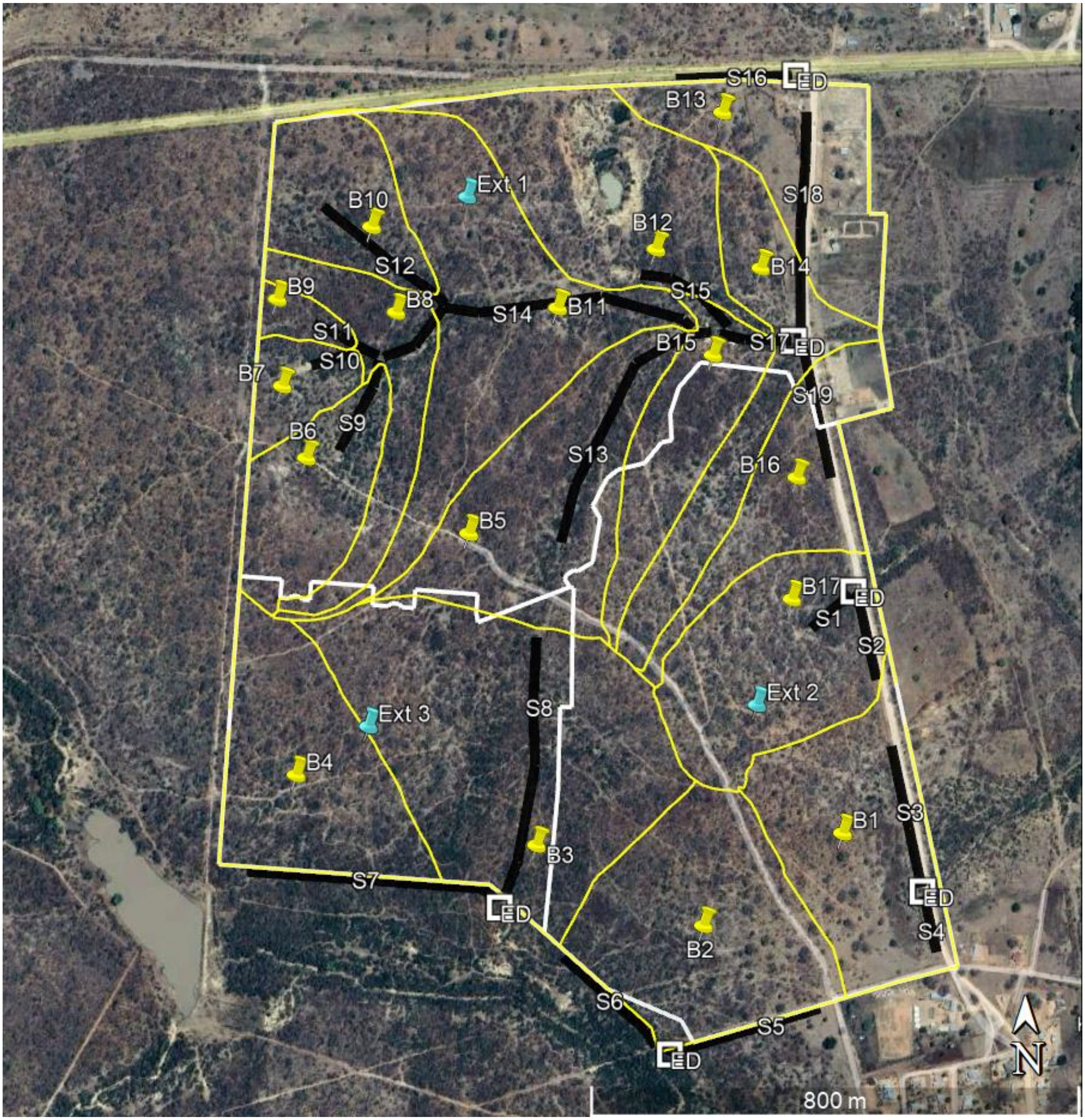
- Excess spoil material from topsoil or bulk earthworks must be placed in areas or even removed entirely off site to minimise silt deposition, scouring and soil erosion.

- Post construction, all exposed areas must be covered in vegetation, grass or landscaped.

ANNEXURE 1: PRACTICAL EXAMPLES OF SWALES

ANNEXURE 2: LAYOUT OF PROPOSED STORMWATER ATTENUATION STRUCTURES


S1
PROPOSED LAYOUT OF STROMWATER ATTENUATION
Stream 6
(To drain catchments B13)
Flow rate Q_{50} = 3.23m³/s
Attenuation V_{50} =1937m³
Flow rate Q_{100} = 3.75m³/s
Attenuation V_{100} =2248m³
Stream 5
(To drain catchments B5, B6, B7, B8, B9,B10,B11, B12, B14, B15, B16)
Flow rate Q_{50} = 25.13m³/s
Attenuation V_{50} =15083m³
Flow rate Q_{100} =29.18m³/s
Attenuation V_{100} =17508m³
Stream 4
(To drain catchment B17)
Flow rate Q_{50} = 6.22m³/s
Attenuation V_{50} =3730m³
Flow rate Q_{100} = 7.22m³/s
Attenuation V_{100} =4329m³
Energy Dissipator
Stream 3
(To drain catchments B1)
Flow rate Q_{50} = 3.51m³/s
Attenuation V_{50} =2108m³
Flow rate Q_{100} = 4,08m³/s
Attenuation V_{100} =2447m³
Stream 2
(To drain catchments B4 & B3)
Flow rate Q_{50} = 10.68m³/s
Attenuation V_{50} =6404m³
Flow rate Q_{100} = 12.39m³/s
Attenuation V_{100} =7434m³
Stream 1
(To drain catchments B2)
Flow rate Q_{50} = 4.12m³/s
Attenuation V_{50} =2470m³
Flow rate Q_{100} = 4.78m³/s
Attenuation V_{100} =2863m³
S16
S15
S18
S12
S14
S11
S17
S10
S19
S13
S9
S8
S1
S2
S3
S7
S4
S6
S5
B10
B9
B12
B14
B6
B15
B4
B3
B2
KA-TS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ED
B13
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S18
B12
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S12
B9
B8
S15
S14
B11
S11
B15
S17
ED
S10
B7
S19
S9
B6
S13
B16
B5
B17
ED
S1
S2
Ext 2
Ext 3
S8
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S3
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ED
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800 m
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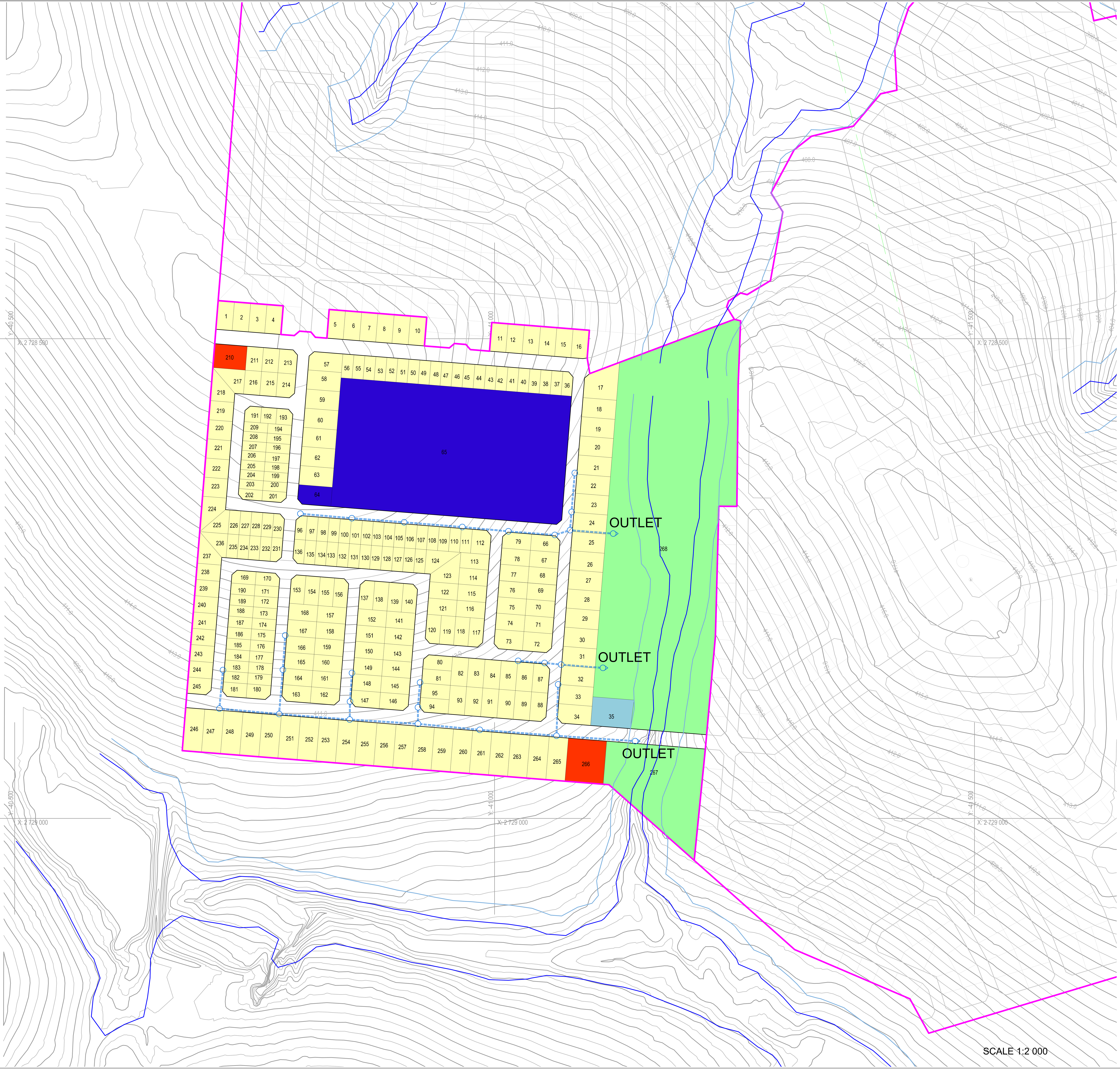
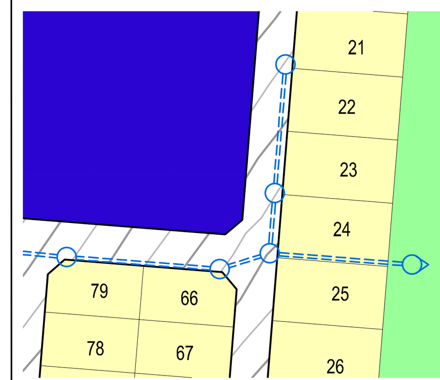


NOTES

KEY

FLOODLINE



STORMWATER PIPE NETWORK

REVISIONS

REV	DATE	SIGN	DESCRIPTION
0	.../.../...	....	....

CLIENT

Bushbuckridge Local Municipality
R533 Graskop Main Road
Bushbuckridge
1280

Tel: 013 065 0814

CONSULTANT

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DRAWING STATUS

FOR INFORMATION

PROJECT TITLE

Proposed township development situated of Greater Seville Ext 3 (the Remainder of Portion 1 and Portion 2 of the Farm Seville 224 KU), Mpumalanga Province

PROJECT LOCATION

The proposed township is situated in 145km north of Mbombela along the R40, in Mpumalanga Province, South Africa. GPS coordinates of site are 24°39'30.99"S 31°24'34.87"E.

DRAWING DESCRIPTION

STORMWATER PIPE NETWORKS

SCALE	DATE	DESIGNED	DRAWN	CHECKED
As Shown	Sept 2022	LM	AK	CM

A1	DRAWING No. SEVILLE/X3/STM/01	REVISION A