Surface Water Hydrology Report - Stormwater Management Plan for the Proposed Oliphants Estate Township Development, Northern Cape

Report Prepared for

Envirolution Consulting (Pty) Ltd

Report Number ENV008

Report Prepared by

SD Hydrological Services (Pty) Ltd

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Acronyms and Abbreviations

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	Definition
EPA	Environmental Protection Agency
DEM	Digital Elevation Model
MAMSL	Meters Above Mean Sea Level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
SWMM	Stormwater Management Model
WMA	Water Management Area

1 Introduction

SD Hydrological Services (Pty) Ltd has been appointed by Envirolution (Pty) Ltd to provide a surface water hydrology report which encompasses a stormwwater management plan and is inclusive of conceptual designs for the proposed Oliphants Estate Township Development located on portions 7 and 18 of the farm Roodepan 70, Northern Cape.

The project aims to provide a stormwater management plans in line with the necessary stormwater management by-laws, whilst also taking into consideration factors such as available space, topography and the project footprint area.

The section to follow briefly summarises the required scope of work.

2 Scope of Work

The scope of works required to undertake the surface water study is listed below:

- **Catchment hydrology and peak flow calculation** – Obtain storm rainfall depths, determine the catchment hydrology and calculate peak flows for respective points of interest.
- **Stormwater management plan –** Develop a stormwater management plan which details the management of stormwater as a result of the project and is inclusive of conceptual designs.
- **Surface water report** – Provide a surface water hydrology report which details all the finding whilst providing the necessary conclusions and recommendations.

A locality map indicating the project location is shown in Figure 2-1 below.

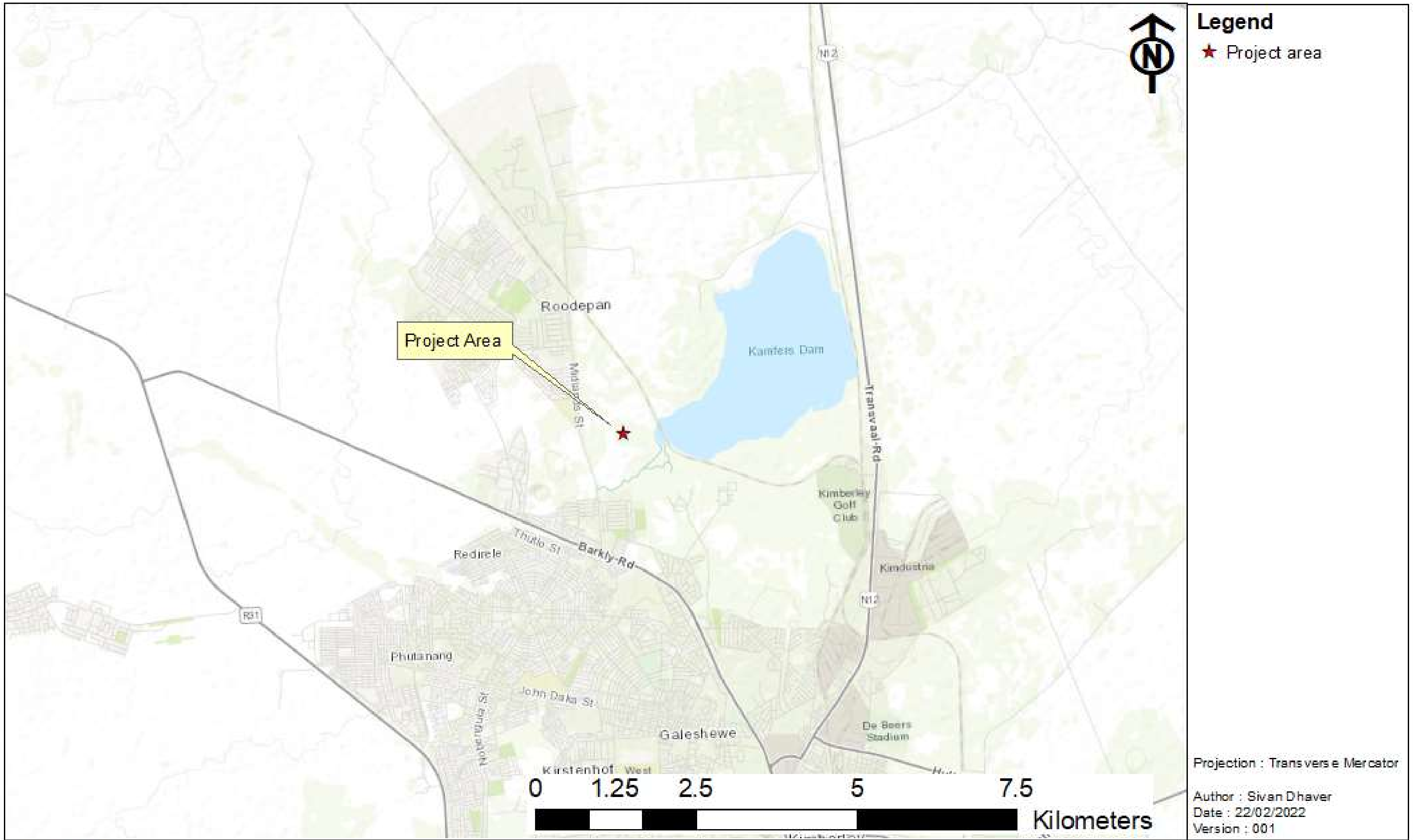

Figure 2.1

TITLE : Locality map

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3 Catchment Hydrology

3.1 Topography and Drainage

The project area falls within the Vaal Water Management Area (WMA). As of April 2016, South Africa has been subdivided into 9 water management areas namely:

- Limpopo
- Olifants
- Inkomathi – Usuthu
- Pongola – Mtavuna
- Vaal Major
- Orange
- Mzimvubu - Tsitsikamma
- Breede – Gouritz
- Berg - Olifants

Each of the water management areas (WMA) is made up of quaternary catchments, which relate to the drainage regions of South Africa, ranging from A – X (excluding O). These drainage regions are subdivided into four known divisions based on size. Each of the quaternary catchments have associated hydrological parameters including area, mean annual precipitation (MAP) and mean annual runoff (MAR) to name a few.

The project area falls in the south-eastern boundary of the C91E quaternary catchment which has a gross area of 1509 km^2. WRSM2012 (Water Resource Simulation Model, or Pitman Model) estimates the total runoff located at the catchment outlet, by using an existing flow gauge to effectively calibrate the hydrological parameters to estimate the MAR. However in the absence of a reliable flow gauge within the project quaternary catchment (C91E) calibration of flows along the project quaternary catchment is undertaken using measured flow data at another location, or results for the MAR is based solely on the simulated runoff.

The simulated monthly runoff volumes for quaternary catchment C91E is 2.06 mcm as per the WR2012 study (WR2012, 2015), Rainfall and evaporation data representative of quaternary catchment C91E was obtained from WR2012 and is the adopted climate data representative of the project area. The MAP and the MAE for the project area is estimated at 371 mm and 2140 mm (Symonds Pan Evaporation) respectively.

The major rivers within the Vaal WMA are the Wilge, Liebensbergvlei, Mooi, Renoster, Vals, Sand, Vet, Haart, Molopo and Vaal. All runoff emanating from the project location drains into the Kamfer Dam. The project area is unique in that it forms part of a larger endorheic catchment, which means all runoff drains to a single location, which does not have a clear outflow. The Kamfer Dam therefore serves as the single outflow location.

Summary of the hydrological setting is shown in Figure 3-1 below.

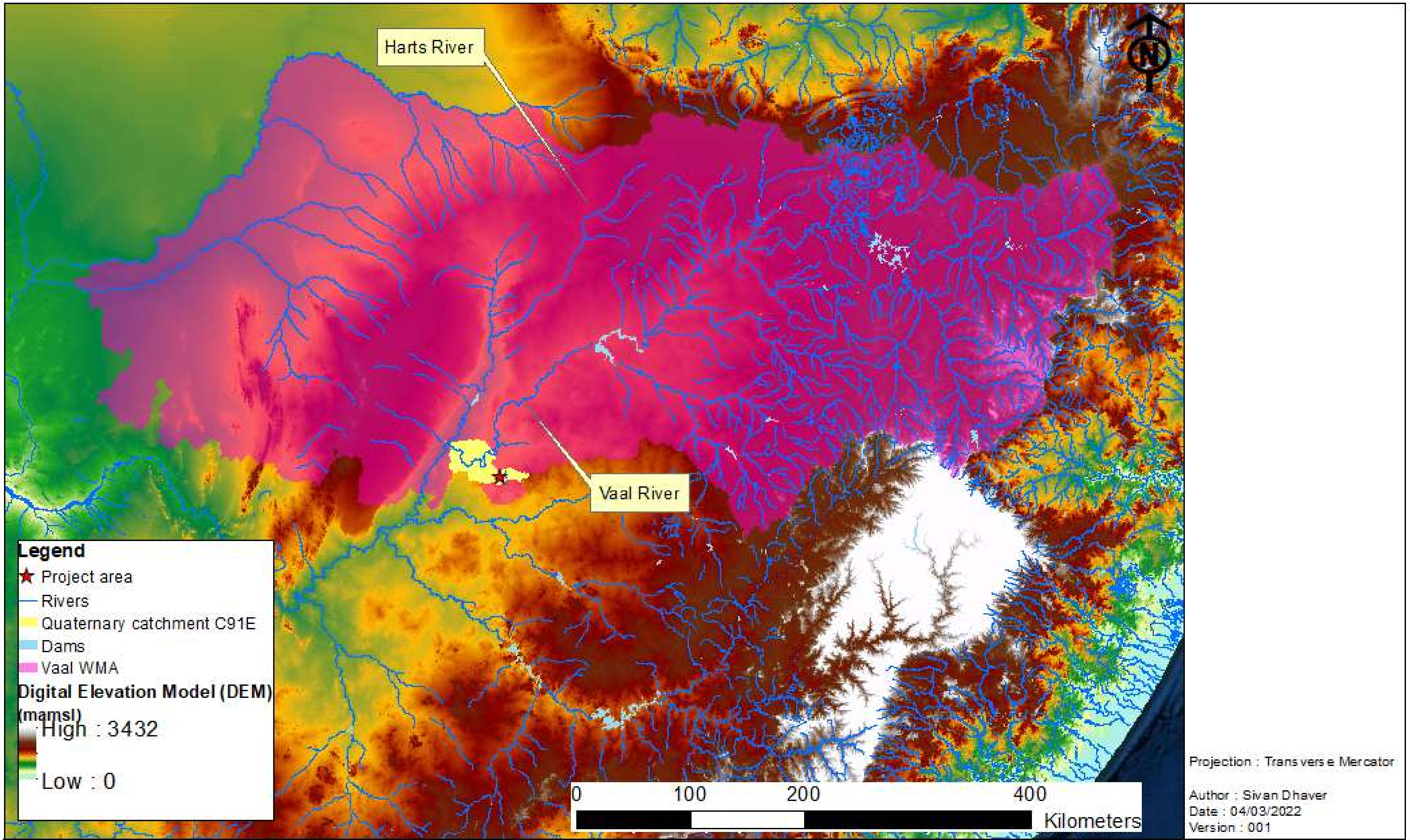


Figure 3.1

Summary of hydrological setting

4 Flood Hydrology

4.1 Storm Rainfall Depths

The design storm rainfall depths were obtained from the design rainfall software (Smithers and Schulze, 2002). The programme is able to extract the storm rainfall depths for various recurrence intervals for the six closest rainfall stations as shown below in Table 4-1 below.

Table 4-1 Summary of six closest SAWS stations as per the design rainfall software

Station Name	SAWS Number	Distance (Km)	Record length (Years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
KIMBERLY-DE BEERS	0290463 W	6.5	49	410	1200
KIMBERLEY (POL)	0290464 AW	7.6	75	399	1219
PLATFONTEIN	0290191 W	13.1	50	345	1129
KIMBERLEY	0290468 A	13.7	41	414	1196
KIMBERLEY - WK	0290468 W	13.7	33	414	1196
ALETHEIM	0290887 W	15.3	45	392	1194

The adopted storm rainfall depth to be used in the calculation of peak flows for the stormwater management plan and is based on the gridded rainfall output obtained from the design rainfall software. The summary of the rainfall depths for the 5 minute duration up to the 1 day storm duration for various recurrence intervals are shown below in Table 4-2.

Table 4-2 Summary of storm rainfall depths

Duration	Rainfall Depth (mm)					
(m/h/d)	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year	1:100 year
5 m	7.9	10.9	13	15	17.7	19.8
10 m	11.8	16.3	19.4	22.4	26.4	29.4
15 m	14.8	20.6	24.4	28.3	33.3	37.2
30 m	19.4	26.9	32	36.9	43.5	48.6
45 m	22.7	31.4	37.4	43.2	50.9	56.8
1 h	25.4	35.1	41.8	48.3	56.9	63.5
1.5 h	29.7	41.1	48.9	56.5	66.6	74.3
2 h	33.1	45.9	54.6	63.1	74.4	83
4 h	38.3	53.1	63.1	73	86	95.9
6 h	41.7	57.8	68.7	79.4	93.6	104.4
8 h	44.3	61.3	73	84.3	99.4	110.9
10 h	46.4	64.3	76.4	88.3	104.1	116.1
12 h	48.2	66.8	79.4	91.8	108.1	120.6
16 h	51.1	70.9	84.3	97.4	114.8	128.1
20 h	53.6	74.3	88.3	102.1	120.3	134.2
24 h	55.7	77.1	91.7	106	124.9	139.4
1 day	44.8	62.1	73.8	85.3	100.6	112.2

5 Stormwater Management Plan

5.1 Approach and Methodology

The proposed footprint area of the Oliphants Estate Township Development is 295 824 m^2 which equates to approximately 30 ha. A detailed flood assessment study was carried out by African Environmental Development which took into consideration the impact of the stream, hydraulic structures and the Kamfer Dam on the flooding of the project area (AED, 2018).

The proposed layout of the Oliphants Estate Township Development is shown in Figure 5-1. The layout shows that the footprint is divided into 4 areas (Area 1, Area 2, Area 3 and Area 4). Based on the no-go areas including the delineated 1:100 year floodlines, wetland buffers and the 1:100 year high water level mark (1160.65 mamsl) of the Kamfer Dam, only portions of Area 1 and Area 2 of the project footprint can be developed.

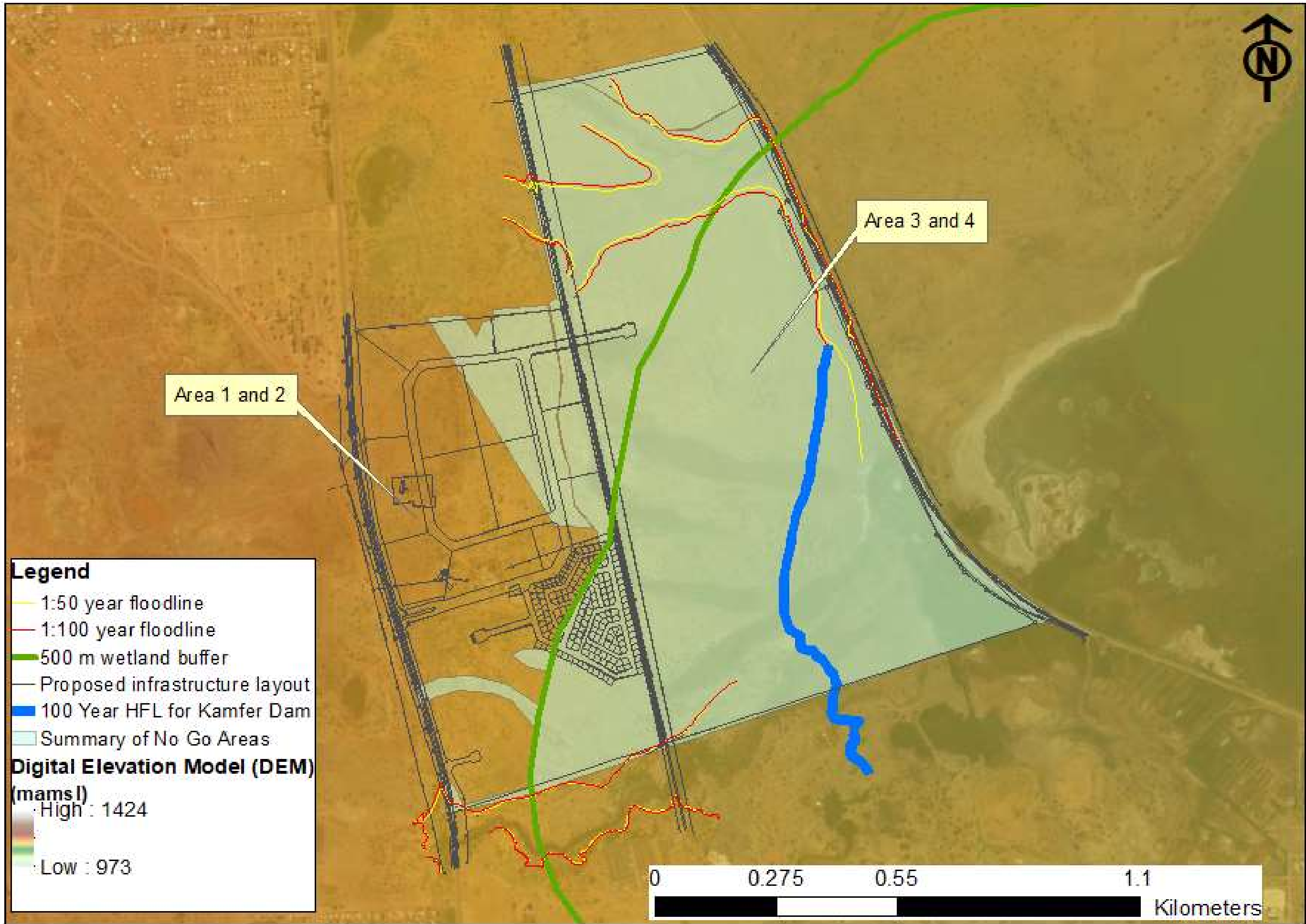
The stormwwater management plan approach for the Oliphants Estate Township Development is to convey runoff directly into the Kamfer Dam whilst ensuring that the post development runoff volume is reduced to as much as possible pre development conditions. The reduction in peak volume may not be possible however measures can be considered and adopted during the design phase of the project as described below.

The stormwater management plan was developed taking into consideration guidelines based on the general stormwater management by-laws governing South Africa, together with the sustainable drainage systems (SuDS). The guidelines are listed below:

- The “Guideline for Human Settlement Planning and Design, Volume 2, CSIR, 2003”, most commonly referred to as the “Red Book”.
- The South African Guideline for Sustainable Drainage Systems, Alternative Technology for Stormwater Management, WRC Report No TT558/13, May 2013

The stormwater management plan was developed using the EPA Stormwater Management Model (SWMM) Version 5.1. Summary of the model input together with the necessary assumptions are noted below:

- The total catchment area for the Oliphants Estate Township Development is estimated at 295 824 m^2.
- The total catchment area was divided into 3 sub catchments and modelled for pre development conditions namely Area 1, Area 2.1 and Area 2.2.
- A green space area (natural catchment) is to account for 20 % of the development footprint which may include yards, parks and general green space areas.
- The model takes into consideration the 1:10 year and 1:50 year 24 hour rainfall event which caters for the minor and major systems respectively (CSIR, 2003).
- Swales are grassed channels which encourage lower runoff velocities and also trap sediments and other pollutants. Swales together sub surface pipes are proposed for the stormwater management plan.
- SuDS best practice guidelines are considered in the recommendations of the stormwater management plan.



Projection : Transverse Mercator

Author : Sivan Dhaver
Date : 04/03/2022
Version : 001

Figure 5.1

Summary of project infrastructure layout

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5.2 Upstream Catchment channel sizing

The runoff generated from the minor upstream catchment is to be diverted around the proposed development area and discharged safely into the receiving streams which feed the Kamfer Dam. The diversion channels around the proposed project footprint are to be vegetated trapezoidal channels (swales), so as to reduce the velocity of flows entering the receiving streams.

Summary of the catchment hydrology and the peak flows used in the sizing of the upstream channels are shown below in Table 5-1 and Table 5-2 respectively

Table 5-1 Summary of catchment hydrology

Name	Area (km^2)	Length of longest watercourse (m)	Height Difference (m)	Rainfall Intensity (Q_{50})	Tc (hours)	C-Factor (50 year)
Upstream catchment 1	0.28	981.3	15.1	119	0.33	0.17
Upstream catchment 2	0.31	892.8	11.3	119	0.33	0.17
Upstream catchment 3	0.21	752.6	27.7	133	0.25	0.17

Table 5-2 Summary of peak flows for upstream catchments

Name	Peak flows for various recurrence intervals (years)					
	2 year	5 year	10 year	20 year	50 year	100 year
Upstream catchment 1	0.43	0.66	0.86	1.11	1.61	2.17
Upstream catchment 2	0.48	0.74	0.95	1.23	1.79	2.41
Upstream catchment 3	0.36	0.55	0.71	0.92	1.33	1.80

The conceptual channel sizes are based on the 1:50 year peak flow estimations for the upstream catchments. The channels are to be trapezoidal in shape and vegetated (see Figure 5-2).

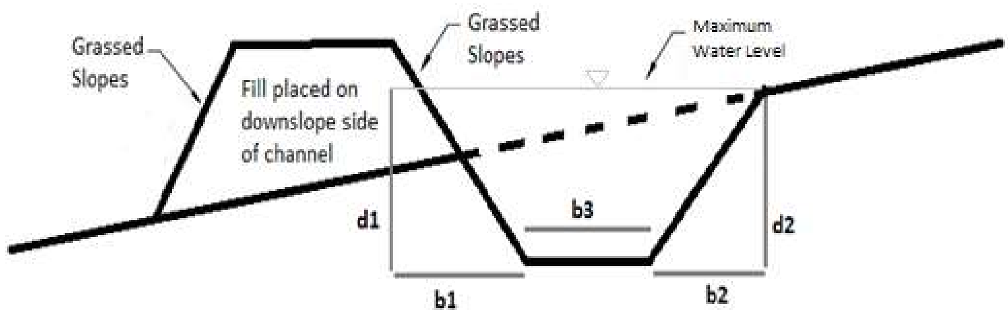

Figure 5-2 Summary of upstream channel design

The sizing of the channels is based on the Manning's Equation which is described below:

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

Where:

A = Area of Channel

R = Hydraulic Radius (area / wetted perimeter);

S = Longitudinal Slope of Channel; and

n = Manning's Roughness Coefficient

The Manning roughness factors used for the channel sizings are 0.03. Summary of the conceptual sizing of the channels are presented in Table 5-3.

Table 5-3 Summary of channel sizing

Channel Section	Q (m^3/s)	Side slope (1:X)	Bottom width (m)	Top width (m)	Calculated depth (m)	Velocity (m/s)	Design depth (m)	Type
A-B	1.61	3	1	7	0.47	1.41	1	Vegetated trapezoidal
A-C	1.79	3	1	7	0.49	1.46	1	Vegetated trapezoidal
D-E	1.33	3	1	7	0.43	1.34	1	Vegetated trapezoidal

5.3 SWMM Model Setup and Stormwater Management Plan

Below is a brief summary of the 3 SuDS treatment train components which were incorporated within the proposed stormwater management plan.

- Good housekeeping, such that all solid waste will be disposed of so that there is no risk to it being transported further downstream via stormwater.
- Source control measures, in the form of rain water harvesting tanks so as to decrease the stormwater runoff to the downstream environment whilst also encouraging reuse of the captured stormwater.
- Local controls, in the form of subsurface pipes and swales which are grassed channels will be used to capture and convey all the stormwater runoff onsite.

The EPA SWMM model diagram for the project area which summarises the proposed stormwater management plan is shown below in Figure 5-3. The model setup includes sub-catchments which represents individual catchments which include the 3 sub-catchments (Area 1, Area 2.1 and Area 2.2) within Area 1 and Area 2 of the Oliphants Estate Township Development.

Runoff from each sub-catchment is collected at the junctions (J1 – J6), where it is routed through the conveyance system and discharged at the outfall nodes (Outfall 1 and Outfall 2) to the downstream environment. The summary of the stormwater management plan proposed is listed below:

- All runoff emanating from the Oliphants Estate Township Development is to be captured and conveyed to the existing drainages and streams which feed the Kamfer Dam. All runoff emanating from the proposed Oliphants Estate Township Development area is to be captured and conveyed via subsurface pipes and swales to the downstream environment.
- The runoff from green space areas such as yards, parks and open space will be allowed to infiltrate into the sub soil layer wherever possible, with the excess surface runoff being discharged to the downstream environment, where it will enter the Kamfer Dam. The green space areas are assumed to account for 20 percent of the Oliphants Estate Township Development.
- The runoff estimation utilises the Soil Conservation Services – Curve Number (SCS-CN) method (Schmidt and Schulze, 1987) as described in Appendix A.
- Rainwater harvesting tanks are required to be installed at all roofed areas to further reduce the runoff entering the downstream environment. Rainwater harvesting tanks are fitted such that runoff generated from rainfall falling on roofed infrastructure areas can be captured and stored for reuse whenever required. The benefits of rainwater harvesting include:
    - Decrease of peak flows anticipated at the downstream conveyance infrastructures.
    - Additional water captured can be reused, thereby decreasing the amount of potable water utilised for purposes such as gardening general washing etc.

Summary of the proposed stormwater management plan is shown below in Figure 5-3 with output of the SWMM model which includes peak flows and hydrographs, shown in appendix B.

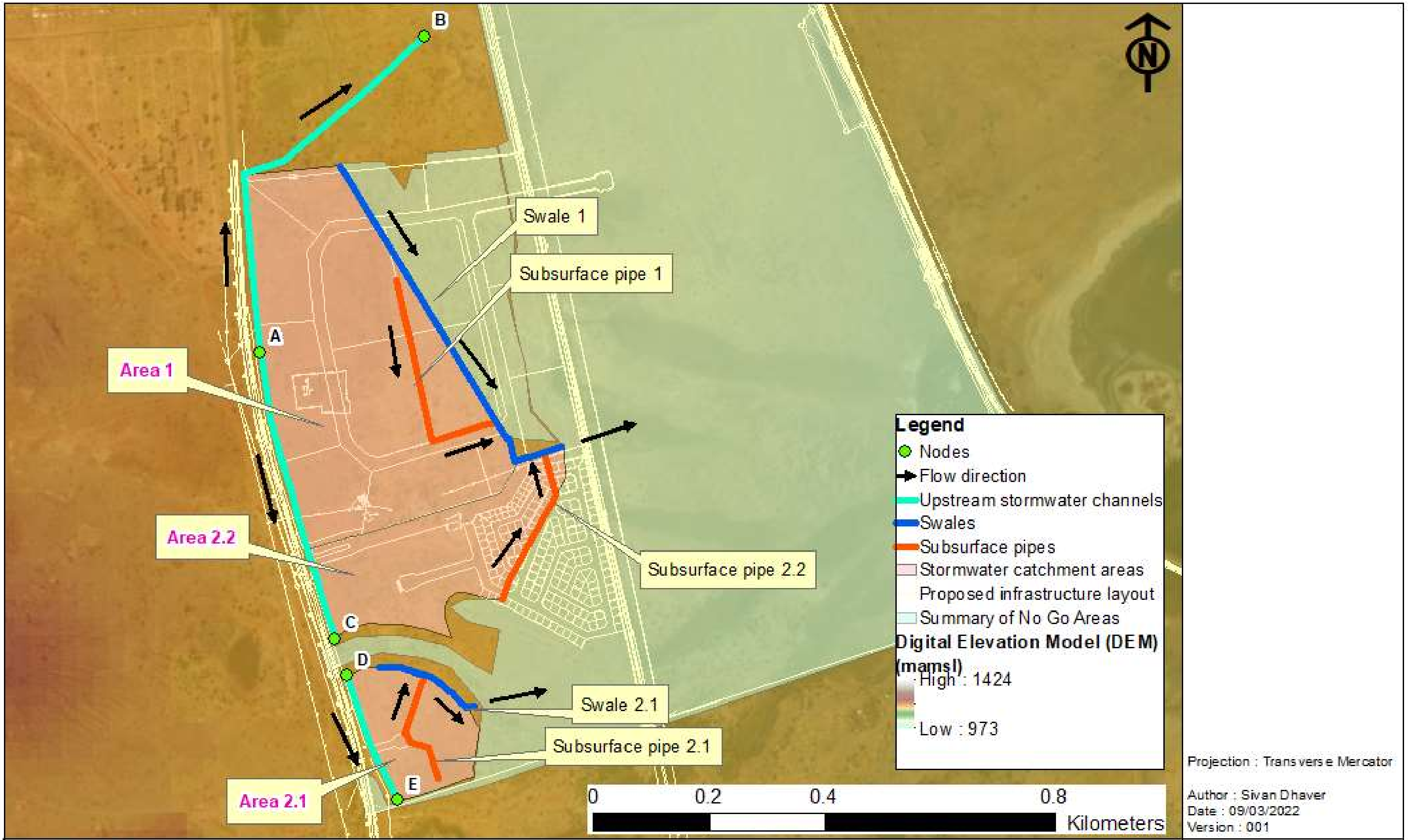

Figure 5.3

Summary of stormwater management plan

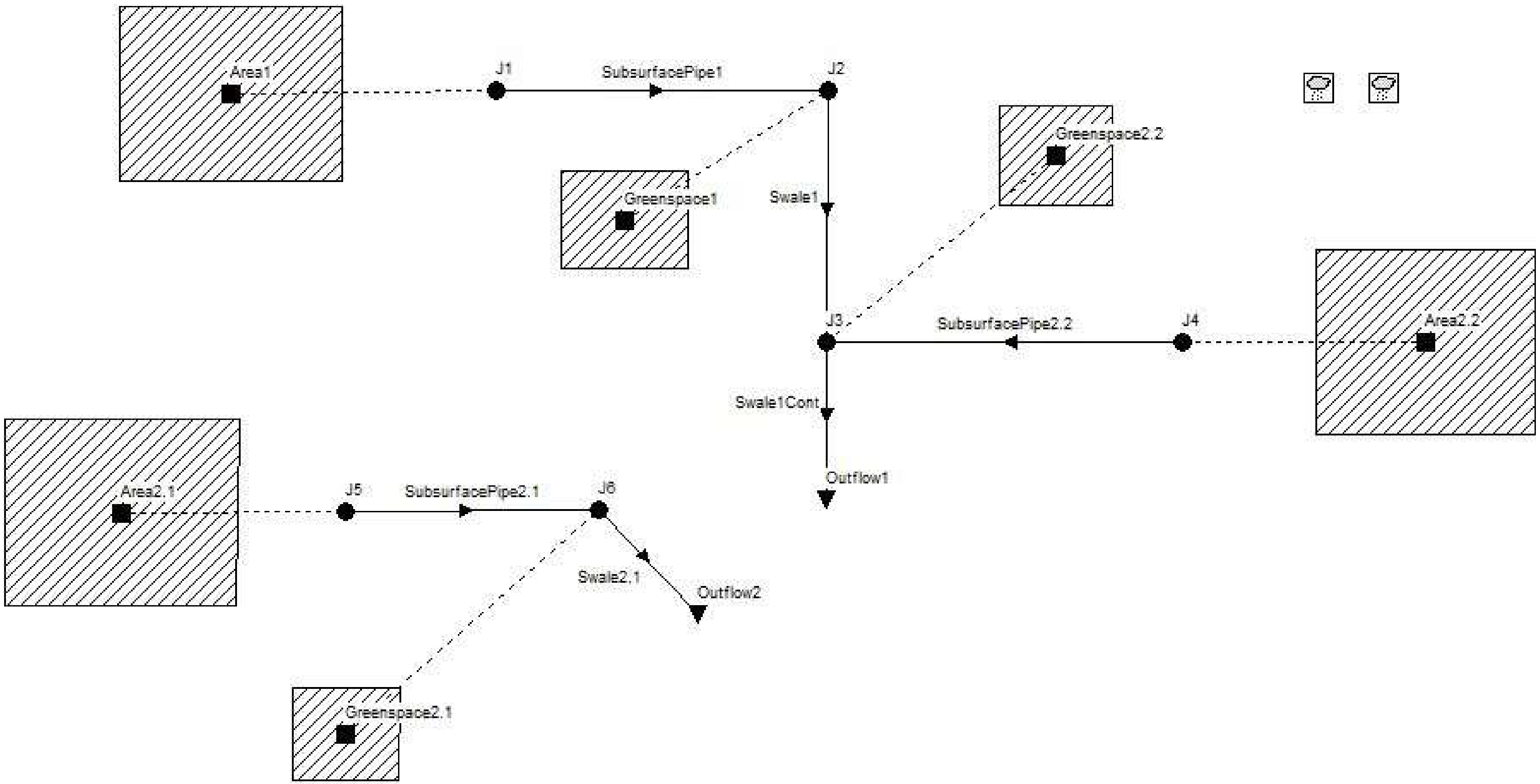

Figure 5-4 Summary of EPA SWMM model setup

5.4 Results of EPA SWMM

Summary of the SWMM model results are shown below:

- The difference in runoff volume for the 1:10 year and 1:50 year storm event for the pre and post development condition are 19 603 m^3 and 28 915 m^3 respectively. These mentioned increased runoff volumes are as a result of the Oliphants Estate Township Development and will report to the Kamfer Dam. The additional volumes are negligible in comparison to the available storage volume of the Kamfer Dam and will not result in a drastic increase in the flood levels of the mentioned Dam. Therefore the discharged flows will not pose a flood risk to the proposed Oliphants Estate Township Development.
- Maximum peak flows for the 1:10 year and 1:50 year storm rainfall events at the outfall nodes which represents anticipated discharge to the environment range from 0.19 m^3/s and 2.618 m^3/s respectively.
- Sub-surface pipe sizes range from 675 mm diameter to 1200 mm diameter, with the largest diameter pipe required at Area 1 of the Oliphants Estate Township Development
- The proposed swales are to be trapezoidal in shape having a bottom width which ranges from 1m – 3m, side slopes of 1:3 (1 vertical for 3 horizontal) and a design depth of 1 m.

Table 5-4 Summary of conduit sizing for surface and sub-surface conduits

Conduit reference as per EPA SWMM Model	Maximum Q (m^3/s)	Diameter (mm)	Bottom width (m)	Design Depth (m)	Side slopes (1:X)	Conduit type
SubsurfacePipe 1	2.09	1200				Sub-surface pipe
SubsurfacePipe 2.1	0.28	675				Sub-surface pipe
SubsurfacePipe 2.2	0.43	675				Sub-surface pipe
Swale1	2.15		2	1	3	Vegetated trapezoidal
Swale1cont	2.62		3	1	3	Vegetated trapezoidal
Swale2.1	0.31		1	1	3	Vegetated trapezoidal

Summary of EPA SWMM output for the 1:10 year and 1:50 year 24 hour rainfall event are shown in Appendix B.

6 Conclusions and Recommendations

The following is concluded:

- Due to the adoption of SuDS, a more environmentally friendlier way of managing the stormwater emanating from the project area is envisaged. These benefits will include lower velocities along the swales resulting in decrease erosion and sedimentation.
- The potential additional availability of rainwater captured via the rainwater harvesting tanks will allow for decrease in potable water used for purposes such as gardening and general surface cleaning. The amount of rainwater harvesting tanks installed is dependent on space and volume water required for gardening purposes and cleaning of surfaces.

The following is recommended:

- Due to the observed rainfall pattern of the project area, it is recommended that all stormwater maintenance occurs prior to the onset of the wet season. Therefore the optimal time to undertake any sort of maintenance should be towards the end of August.

Prepared by

Sivan Dhaver, (*Pr Sci Nat*)

Hydrologist

7 References

Stormwater Management Model (SWMM) Version 5.1, United States Environmental Protection Agency (EPA), 2018.

Guideline for Human Settlement Planning and Design, Volume 2, CSIR, 2003.

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Appendices

Appendix A: SCS Methodology

The SCS method, described fully in Schmidt and Schulze (1987), is particularly suited to small catchments (less than 30 km2) and takes into account most of the factors that affect runoff, such as quantity, time distribution and duration of rainfall, land use, soil type and size and characteristics of the generating catchment. It is based on the principle that runoff is caused by the rainfall that exceeds the cumulative infiltration of the soil. Soil types are divided into four hydrological groups, ranging from soils with low runoff potential (well-drained with high infiltration ability and permeability such as sand and gravel) to soils with high runoff potential (very low infiltration rates and permeability such as shallow soils with clay, peat or rock).

The method used a curve number (CN) which can be determined from observation of the characteristics of the catchment. The curve number expresses a catchment's stormflow response to a rainfall event (Schulze et al. 1992). This response is dependent on the catchment characteristics such as hydrological soil properties, catchment slope and land use.

The SCS storm flow depth equation is given below:

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \quad \text{for } \boldsymbol{P > I_a}$$

where

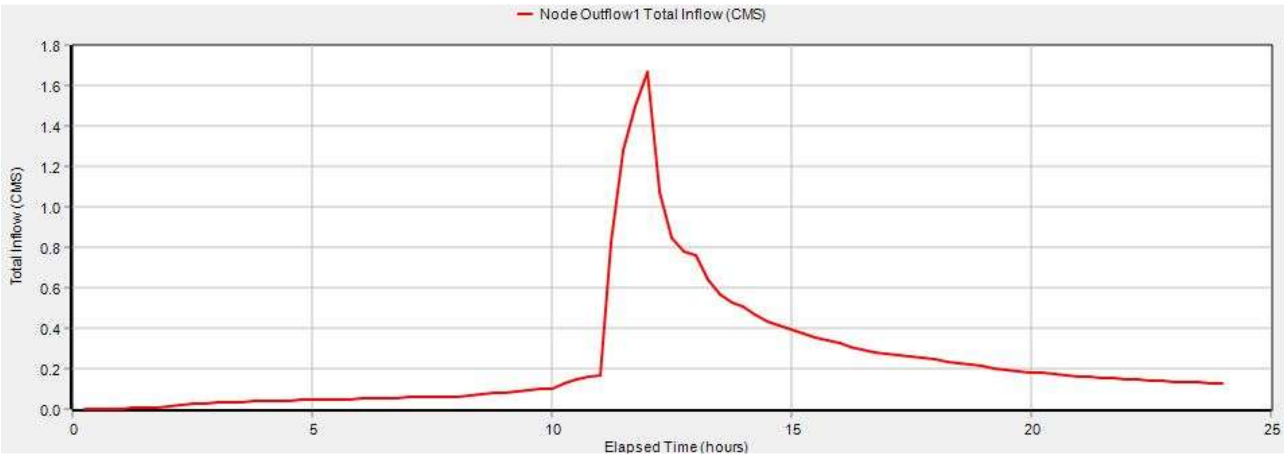
Q	=	stormflow depth (mm),
P	=	daily rainfall depth (mm), usually input as a one-day design rainfall for a given return period,
S	=	potential maximum soil water retention (mm),
	≡	index of the wetness of the catchment's soil prior to a rainfall event,
I_a	=	initial losses (abstractions) prior to the commencement of stormflow, comprising of depression storage, interception and initial infiltration (mm)
	≡	$0.1\,S$

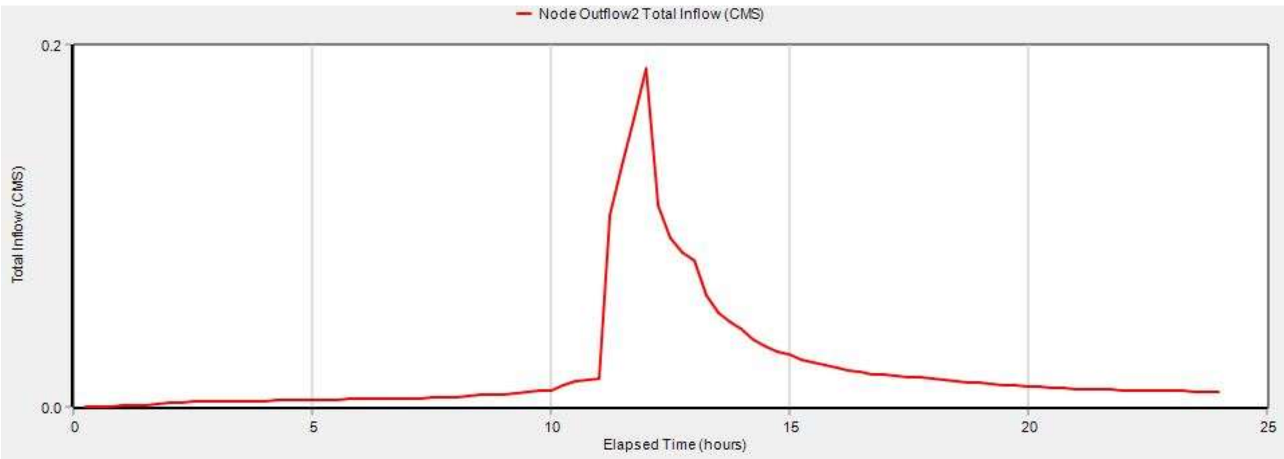
Appendix B: EPA SWMM Output

1:10 year flow results

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Imperv Runoff mm	Perv Runoff mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
Area1	91.87	0.00	0.00	34.87	26.91	22.19	49.09	16.79	1.37	0.534
Area2.1	91.87	0.00	0.00	34.87	27.19	26.77	53.96	1.62	0.18	0.587
Area2.2	91.87	0.00	0.00	34.87	27.15	26.28	53.43	2.67	0.27	0.582
Greenspace1	91.87	0.00	0.00	73.05	4.54	10.47	15.01	0.60	0.04	0.163
Greenspace2.1	91.87	0.00	0.00	73.05	4.54	12.04	16.59	0.17	0.02	0.181
Greenspace2.2	91.87	0.00	0.00	73.05	4.54	11.47	16.01	0.32	0.02	0.174

Link	Type	Maximum |Flow| CMS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| m/sec	Max / Full Flow	Max / Full Depth
SubsurfacePipe1	CONDUIT	1.364	0	12:01	2.71	0.51	0.50
SubsurfacePipe2.1	CONDUIT	0.175	0	12:01	1.52	0.28	0.36
SubsurfacePipe2.2	CONDUIT	0.269	0	12:01	1.71	0.43	0.46
Swale1	CONDUIT	1.395	0	12:02	1.20	0.14	0.38
Swale1Cont	CONDUIT	1.685	0	12:02	1.20	0.13	0.35
Swale2.1	CONDUIT	0.190	0	12:02	0.82	0.02	0.16





1:50 year flow results

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Imperv Runoff mm	Perv Runoff mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
Area1	125.12	0.00	0.00	40.75	36.82	38.12	74.94	25.63	2.09	0.599
Area2.1	125.12	0.00	0.00	40.75	37.16	43.73	80.89	2.43	0.28	0.646
Area2.2	125.12	0.00	0.00	40.75	37.11	43.12	80.23	4.01	0.43	0.641
Greenspace1	125.12	0.00	0.00	93.95	6.21	20.36	26.57	1.06	0.07	0.212
Greenspace2.1	125.12	0.00	0.00	93.95	6.21	22.40	28.61	0.29	0.03	0.229
Greenspace2.2	125.12	0.00	0.00	93.95	6.21	21.65	27.86	0.56	0.05	0.223

Link	Type	Maximum |Flow| CMS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| m/sec	Max / Full Flow	Max / Full Depth
SubsurfacePipe1	CONDUIT	2.088	0	12:01	2.99	0.77	0.66
SubsurfacePipe2.1	CONDUIT	0.280	0	12:01	1.72	0.45	0.47
SubsurfacePipe2.2	CONDUIT	0.431	0	12:01	1.91	0.69	0.61
Swale1	CONDUIT	2.146	0	12:02	1.35	0.21	0.47
Swale1Cont	CONDUIT	2.618	0	12:02	1.37	0.20	0.44
Swale2.1	CONDUIT	0.310	0	12:02	0.94	0.03	0.21