Bio2Watt Surface Water Specialist Study

Report Prepared for

Bio2Watt Energy Holdings (Pty) Ltd.

Report Number 596240

Report Prepared by

srk consulting

January 2024

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SRK Project Number 596240

January 2024

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Executive Summary

Bio2Watt Energy Holdings (Pty) Ltd. (BEH) requested SRK Consulting (South Africa) (Pty) Ltd. (SRK) to undertake a surface water impact study: which includes the delineation of the 1:50-year, 1:100-year floodlines, and Water quality analysis along the watercourses of the proposed plant site and extended construction area.

Activities

A floodline study was conducted and the activities included the following:

- Delineating the catchment areas using 1:50,000 topographical maps and the Digital Elevation Model (DEM).
- Rainfall data were collected, and stormwater depths were estimated from the Schmidt Schulze database.
- Peak flows were estimated using the rational method for the smaller catchments and the SWMM (SCS) hydrological model was compiled for each of the larger drainage catchments to determine the peak flow rates.
- Hydraulic modelling was conducted along the Hennops River, RietSpruit, and Swartbooi Spruit to estimate the flood levels. The peak flow data and other relevant information were entered into the backwater model (GeoHECRAS) to produce the results on the flooding extent along the riverbanks in the vicinity of the proposed development site.
- A risk assessment was undertaken in terms of the proposed development may have on the surface water

The collected information was then compiled into maps and tables, summarising the findings of the study:

- The floodline information to be used to ensure that no new developments at the intended site are situated within the 1:100-year floodline;
- The BEH site Boundary remains outside the 1:100 year floodline;
- Bridge M26 (1045.9 Cross-section) near the site, can accommodate a 100-year flood;
- The 1:50 year and 1:100year flood events breach the Raslouw Substation;
- A survey is recommended for a detailed review of the breach of the Raslouw Substation and crossing of the powerline/ gas pipeline of the lower Riet Spruit (RS1-2972 to RS1-678)
- The BEH should build the powerline and gas pipeline in accordance with the 100 year floodline;
- The floodlines be revised should watercourse/control structures be modified in the future; and
- Water Quality Monitoring to be undertaken monthly for at least 6 months prior to construction to establish a baseline.

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by BEH. The opinions in this Report are provided in response to a specific request from BEH to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

List of Abbreviations

amsl:	Average Mean Sea Level
bgl:	below ground level
BPG:	Best Practice Guidelines
CoT:	City of Tshwane
DEM:	Digital Elevation Model
DRE:	Design Rainfall Estimation
DWAF:	Department of Water Affairs and Forestry
DWS:	Department of Water and Sanitation
EHS	Environmental Health and Safety
EMPr:	Environmental Management Programme
GPS:	Global Positioning System
ha:	Hectares
HN1:	Hennops River Downstream
HN1T1:	Hennops River downstream first Tributary
HN2:	Hennops River Upstream
HN2T1:	Hennops River upstream first Tributary
HN2T2:	Hennops River upstream second Tributary
MAE:	Mean Annual Evaporation
MAP:	Mean Annual Precipitation
mbgl:	Meters Below Ground Level
N&S:	Norms and Standards
RMF:	Reginal maximum flood
RS1:	Rietspruit Downstream
RS1T1:	Rietspruit Downstream first Tributary
RS1T2:	Rietspruit Downstream second Tributary
RS2:	Rietspruit Midstream
RS2T1:	Rietspruit Midstream first Tributary
RS3:	Rietspruit Upstream
SANAS:	South Africa National Accreditation System
SANS:	South African Norms and Standards
SAR:	Site Assessment Report
SCS:	Soil Conversation Services
SDF:	Standard design flood

Declaration of Independence

We act as an independent specialists in this application;

We perform the work relating to the application objectively, even if this results in views and findings that are not favourable to the applicant;

We declare that there are no circumstances that may compromise my objectivity in performing such work;

We have the expertise in conducting the specialist study relevant to this application, including knowledge of the various Acts, regulations and any guidelines that have relevance to the proposed project;

We will comply with the Acts, regulations and all other applicable legislation;

We have no, and will not engage in no conflicting interests in the undertaking of this study;

We undertake to disclose to the applicant and the competent authority all material information in the possession of SRK that reasonably has or may have the potential to influence any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority; and

All the particulars furnished by me in this report are true and correct.

Project Team

The SRK project team for the Surface water specialist study is presented in the table below.

Team Member	Role	Specialist area
Manda Hinsch	Principal Scientist	Water Quality and Risk Assessment
Peter Shepherd	Reviewer (Principal Hydrologist)	Water Management and Hydrology
Lee Johnstone	Hydrologist	Water Science and Management

1 Introduction and Scope of Report

1.1 Background

Bio2Watt Energy Holdings (Pty) Ltd. (BEH) requested SRK Consulting (South Africa) (Pty) Ltd. (SRK) to prepare a surface water report which includes the delineation of the 1:50 year, and 1:100 year floodlines along the watercourses close to the proposed BEH plant site and the proposed extended construction area. The National Water Act, Act 36 of 1998, Chapter 14 Part 3 requires that for any existing or new development situated in the vicinity of watercourses, floodlines need to be shown on the plans of the existing/proposed development sites to obtain relevant approvals from local authorities and to ensure that developments are not negatively impacted and damage to property is averted during flooding events. Furthermore, a water quality analysis aligned with the Environmental Health and Safety (EHS) Guidelines is requested, particularly focusing on the sections related to general environmental health and safety standards, as well as those specifically addressing wastewater and ambient water quality. The results of the BEH floodline study and water quality analysis are covered in this report.

Freshwater Aquatic Ecology is not included in the scope of this report, please see “Wetland Baseline & Impact Assessment for the proposed Sutherland Ridge Biogas Waste-to-Energy Facility and Grid Connection Projects” for aquatic ecology and wetland impacts.

A Surface water study was conducted, and the activities included the following:

- Delineating the catchment areas using 1:50,000 topographical maps and the Digital Elevation Model (DEM).
- Rainfall data were collected, and stormwater depths were estimated from the Schmidt Schulze database.
- Peak flows were estimated using the rational method for the smaller catchments and the SWMM (SCS) hydrological model was compiled for each of the larger drainage catchments to determine the peak flow rates.
- Hydraulic modelling was conducted along the Hennops River, RietSpruit, and Swartbooi Spruit to estimate the flood levels. The peak flow data and other relevant information were entered into the backwater model (GeoHECRAS) to produce the results on the flooding extent along the riverbanks in the vicinity of the proposed development site.
- A *in situ* water quality assessment was undertaken.
- A risk assessment was undertaken in terms of the proposed development may have on the surface water
- The collected information was then compiled into maps, summarising the findings of the study.

1.2 Uncertainties and Assumptions

A detailed survey was not done on behalf of BEH, as a result, potentially resulting in misrepresented floodlines in certain areas. The survey was acquired through the City of Tshwane (CoT); it is assumed that any developments between the time of survey (2014) and the present (January 2024) had not significantly impacted river channels. Despite this, it's crucial to note the limitations of the survey's comprehensiveness. Downstream of the Hennops River, the surface water quality remains unknown due to safety concerns preventing the collection of water quality samples. Samples were specifically taken underneath the R55 bridge (see Figure 22), and an assumption is made that the surface water quality at the intended BEH site matches that of the sample location. These factors underscore the need for caution in interpreting survey results, especially concerning floodlines, and emphasize the importance of accounting for potential discrepancies and safety limitations in planning future developments or projects in the area.

1.3 Legislation and Guidelines

- National Water Act, 1998 (Act No. 36 of 1998) (NWA);
- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and associated Environmental Impact Assessment (EIA) 2014 Regulations; and
- Department of Water and Sanitation (DWS) Best Practice Guideline documents.
- IFC Performance StandardsThe IFC's Environmental and Social Performance Standards define responsibilities for Bio2Watt Energy Holdings (Pty) Ltd for managing their environmental and social risks which is focussed on surface water management and incumbent to **IFC Performance Standard 3 Resource Efficiency and Pollution Prevention** in the scope of this report. Refer to Table 1-1
    - Environmental Health and Safety (EHS) Guidelines, General Environmental Health and Safety (EHS) Guidelines: Environmental Wastewater and Ambient Water Quality *Wastewater and Ambient Water Quality*

Table 1-1: IFC Performance Standard 3 Resource Efficiency and Pollution Prevention

PS Requirements	Applicable to surface water (Y/N)	How the PS has been addressed
a) General Env, Health & safety Guidelines (Pollution prevention & control and waste management techniques, compare water & Air emissions against EHS Guideline, Impacts to ambient conditions)	No	No water will be discharged into the environment except clean stormwater.
b) Resource Efficiency (resource conservation and energy efficiency measures incorporated into the design and operations	Yes	Water requirements have been quantified. A stormwater management plan to be included in the design of the project layout plan to prevent pollution of water resources from storm water. A water management and monitoring plan has been incorporated for implementation.
c) Green House Gases (GHG quantification	No	
d) Options for GHG emission reductions	No	
e) Water consumption (Significant consumer of water? Measures to reduce water usage	Yes	This process is not water intensive however one should continuously monitor water usage and investigate further water savings
f) Pollution Prevention Avoidance or minimization of pollutants/emissions;	Yes	The process itself is focused on recycling of waste to produce energy. The operator of the plant is encouraged to recycle and minimise the production of waste resulting from the operation of the plant. Any waste produced which can not be recycled or re-used will be disposed of at a licensed waste site.
g) Waste (Demonstrate measure to Avoid, reduce, recover and re-use waste. Environmentally sound disposal of hazardous and non-hazardous waste, Use of legitimate and reputable contractors, chain of custody documentation to final destination,	No	
Haz Materials management (Hazardous Materials Management including wastes/inputs during production, handling, storage, and use, any banned or phased out substances or chemicals	Yes	Application is made for an integrated Environmental Authorisation and waste management licence which will stipulate conditions for management of all waste.

PS Requirements	Applicable to surface water (Y/N)	How the PS has been addressed
Pesticide Use and Management (Will pesticides be used?)	Yes	The proposed project will not make use of pesticides

2 Background and Brief

2.1 Background

In accordance with Item 2(1)(d)(ii) in Appendix 2 of GN 982, as amended, this Section provides a description of the proposed activities, including associated structures and infrastructure.

BEH is a specialized company operating in South Africa, focused on the development and management of biogas projects. Their primary objective is to harness the potential of organic waste and convert it into renewable energy, predominantly in the form of biogas. To achieve this, BEH establishes and operates anaerobic digestion facilities, utilising a natural biological process that breaks down organic matter, such as agricultural waste and food waste without the presence of oxygen. This process yields biogas, composed mainly of methane and carbon dioxide. BEH has identified Sunderland Ridge in Centurion, Pretoria, as a potential site for a biogas plant.

BEH are proposing the establishment of an anaerobic digestion, organic waste-to-energy biogas plant in Sunderland Ridge. The plant will process organic waste (from agriculture and the food industry) to produce biogas and digestate. The digestate will be sold for use as a soil enhancer/fertiliser) and two alternatives for the biogas are being considered. The biogas will be converted to electricity and fed into the national grid and compressed and sold to an off taker.

Aside from the biogas plant, BEH also has plans to build a powerline as seen in Figure 2-1 The powerline's new route is designed to connect with the Raslouw Substation located to the southeast of the site. In terms of the gas infrastructure, an existing Sasol line runs in proximity to the Raslouw substation. Consequently, the intended gas pipeline will be interconnected with a Sasol line.

The Sunderland Ridge Biogas Plant will divert waste from traditional methods of composting, landfills and at times burying of waste, to a sustainable solution, which will see baseload energy being produced in the country, and much needed green jobs created. The plant will prevent a significant amount of methane from entering the environment daily, methane being up to 80 times more destructive than carbon dioxide regarding climate change. The plant will see the circular green economy being enhanced in the Gauteng Province on an industrial scale. The Plant footprint is approximately 5ha in extent.

To find details on alternative construction designs, please see section 7 of the Environmental Impact Assessment (EIA) report. It's important to note that these alternative designs have been excluded from this study because they do not alter the project area's size or its positioning in relation to potential flood and water quality areas.

2.2 Project Activities

The following activities were undertaken to determine the floodlines along rivers within the intended BEH construction site, powerline, and gas pipeline:

- Identification and delineation of the watercourse/s impacted by construction and site activities;
- Delineation of catchments draining into affected rivers;
- Verification of available rainfall data from rainfall stations in the vicinity of the site;

- Hydrological study to determine the latest peak flows emanating from catchments draining the site;
- Hydraulic modelling of flood peaks using backwater calculation method (GeoHECRAS) considering all factors within each river reach catchment that have the potential flooding impact along the riverbanks;
- Water Quality assessment;
- Risk Assessment; and
- Compile a report and associated floodline drawing/s.

2.3 Available Information

The following information sources were consulted as part of this task:

- Topographical information in the form of maps, and aerial photographs;
- 1m contours obtained from the City of Tshwane (CoT);
- Satellite photos available on Google Earth;
- Photographs taken during site visits; and
- Daily Rainfall data available: Design Rainfall Estimation in South Africa.
- Analysis of background surface water quality

2.4 Description of the Study Area

The catchment area of the proposed project spans 442 square kilometres, covering substantial portions of urban and industrialized regions, along with smaller sections consisting of open fields and shrubby vegetation. The longest water course in the catchment extends over 41 kilometres and directly influences the site. Overall, the development within BEH's intended site is limited and primarily characterized by grassy areas with sloping topography.

BEH has identified a potential site for a biogas plant that is in close proximity to the Sunderland Ridge Industrial area (25°49'56.12"S, 28° 5'13.36"E), approximately 10 kilometres northwest of Centurion Central, within the Gauteng Province and the Tshwane Municipality. The site is surrounded by various notable features. To the south lies the Mooiplaats informal settlement, which within it, is a large landfill located at the higher-end site boundary. On the eastern side of the site, the Sunderland Ridge industrial area is situated. Approximately 860m lies the Hennops River, a significant watercourse in the vicinity. The site itself is positioned between the M26 and the R55 Highway.

In addition to the biogas plant BEH intents to construct an access road, gas pipeline and powerline. An access road off the Main Road, M26, will be constructed by the landowner. The site location perimeter will be fenced, with suitable access control to be provided by the landowner in consultation with BEH.

The gas pipeline will run east along the northern boundaries of the Sunderland Ridge Industrial Area and tie into the existing Sasol pipeline just past the R55 and Wierda Road intersection. The Sasol pipeline runs parallel to the R55. The pipeline will be approximately 2.4km in length and will fall within the road reserve.

A powerline running east along the northern boundaries of the Sunderland Ridge Industrial Area, then south from the intersection of the R55 and Wierda Road to the Rasslouw substation, approximately 4km in length was a third alternative considered. The pipeline will be approximately 4km in length and will fall largely within the road reserve.

The Watercourses used, as seen in Figure 2-2, include;

- HN1 (Hennops River Downstream);
- HN1T1 (Hennops River downstream first Tributary);

- HN2 (Hennops River Upstream);
- HN2T1 (Hennops River upstream first Tributary);
- HN2T2 (Hennops River upstream second Tributary);
- RS1 (Rietspruit Downstream);
- RS1T1 (Rietspruit Downstream first Tributary);
- RS1T2 (Rietspruit Downstream second Tributary);
- RS2 (Rietspruit Midstream); and
- RS3 (Rietspruit Upstream).

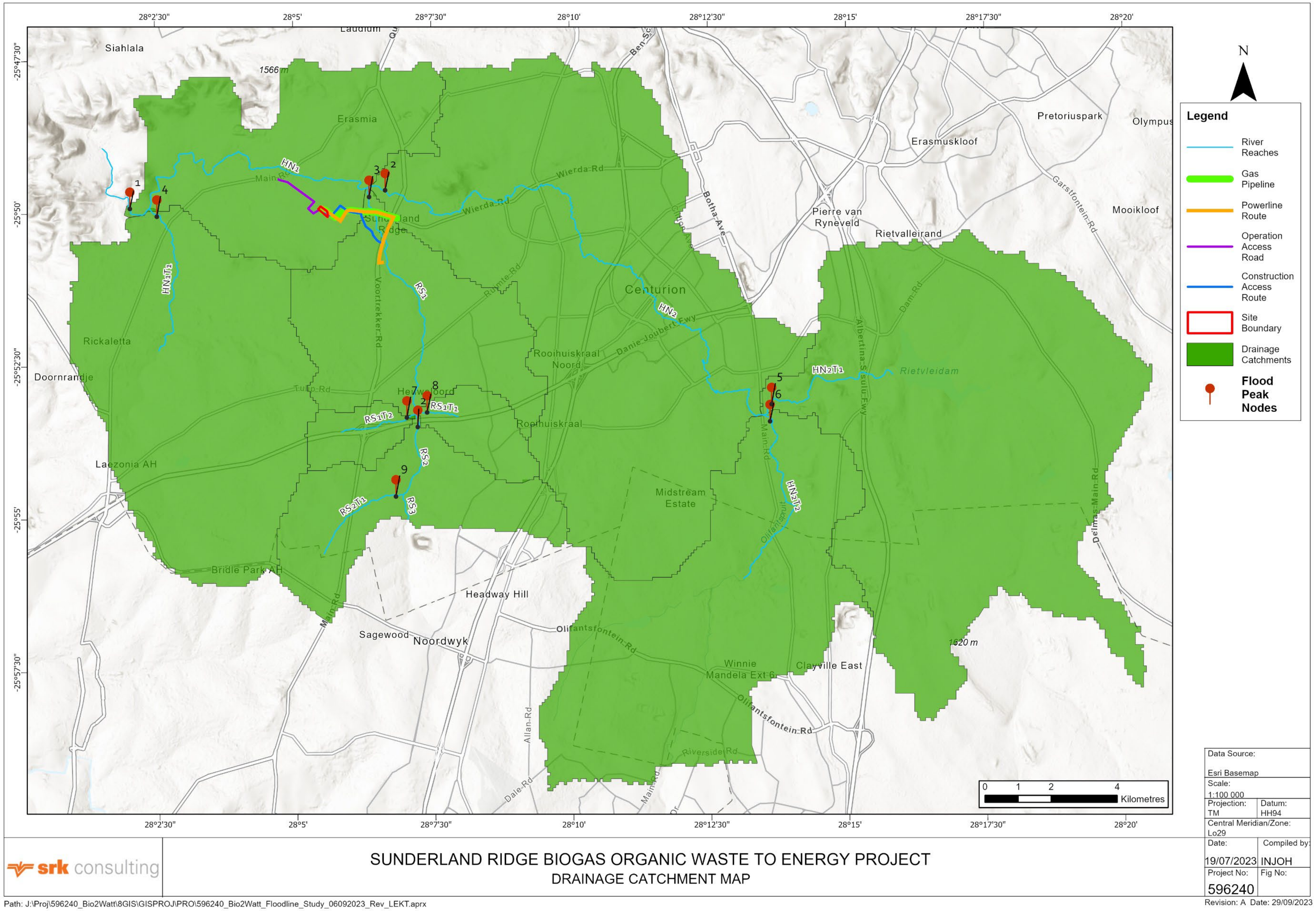

Figure 2-1: Locality Map Highlighting the Drainage Catchment relative to the Study Site.

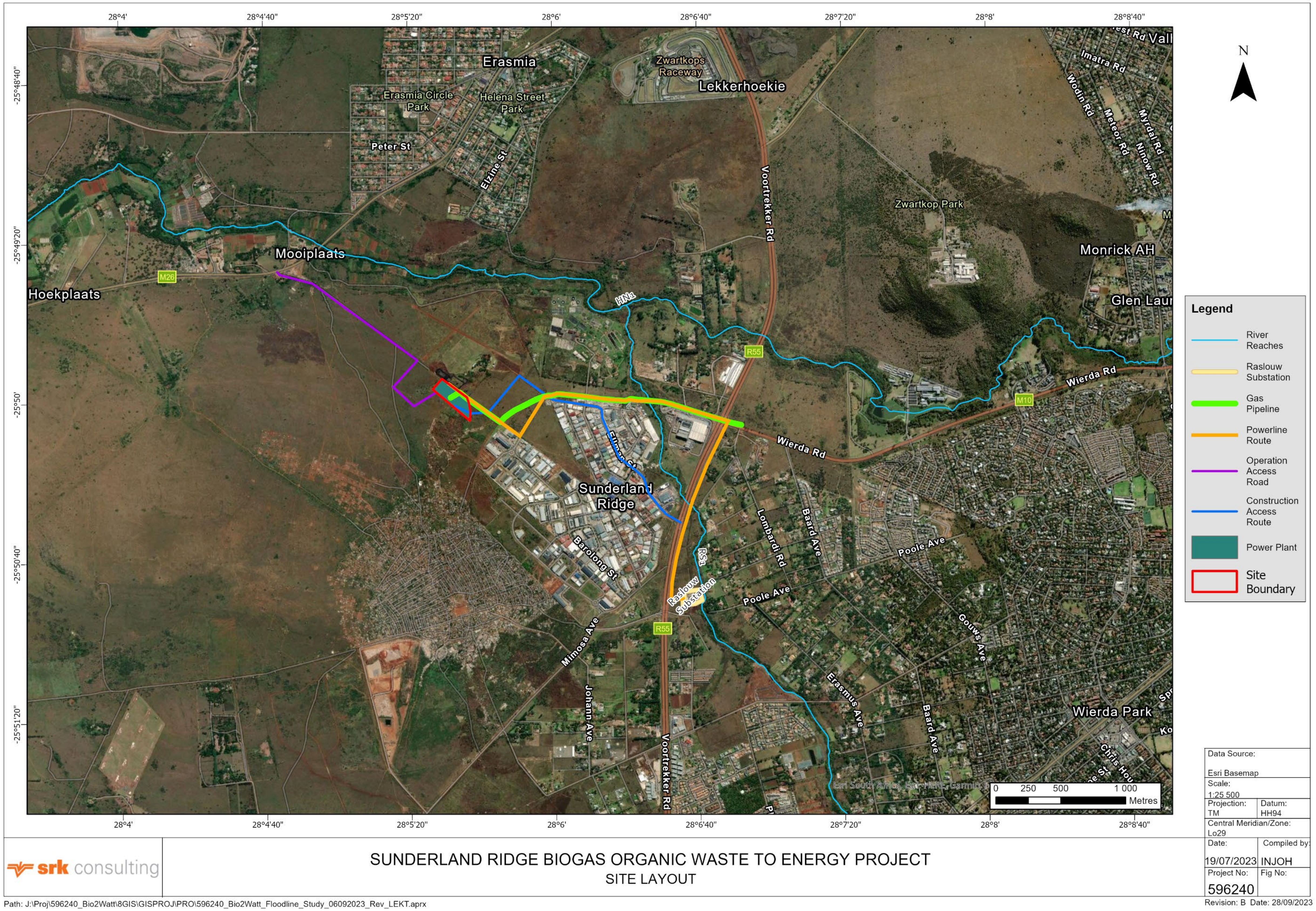

Figure 2-2: BEH site boundary, including the intended powerline and gas pipeline.

3 Topography Details

The catchment area for the calculations of the flood peaks for all the watercourses was delineated using the 1:50 000 topographical maps. As no survey information was provided from BEH, to determine the local topography, a Digital Elevation Model (DEM) was created using 1m contours obtained from the City of Tshwane Municipality. This 1 m contour detailed survey was also used to abstract cross-sectional data of the watercourses and the floodplains within the site boundary.

3.1 Site Visit

On July 5th 2023, a site visit was conducted to examine the study area and gather information on the catchment characteristics and land cover. The purpose was to assess the typical land cover and understand how the catchment drains into the Hennops River, which runs near the BEH site. The catchment area comprises a combination of rural and industrial landscapes, whereas the site itself is primarily rural with nearby industrial and residential areas. Importantly, no features were observed during the visit that would impede or alter the stormwater run-off on the intended site, such as channels, culverts, or manmade structures. The site appeared to have a relatively uninterrupted flow of stormwater.

3.2 River Vegetation and Manning's n-value

Manning's n-value is a coefficient, which is a measure of the roughness of the river. This roughness is determined by the irregularity of the stream, presence of boulders, density and type of vegetation, degree of erosion of the riverbanks, etc. This section includes a selection of photographs illustrating the condition of the riverbeds and flood plains. Manning's "n" values within the watercourses and along the floodplains are shown in photos in Figure 3-1.

3.3 River Vegetation and Manning's n-value

Manning's n-value is a coefficient, which is a measure of the roughness of the river. This roughness is determined by the irregularity of the stream, presence of boulders, density and type of vegetation, degree of erosion of the riverbanks, etc. This section includes a selection of photographs illustrating the condition of the riverbeds and flood plains. Manning's "n" values within the watercourses and along the floodplains are shown in photos in Figure 3-1.

Topography along the proposed development site

Topography along the proposed development site

Topography along the proposed development site

Topography along the proposed development site

M26 over the Hennops River (cross-section 1045.9)

Hennops River in August 2023

srk consulting	**BEH** SITE PHOTOS	Project No. **596240**

Figure 3-1: Pictures were taken during the Site Visit (04/07/2023) and the Hennops River (02/08/2023)

4 Rainfall Assessment

Rainfall data was obtained from 'City of Tshwane Regional Flood Management System: Meteorological Data (July, 2012), Rainfall Analyses and Climate Change' under Roads and Stormwater and Open Space Management. The analysis was based on the "Design Rainfall Estimation in South Africa" (DRE) program developed by JC Smithers and RE Schulze. The program implemented procedures from the Water Research Commission (WRC) project entitled "Rainfall Statistics for Design Flood Estimation in South Africa" (WRC Project K5/1060). We have included a brief insert for background purposes and more technical information can be obtained from JC Smithers from the School of Bioresources Engineering and Environmental Hydrology, University of Natal. In this study (July 2012), Zone C: 140 -155, 1:50 year recurrence interval for a 24-hour rainfall event was used (see Table 4-1).

4.1 Storm Rainfall Depths

Table 4-1: Rainfall Depths for various time durations for the adopted Rainfall Station

Duration	Return Period Rainfall (mm)						
	1:2yr	1:5yr	1:10yr	1:20yr	1:50yr	1:100yr	1:200yr
5 min	9.2	12.6	15.1	17.6	21.2	24.2	27.4
10 min	13.6	18.6	22.3	26.0	31.4	35.8	40.5
15 min	17.1	23.4	27.9	32.7	39.4	44.9	50.8
30 min	21.8	29.8	35.7	41.7	50.3	57.3	64.9
45 min	25.2	34.4	41.1	48.1	58.0	66.1	74.8
60 min	27.9	38.1	45.5	53.2	64.2	73.2	82.8
90 min	32.1	43.9	52.5	61.4	74.1	84.4	95.5
120 min	35.5	48.5	58.0	67.9	81.9	93.3	105.6
240 min	41.9	57.2	68.4	80.0	96.5	110.0	124.5
360 min	46.1	62.9	75.3	88.1	106.2	121.1	137.0
480 min	49.3	67.4	80.6	94.3	113.7	129.6	146.7
600 min	52.0	71.0	85.0	99.4	119.9	136.7	154.7
720 min	54.3	74.2	88.7	103.8	125.2	142.7	161.5
960 min	58.1	79.4	95.0	111.2	134.1	152.8	173.0
1200 min	61.3	83.7	100.2	117.2	141.4	161.1	182.4
1440 min	63.9	87.3	104.4	122.2	147.4	168.0	190.2

Regional index storm-based approaches which utilise L-moments for design rainfall estimation were developed by Smithers and Schulze (2000a) for durations, 24 h using digitised rainfall data from 172 stations which had at least 10 years of record, and for 1 to 7-day durations by Smithers and Schulze (2000b) using daily rainfall from 1 789 stations which had at least 40 years of record.

5 Flood Hydrology

The hydrological modelling task involves the detailed evaluation of the hydrology of the river for use in the determination of the 1:50-year and 1:100-year floodlines. Hydrological modelling uses both deterministic and empirical modelling techniques to aid in the estimation of peak flow rates along natural watercourses and artificial structures within the river system.

The model parameters include:

- Catchment slope, size and shape for the defined river catchment. The catchment extended up to the origin of the river;
- Land-use information regarding current and potential future development conditions;
- Water course size and shape;
- Storm rainfall, estimated from the available daily rainfall record/s.
- Suitable sub-catchment/s were delineated which were used as node/s in the hydraulic model.
- The hydrological modelling included the following procedures:
  - The available rainfall record/s as obtained from different sources were analysed to determine the relevant storm rainfall record/s using weighting where necessary; and
  - The flood peaks at each sub-catchment were determined for 1:2 to 1:200-year storm events.

5.1 Flood Peak Data

To conduct hydraulic modelling for the proposed development site, peak flow rates were determined along the watercourse. The magnitude of the flood peak depended on the catchment characteristics and rainfall intensity. Various methods, including the Regional Maximum Flood (RMF), Standard Design Flood (SDF), and Alternative Rational methods, were utilised to calculate the peak flow rates for the catchment.

The SDF method, developed by Alexander (2002), provided a standardized approach to flood calculations. It involved a calibrated discharge coefficient for recurrence periods of 2 and 100 years. Discharge parameters were calibrated using historical data from 29 homogeneous basins in South Africa.

Unit hydrographs were applicable to catchments ranging from 15 to 5000 km^2. They established the unique physical parameters of a catchment by representing the hydrograph of one millimetre of run-off following rainfall of unit duration, with uniform spatial and temporal distribution. The duration and volume of the hydrograph were determined based on the duration and intensity of the rainfall.

The Alternative Rational Method, an adjustment of the Rational Method, incorporated local South African conditions. It could be employed for catchments larger than 15 km^2. Input data for this method included the catchment area contributing to the discharge point, rainfall intensity, and runoff coefficient representing soil permeability, land use, and catchment slope. We assessed various modelling methods to determine the most suitable approach for this study. However, for this study, PCSWMM software was adopted, as it is a versatile modelling tool, for studying larger catchments with an urban focus. By integrating PCSWMM's robust flood modelling capabilities, our approach enables comprehensive analysis of flood scenarios, a critical concern in larger catchments, especially in urban settings. The methodology promotes an integrated approach, harnessing PCSWMM's capacity to handle multiple facets of watershed modelling within a unified platform, thus enhancing the comprehensiveness of our analysis. With an explicit urban focus, our methodology addresses the complexities of impervious surfaces and complex drainage systems, ensuring the relevance of our findings to urban planning and management. In summary, our approach leverages PCSWMM's strengths in customization, flood modelling, integration, and urban suitability to provide a comprehensive and tailored methodology for larger catchment modelling in urban environments.

Hydrological and hydraulic parameters of the contributing catchments for each river's reach were estimated. Table 5-1 provides the catchment characteristics for the study area. Using the SWMM (SCS) hydrological model, peak flow rates were determined by incorporating the derived river reaches and catchments as seen with flood peak nodes in Figure 2-2. The major rivers considered included Hennops River (HN1 and HN2) and Riet Spruit (RS1, RS2, RS3, RS1T1). While HN1T1, HN2T1, HN2T2, and RS1T1 were included in the model, they were not the primary focus due to their proximity to the site.

Table 5-1: Summary of the Catchment Characteristics

River Reach	Catchment area (Km^2)	Flood Peak Node (cross-section)	100-year Flood Peak (m^3/s)	Length (km)	10/85 Distance (km)	Height Difference (m)	10/85 Slope (m/m)	Tc (hours)
HN1	3875.6	1 (0)	1416	22.90	17.2	185	0.026	11.5
HN1T1	61.1	4 (0)	323	4.90	3.7	58	0.009	8.1
HN2	227.0	2 (0)	1136	16.23	12.2	37	0.005	14.5
H2T1	83.5	5 (0)	465	4.37	3.3	38	0.036	3.8
H2T2	78.5	6 (0)	460	7.80	5.9	80	0.010	5.0
RS1	96.3	3 (0)	350	11.40	8.6	77	0.011	11.0
RS1T1	6.1	8 (0)	92	0.96	0.7	25	0.020	0.8
RS1T2	4.7	7 (0)	74	0.69	0.5	26	0.011	0.4
RS2	22.1	2 (0)	163	9.80	7.4	31	0.005	31.3
RS2T1	4.7	9 (0)	74	0.69	0.5	26	0.004	0.4

Tc denotes the time needed for water to flow from the most remote point in a watershed to the watershed outlet.10-85 Length denotes the difference between the length of the main watercourse at 85% of the total length and at 10% of the total length.10-85 H Denotes the difference in height (m) of the main watercourse at 85% of the total length (m) of the main watercourse and 10% of the total length of the main watercourse. The flood peaks are summarized in Table 5-2. The cross sections where the peaks were calculated are shown in Figure 6-1. The flood peaks at reference sections along watercourses are summarised in Table 5-2. Shows the results of the SWMM hydrological model results, which were then used to calculate the calculation of the 1:50-year and 1:100-year flood levels along the selected river reaches.

Table 5-2: Summary of Flood Peaks near the BEH Site

River Reach and Cross-Section	Rational SCS 1:50 Year Peak Flow (m^3/s)	Rational SCS 1:100 Year Peak Flow (m^3/s)	Alternative rational 1:50 year Peak Flow (m^3/s)	Alternative rational 1:100 Year Peak Flow (m^3/s)	SCS 1:50 year Peak Flow (m^3/s)	SCS 1:100 Year Peak Flow (m^3/s)
RS1 - 0	320	399	376	447	288	350
HN1 - 9569	1077	1336	1209	1435	1165	1416
HN2 - 13903	791	983	802	949	934	1135

Note: The SWMM (SCS) hydrological model was the adopted method for this study.

6 Hydraulic Modelling

The 1 m contour survey from the CoT in the intended area was used to create a Digital Elevation Model (DEM), to determine the flood levels of the nearby watercourses. The DEM data was inputted into the GeoHECRAS model (version 4.1.0, which has been the latest version since of July 2022), which utilizes detailed channel morphology and site-specific hydrological data to perform two-dimensional hydraulic calculations for a river network. GeoHECRAS was used over its counterpart HEC-RAS as it offers enhanced capabilities and advantages over the standalone HEC-RAS.

Within the hydraulic model, it is assumed that the hydrological processes within the catchment are in a steady state, meaning that inputs (such as precipitation) and outputs (such as streamflow) remain relatively constant over time. While this assumption simplifies modelling, it may not always hold true, especially during extreme weather events. Another assumption is that similar landuse areas within the catchment area are homogeneous in terms of soil type, and topography. This simplifies calculations by treating the catchment as a single unit rather than accounting for variations within it.

By employing standard backwater techniques, the GeoHECRAS model calculates high-water levels for different steady flow conditions, considering structures and controls present along the watercourse. To initiate the calculations, the model requires specific boundary river flow conditions as a starting point.

Table 6-1 summarizes the main parameters of the GeoHECRAS model. It combines detailed channel morphology and site-specific hydrological data to conduct one-dimensional hydraulic calculations for the river network. The model uses two-dimensional calculations to determine the high-water level under various steady flow conditions, accounting for structures and controls along the watercourse. The model also relies on specific boundary river flow conditions as a calculation starting point.

Table 6-1: GeoHECRAS Model Boundary Conditions

Parameter	Average Value/ Selection	Reason
Manning's n-value (main channel flow) along the Hennops River (HN1), Relative to the BEH intended site.	0.014-0.05	There is a defined channel, with riparian vegetation.
Manning's n-value (floodplains), along the site (intended plant) boundary.	0.04-0.06	Sparse to medium vegetation.
Boundary condition	Normal flow depth	Control structures present.
Flow regime	Mixed flow	Slope and cross-section changes requiring super and sub-critical flow regimes.

The GEOHECRAS model cross-sections were named in accordance with the defined River Referencing System (RRS). The GeoHECRAS model was then used in conjunction with the Geographic Information System (GIS) program, Arc Map (With 3-D analyst and spatial analyst extensions). GIS was also used to create cross-sections and other geometrical data for use in GeoHECRAS and was used to export water surface data from GeoHECRAS into a GIS database. Further details of the GeoHECRAS model parameter files are given in Appendix A. An overview of the cross-sections is seen in Figure 71 and Appendix A.

The 1:50-year and 1:100-year average flood depths and average flood velocities resulting from the GeoHECRAS Model simulation along the floodplains are given below in Tables 72, 73, 74 and 75.

Table 6-2: Summary of Average Flood Depths Along Floodplains of the Rivers in Relation to the BEH site

River Reach	Average Flood Depth (m)	
	1:50 year	1:100 Year
RS1: (Raslouw Substation and powerlines) 2972 to 678	3.87	4.12
HN1: Cross-sections 11072 to 13007	3.23	3.52

Note: the flood depth is the difference between the lowest channel height and the water surface level

Table 6-3: Summary of Average Flood Velocity Along Floodplains of the Rivers in Relation to the BEH site

River Reach	Average Channel Velocity (m/s)	
	1:50 year	1:100 Year
RS1: (Raslouw Substation and powerlines) 2972 to 678	3.21	3.44
HN1: Cross-sections 11072 to 13007	3.56	3.77

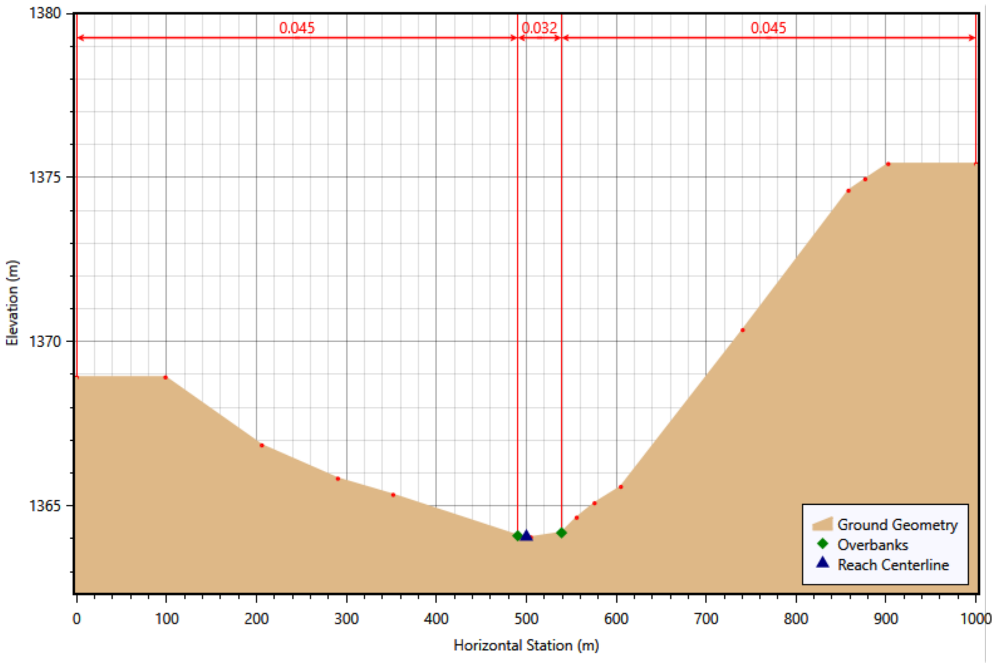

Figure 6-1: Cross-section HN1-10286, a typical cross-section of the river near the intended BEH site

Table 6-4: Culvert: HN1 RS: 10905 Summary

Parameter		Parameter	
Q Culv Group (m^3/s)	1415.92	Culv Vel US (m/s)	3.04
# Barrels	1	Culv Vel DS (m/s)	2.65
Q Barrel (m^3/s)	1415.92	Culv Inv El Up (m)	1366.14
E.G. US. (m)	1369.18	Culv Inv El Dn (m)	1365.89
W.S. US. (m)	1369.07	Culv Frctn Ls (m)	0.02
E.G. DS (m)	1368.73	Culv Exit Loss (m)	0.19

Parameter		Parameter	
W.S. DS (m)	1368.56	Culv Entr Loss (m)	0.24
Delta EG (m)	0.45	Min El Weir Flow (m)	1369.8
Delta WS (m)	0.51		
E.G. IC (m)	1368.9		
E.G. OC (m)	1369.18		
Culvert Control	Outlet		
Culv WS Inlet (m)	1368.47		
Culv WS Outlet (m)	1368.56		
Culv Nml Depth (m)	1.18		
Culv Crt Depth (m)	1.72		

6.1 Findings of the Floodline Study

The 1:50 and 1:100-year floodlines were determined based on the HECRAS model and peak flow rates as given in Table 6-3 above.

Details of the GeoHECRAS model output data are given in Appendix A.

The floodlines are shown in Figure B1 in Appendix B. From the floodline study, the following was observed:

- The Site boundary is situated outside the 1:100 year floodline.
- Bridge M26 (1045.9 Cross-section) near the site, can accommodate the 1:100-year flood event;
- The Raslouw Substation is breached by the 1:50 year and 1:100 year events.
- The powerline and gas pipeline will be impacted by the 1:50 year 100 year floodline.
- As the gas pipeline will be impacted by the 1:50 and 100 year flood event, to ensure protection and prevent erosion, the pipe's bottom must be positioned above the floodline, with support structures safeguarded by rock baffles or similar. Following storm events, routine cleaning and maintenance are essential around the piers/piles. It's advisable to set expectations for inspections and maintenance in September, ahead of the rainy season.

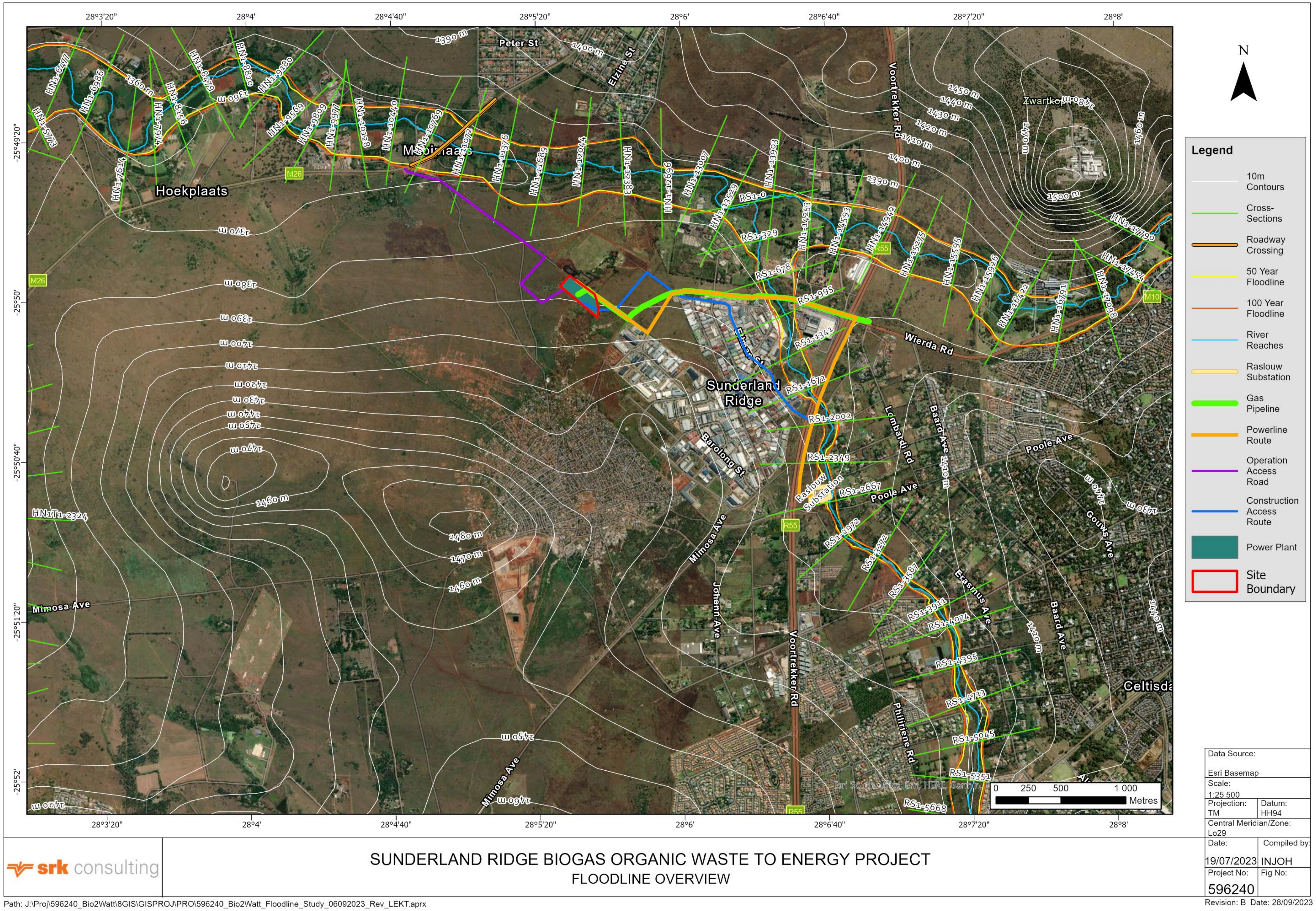

Figure 6-2: 50 and 100-Year Floodline overview in relation to BEH indented Site Boundary and Power Plant. (Note: not all cross-sections are represented for reporting purposes)

7 Water Quality Analysis

A site visit was undertaken on July 5th 2023 and a water quality sample collected under the bridge on the R55 which will constitute an upstream point from the site.

Water is provided to water users in the catchment from Rand Water however there is a possibility that users from neighbouring informal communities may utilise water from the river. Although the chemical quality is acceptable it is suspected that the microbiology may be not acceptable, considering the odour of the water.

The quality is evaluated against SANS 241 :2015. The chemical quality of the river at this time and stage is within limits. However, monitoring should continue for at least 6 months prior to construction.

Table 7-1: Water Quality Analysis

Analyses			Unit	Method	001	002 (Control)	SANS 214:2015
A	AQL	pH @ 25°C	pH	ALM 20	8.13	8.14	
A	AQL	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	58.0	58.5	
A	AQL	Total Alkalinity	mg $CaCO_3$/l	ALM 01	214	217	
A	AQL	Chloride (Cl)	mg/l	ALM 02	42.3	41.6	≤ 300
A	AQL	Sulfate (SO_4)	mg/l	ALM 03	30.0	30.6	≤ 500
A	AQL	Nitrate (NO_3) as N	mg/l	ALM 06	0.938	1.02	≤ 11
A	AQL	Total oxidised nitrogen as N	mg/l	ALM 06	0.938	1.02	
A	AQL	Ammonium (NH_4) as N	mg/l	ALM 05	10.4	11.6	≤ 1.5
A	AQL	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.843	0.856	
A	AQL	Fluoride (F)	mg/l	ALM 08	0.684	<0.263	≤ 1.5
A	AQL	Calcium (Ca)	mg/l	ALM 30	33.7	35.1	
A	AQL	Magnesium (Mg)	mg/l	ALM 30	16.7	17.5	
A	AQL	Sodium (Na)	mg/l	ALM 30	42.0	46.6	≤ 200
A	AQL	Potassium (K)	mg/l	ALM 30	10.4	11.0	
A	AQL	Aluminium (Al)	mg/l	ALM 31	<0.002	0.111	≤ 300
A	AQL	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	≤ 2 000
A	AQL	Manganese (Mn) (Chronic Health)	mg/l	ALM 31	0.353	0.354	≤ 400
A	AQL	Chromium (Cr)	mg/l	ALM 31	<0.003	<0.003	≤ 50
A	AQL	Copper (Cu)	mg/l	ALM 31	0.008	0.009	≤ 2 000
A	AQL	Nickel (Ni)	mg/l	ALM 31	0.015	0.023	≤ 70
A	AQL	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	≤ 5
A	AQL	Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	≤ 500
A	AQL	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	≤ 3
A	AQL	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	≤ 10
A	AQL	Total suspended solids (TSS)	mg/l	ALM 25	<4.5	<4.5	

8 Surface Water Quality Impacts and Risk Assessment

8.1 Impacts during construction

The potential impacts on surface water during the construction phase of the proposed project are as follows:

- Accidental spillages of hazardous substances from construction vehicles used during construction, as well as from hazardous storage areas.
- Debris from poor handling of materials and/or poor waste management practises; and
- Contaminated dirty water runoff to surrounding areas resulting in the impact on local surface water quality.

It is expected that without the implementation of mitigation measures, the impacts on the surface water quality and the hydrology of the area will be of medium (-) significance, which can be reduced to low (-) significance with the implementation of mitigation measures.

Table 8-1: Surface Water Impact Assessment Results for the Construction Phase

Impact:		***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Potential deterioration in water quality because of accidental spillages of hazardous substances such as hydrocarbons from vehicles and machinery used during construction.	Without mitigation	Regional	Medium	Medium-term	Medium	Probable	MEDIUM	– ve	High
		2	2	2	6				
	Essential mitigation measures:								
	• BEH shall ensure that clean and dirty water are kept separate. • Spill kits to be made available at areas of possible spillages of hazardous substances. • Remediation of spillages must be conducted on a continual basis. • Contaminated runoff will be contained and re-used or treated to suitable standard where it can be discharged to surface water where necessary or with permission from the water services authority be discharged to the municipal system;. • No direct discharge of polluted water to the environment is permitted.								
	With mitigation	Local	Low	Short-term	Very low	Possible	INSIGNIFICANT	– ve	High
		1	1	1	3				
Impact:		***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Possible contaminated dirty water runoff to surrounding areas resulting in the impact on local surface water quality	Without mitigation	Regional	Medium	Medium-term	Medium	Probable	MEDIUM	– ve	High
		2	2	2	6				
	Essential mitigation measures:								
	• No washing of vehicles shall be allowed outside demarcated areas. Washing bays for vehicles and other equipment will be clearly demarcated and will not be allowed to contaminate any surface runoff. • BEH shall ensure that clean and dirty water are kept separate. • Remediation of spillages must be conducted on a continual basis. • Spill kits to be made available at areas of possible spillages of hazardous substances. • No activities shall be allowed within 100 metres from the nearby steams and 500 meters from riparian areas without consent from the DWS.								
	With mitigation	Local	Low	Short-term	Very low	Possible	INSIGNIFICANT	– ve	High
		1	1	1	3				
Impact:		***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Poor stormwater management leading to runoff from stockpiled material removed causing pollution of the water resources.	Without mitigation	Regional	Medium	Medium-term	Medium	Probable	MEDIUM	– ve	High
		2	2	2	6				
	Essential mitigation measures:								
	• Ensure clean and dirty water segregation.								
	With mitigation	Local	Low	Short-term	Very low	Possible	INSIGNIFICANT	– ve	High
		1	1	1	3				

8.2 Surface Water Quality Impacts During Operation

The potential impacts on surface water during the operational phase of the proposed project are as follows:

- Surface runoff contamination as a result of improper chemical storage/handling;
- Pipelines transporting non-potable water traversing drainage lines failing;
- Contamination of runoff by poor materials/waste handling practices; and
- Contaminated dirty water runoff from the plant to surrounding areas resulting in the impact on local surface water quality.

It is expected that without the implementation of mitigation measures, the impacts on the hydrology will be of medium-low (-) significance, which can be reduced to very low (-) significance with the implementation of mitigation measures.

It is assumed that the sanitation waste water will be discharged to municipal sewage system.

Table 8-2: Surface Water Impact Assessment for the Operational Phase

Impact:		***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Surface water impacts from improper storage, transportation, and handling of products, raw materials, and waste	Without mitigation	Regional	Medium	long-term	High	Probable	High	– ve	Medium
		2	2	3	7				
	Mitigation measures:								
	• Install bunds under and around storage tanks • Using specialist service providers equipped for transportation via road. • Adequate training for people on proper handling the product, raw materials, and waste responsibly • Ensure relevant standards and good practice are adhered to for all installations								
	With mitigation	Regional	Low	Medium-term	Low	Possible	VERY LOW	– ve	Medium
		2	1	2	5				
Impact:		***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Potential surface water impacts from liquid bulk storage and transportation	Without mitigation	Regional	Medium	Medium-term	Medium	Probable	MEDIUM	– ve	Medium
		2	2	2	6				
	Mitigation measures:								
	• Install bunds under and around storage tanks • Use reputable service providers for transportation • Undertakemonthly monitoring and maintenance								
	With mitigation	Regional	Low	Medium-term	Low	Possible	VERY LOW	– ve	Medium
		2	1	2	5				
Impact:		***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Potential surface water impacts due to failing pipeline conveying non-potable water above surface	Without mitigation	Regional	Medium	Medium-term	Medium	Probable	MEDIUM	– ve	Medium
		2	2	2	6				
	Mitigation measures:								
	• The monitoring and surveillance of non-potable water surface pipeline network; • Implement technology on pipelines which will give early warning of minor leaks								
	With mitigation	Regional	Low	Medium-term	Low	Possible	VERY LOW	– ve	Medium
		2	1	2	5				

9 Conclusions and Recommendations

The following is recommended:

- The floodline information to be used to ensure that no new developments at the intended site are situated within the 1:100-year floodline;
- The BEH site Boundary remains outside the 100 year flood;
- Bridge M26 (1045.9 Cross-section) near the site, can accommodate a 100-year flood;
- 100 year and 50-year floods breach the Raslouw Substation;
- A survey is recommended for a detailed review of the breach of the Raslouw Substation and crossing of the powerline/ gas pipeline of the lower Riet Spruit (RS1-2972 to RS1-678)
- The BEH should build the powerline in accordance to the 100-year floodline.
- The floodlines be revised should watercourse/control structures be modified in the future.
- Water Quality Monitoring to be undertaken monthly for at least 6 months prior to construction and then quarterly thereafter
- Since the anticipated pipelines will be traversing drainage lines a Water Use Authorisation will be required in terms of the National Water Act, of 1998 Section 21(c) and (i)

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendices

Appendix B: Hydrology Summary

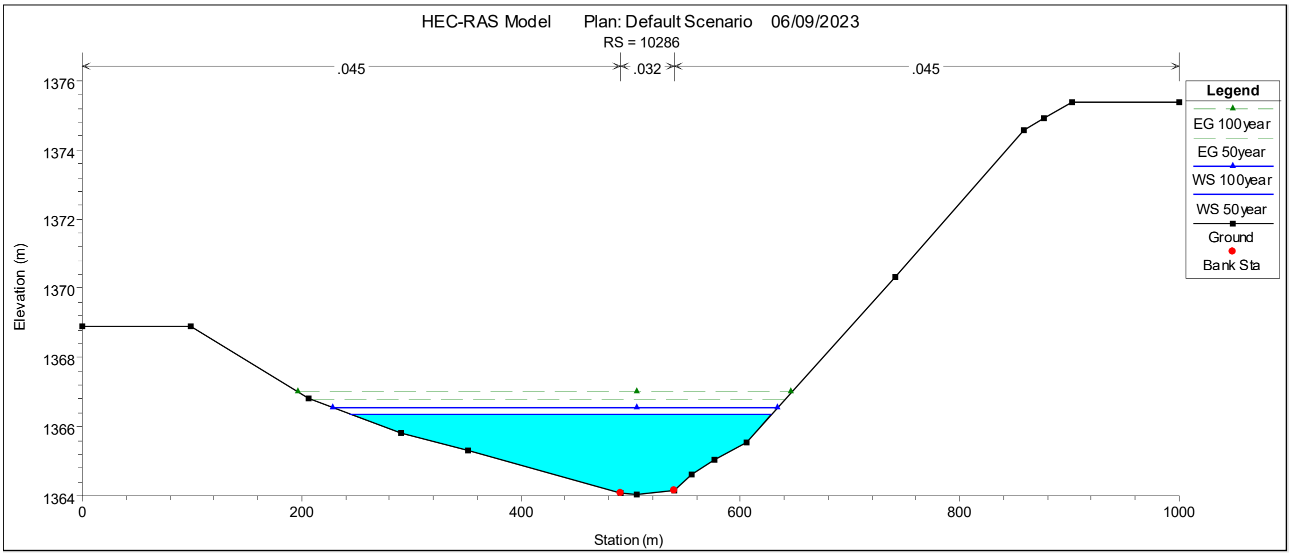

Figure A1. HN1-10286. A typical cross-section along the Hennops River near the intended site with 50 and 100 year surface water profiles.

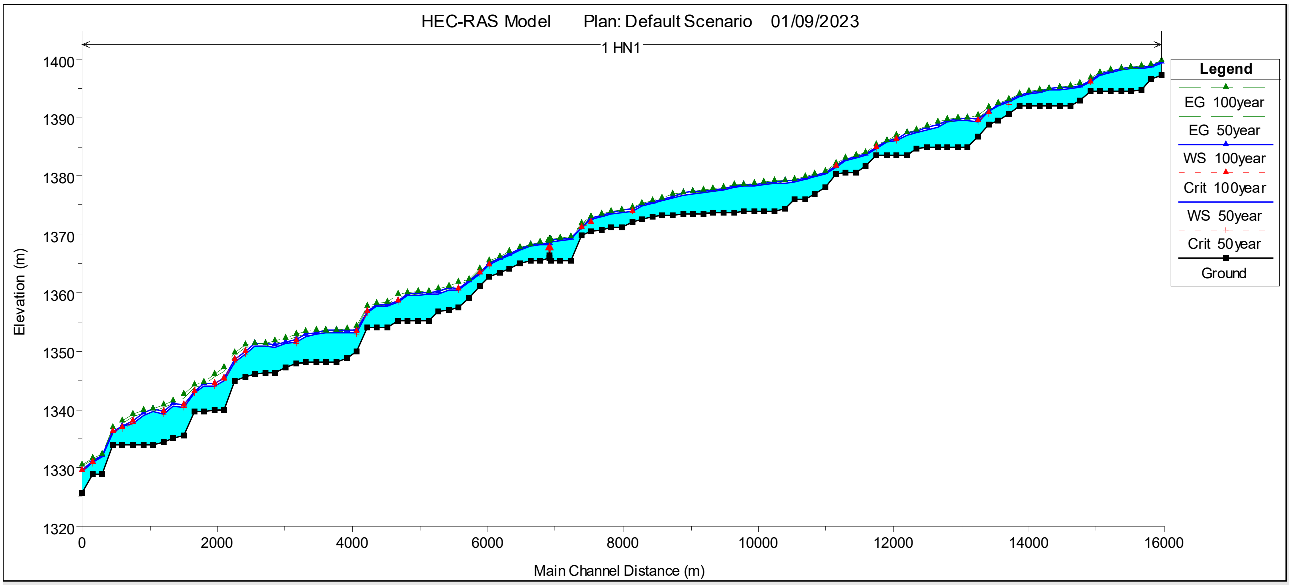

Figure A2. HN1 (Hennops River Downstream) elevation profile with 50- and 100-year surface water profiles.

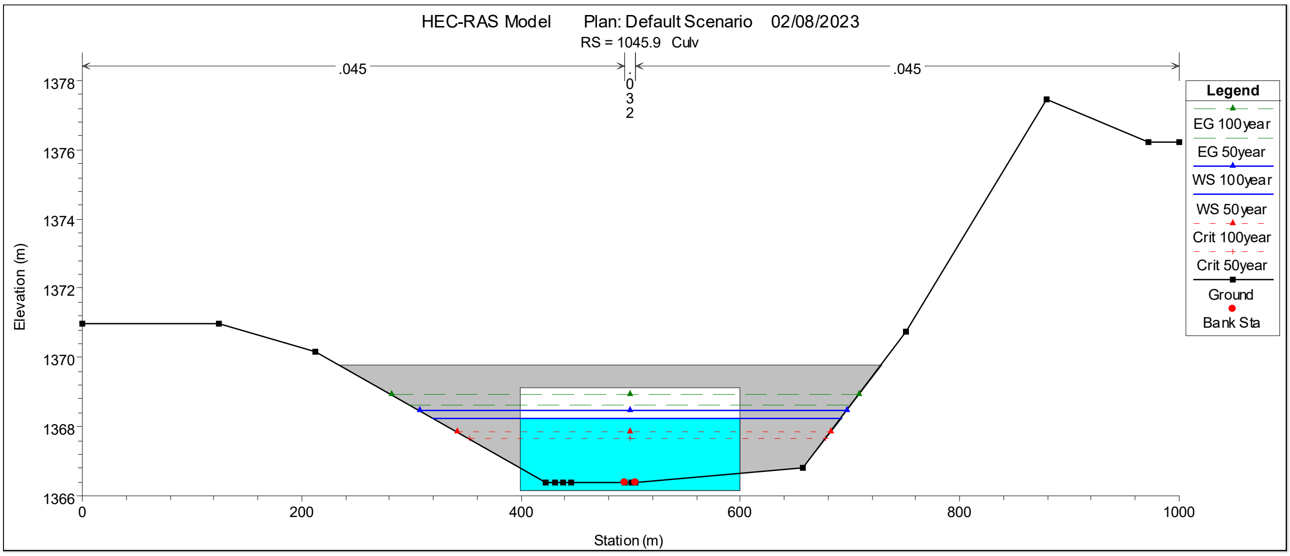

Figure A3. Bridge M26 (1045.9 Cross-section) with 50- and 100-year surface water profiles.

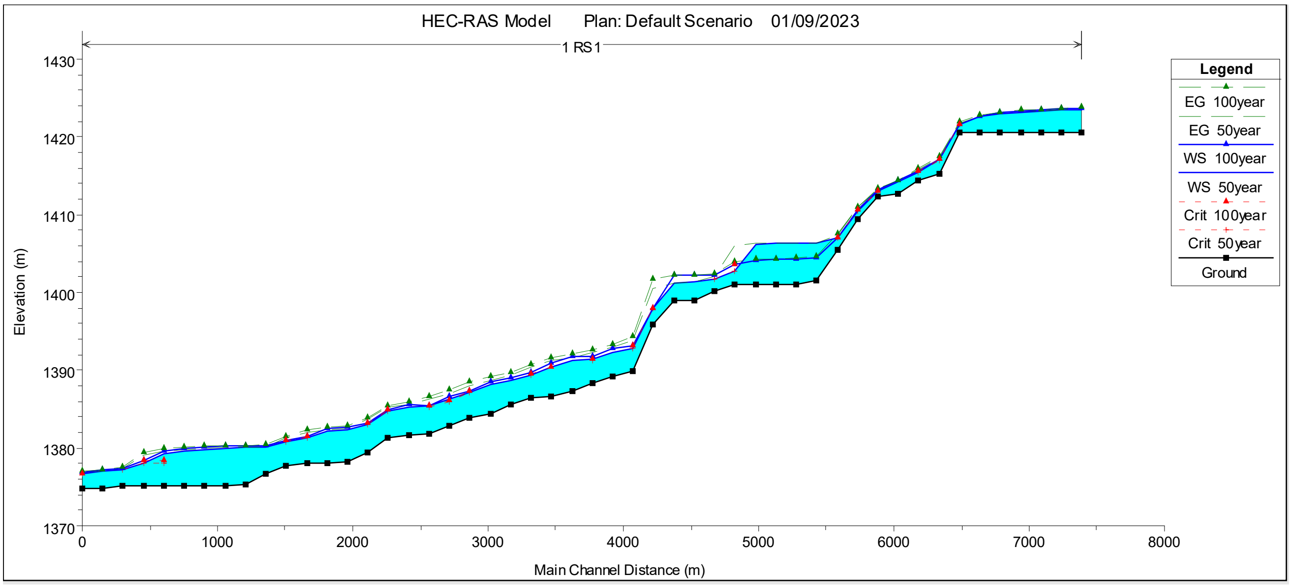

Figure A4. RS1 (Riet Spruit Downstream) elevation profile with 50- and 100-year surface water profiles.

Appendix B: Hec Ras and PCSWMM Summary

One Drive link with Hec-Ras and PCSWMM Summary: [596240_Floodline_Overview_31082023.xlsx]

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
RS1	5668	50year	288.15	1401.08	1406.27		1406.28	0.000068	0.75	695.99	223.05	0.11
RS1	5668	100year	350.36	1401.08	1404.34		1404.42	0.000865	1.94	320.92	166.63	0.35
RS1	5505	50year	288.15	1401.08	1406.26		1406.27	0.000043	0.62	859.02	263.56	0.09
RS1	5505	100year	350.36	1401.08	1404.25		1404.3	0.000596	1.65	391.99	201.82	0.3
RS1	5351	50year	288.15	1401.08	1406.26		1406.26	0.000039	0.59	906.32	278.19	0.08
RS1	5351	100year	350.36	1401.08	1404.16		1404.21	0.000619	1.65	394.94	210.51	0.3
RS1	5197	50year	288.15	1401.08	1402.81	1402.81	1405.93	0.051148	9.72	46.17	48.73	2.42
RS1	5197	100year	350.36	1401.08	1403.57	1403.57	1403.96	0.0063	4.4	176.18	185.2	0.91
RS1	5045	50year	288.15	1400.13	1401.66	1401.66	1402.08	0.010947	4.18	119.69	136.68	1.11
RS1	5045	100year	350.36	1400.13	1402.21		1402.42	0.003749	3.03	201.17	162.02	0.68
RS1	4877	50year	288.15	1398.96	1401.34		1401.4	0.000933	1.66	306.31	207.78	0.35
RS1	4877	100year	350.36	1398.96	1402.21		1402.24	0.000344	1.25	507.4	256.45	0.22
RS1	4713	50year	288.15	1399.04	1401.17		1401.23	0.001251	1.79	274.07	194.51	0.4
RS1	4713	100year	350.36	1399.04	1402.15		1402.19	0.000368	1.26	491.81	246.71	0.23
RS1	4558	50year	288.15	1395.84	1397.92	1397.92	1400.47	0.029269	8.6	52.3	45.18	1.92
RS1	4558	100year	350.36	1395.84	1397.93	1397.93	1401.63	0.042226	10.37	52.89	45.64	2.31
RS1	4395	50year	288.15	1389.84	1392.83	1392.83	1393.89	0.007437	5.59	77.96	41.37	1.03
RS1	4395	100year	350.36	1389.84	1393.21	1393.21	1394.32	0.006867	5.82	94.78	47.62	1.01

RS1	4235	50year	288.15	1389.13	1392.35		1392.93	0.004055	4.34	104.98	52.79	0.77
RS1	4235	100year	350.36	1389.13	1392.76		1393.35	0.003661	4.46	127.52	58.84	0.75
RS1	4074	50year	288.15	1388.31	1391.49	1391.17	1392.24	0.005044	4.8	92.05	45.42	0.86
RS1	4074	100year	350.36	1388.31	1391.82	1391.49	1392.67	0.005212	5.21	107.83	52.21	0.89
RS1	3911	50year	288.15	1387.35	1391.31		1391.67	0.001983	3.48	146.9	80.77	0.56
RS1	3911	100year	350.36	1387.35	1391.75		1392.09	0.00175	3.51	185.3	91.45	0.53
RS1	3753	50year	288.15	1386.7	1390.46		1391.21	0.004114	4.7	95.61	46.06	0.79
RS1	3753	100year	350.36	1386.7	1390.87	1390.42	1391.67	0.003948	4.94	116.09	55.19	0.79
RS1	3587	50year	288.15	1386.48	1389.4	1389.37	1390.38	0.007305	5.46	82.21	45.84	1.02
RS1	3587	100year	350.36	1386.48	1389.65	1389.58	1390.81	0.007936	6.01	94.5	52.31	1.08
RS1	3429	50year	288.15	1385.64	1388.71		1389.38	0.005025	4.68	99.66	54.51	0.85
RS1	3429	100year	350.36	1385.64	1389.06		1389.76	0.00472	4.88	120.06	61.3	0.84
RS1	3272	50year	288.15	1384.4	1388.22		1388.76	0.003084	4.08	111.88	53.45	0.68
RS1	3272	100year	350.36	1384.4	1388.57		1389.16	0.003122	4.36	131.7	60.15	0.69
RS1	3124	50year	288.15	1383.88	1387.1	1387.1	1388.05	0.006896	5.34	82.57	45	0.98
RS1	3124	100year	350.36	1383.88	1387.37	1387.37	1388.43	0.007086	5.73	95.08	47.87	1.01
RS1	2972	50year	288.15	1382.88	1386.23	1385.87	1387.02	0.004895	4.9	94.1	49.69	0.85
RS1	2972	100year	350.36	1382.88	1386.68	1386.08	1387.5	0.004503	5.11	122.55	70.72	0.84
RS1	2822	50year	288.15	1381.75	1385.35	1385.24	1386.27	0.004941	5.07	85.48	40.01	0.86
RS1	2822	100year	350.36	1381.75	1385.49	1385.48	1386.68	0.006171	5.81	91.11	40.82	0.96
RS1	2667	50year	288.15	1381.69	1385.34		1385.62	0.002039	3.26	154.12	78.29	0.55
RS1	2667	100year	350.36	1381.69	1385.53		1385.88	0.002353	3.63	169.68	81.92	0.6
RS1	2504	50year	288.15	1381.39	1384.69	1384.69	1385.19	0.003786	4.25	142.11	122.4	0.75

RS1	2504	100year	350.36	1381.39	1384.84	1384.84	1385.39	0.004164	4.59	160.66	126.19	0.79
RS1	2349	50year	288.15	1379.5	1382.97	1382.97	1383.66	0.004419	4.68	112.12	78.11	0.81
RS1	2349	100year	350.36	1379.5	1383.2	1383.2	1383.94	0.004578	4.97	130.51	83.36	0.83
RS1	2180	50year	288.15	1378.27	1382.35		1382.55	0.001325	2.8	182.18	84.87	0.45
RS1	2180	100year	350.36	1378.27	1382.65		1382.88	0.001448	3.08	209.8	97.69	0.48
RS1	2002	50year	288.15	1377.99	1382.21		1382.36	0.000949	2.49	220.24	109.42	0.39
RS1	2002	100year	350.36	1377.99	1382.51		1382.68	0.001019	2.7	254.58	121.25	0.41
RS1	1836	50year	288.15	1378.11	1381.31	1381.31	1382.02	0.005842	4.86	100.76	64.69	0.91
RS1	1836	100year	350.36	1378.11	1381.51	1381.51	1382.31	0.006261	5.25	113.49	66.35	0.95
RS1	1672	50year	288.15	1377.64	1380.82	1380.82	1381.24	0.00357	4.04	162.94	161.86	0.72
RS1	1672	100year	350.36	1377.64	1380.94	1380.94	1381.41	0.004005	4.39	182.39	165.71	0.77
RS1	1505	50year	288.15	1376.62	1380.07		1380.16	0.000937	2.1	288.02	192	0.37
RS1	1505	100year	350.36	1376.62	1380.32		1380.41	0.000905	2.17	337.03	202.85	0.37
RS1	1341	50year	288.15	1375.33	1380.03		1380.07	0.000294	1.46	420.89	204.07	0.22
RS1	1341	100year	350.36	1375.33	1380.27		1380.32	0.000321	1.58	471.56	213.14	0.23
RS1	1156	50year	288.15	1375.21	1380		1380.03	0.000195	1.23	467.05	193.42	0.18
RS1	1156	100year	350.36	1375.21	1380.24		1380.28	0.000222	1.36	514.03	200.63	0.19
RS1	995	50year	288.15	1375.21	1379.84		1379.97	0.000706	1.92	251.5	167.84	0.32
RS1	995	100year	350.36	1375.21	1380.06		1380.21	0.000767	2.08	290.02	182.1	0.34
RS1	842	50year	288.15	1375.21	1379.68		1379.84	0.000944	2.18	248.94	224.42	0.37
RS1	842	100year	350.36	1375.21	1379.92		1380.08	0.000916	2.25	305.01	245.44	0.37
RS1	678	50year	288.15	1375.21	1379.18	1378.1	1379.61	0.002113	2.96	123.81	253.17	0.53
RS1	678	100year	350.36	1375.21	1379.63	1378.46	1379.9	0.001339	2.58	249.73	307.35	0.43

RS1	496	50year	288.15	1375.21	1378.11	1378.11	1379.05	0.006447	4.44	76.03	51.51	0.92
RS1	496	100year	350.36	1375.21	1378.34	1378.34	1379.43	0.006737	4.83	89.2	63.13	0.95
RS1	329	50year	288.15	1375.21	1377.18	1377.18	1377.41	0.006267	3.45	194.15	316.55	0.85
RS1	329	100year	350.36	1375.21	1377.29		1377.51	0.005681	3.43	229.97	321.09	0.82
RS1	169	50year	288.15	1374.8	1377.07		1377.09	0.000545	1.23	475.87	531.16	0.27
RS1	169	100year	350.36	1374.8	1377.19		1377.22	0.000709	1.46	542.09	588.38	0.31
RS1	0	50year	288.15	1374.8	1376.76	1376.69	1376.91	0.004099	3.14	247.94	406.15	0.71
RS1	0	100year	350.36	1374.8	1376.85	1376.75	1377	0.004096	3.23	284.42	417.65	0.72
HN1	17790	50year	1165.52	1385.01	1389.15		1389.34	0.001749	3.37	674.74	285.07	0.53
HN1	17790	100year	1415.92	1385.01	1389.45		1389.67	0.001824	3.61	763.42	297.96	0.55
HN1	17635	50year	1165.52	1385.01	1388.43		1388.89	0.005219	5.12	447.24	240.62	0.88
HN1	17635	100year	1415.92	1385.01	1388.7		1389.2	0.005292	5.42	514.33	255.24	0.9
HN1	17454	50year	1165.52	1385.01	1388		1388.23	0.003032	3.55	584.97	302.26	0.66
HN1	17454	100year	1415.92	1385.01	1388.27		1388.53	0.003056	3.78	670.51	317.4	0.67
HN1	17268	50year	1165.52	1384.72	1387.32		1387.65	0.004973	4.08	488.52	275.57	0.82
HN1	17268	100year	1415.92	1384.72	1387.61		1387.96	0.004716	4.27	570.07	289.62	0.81
HN1	17098	50year	1165.52	1383.57	1387.08		1387.22	0.001462	2.76	723.88	290.75	0.47
HN1	17098	100year	1415.92	1383.57	1387.35		1387.52	0.001585	3.02	804.99	300.02	0.5
HN1	16954	50year	1165.52	1383.56	1386	1385.99	1386.68	0.012292	6.28	359.66	260.41	1.28
HN1	16954	100year	1415.92	1383.56	1386.22	1386.21	1386.95	0.012049	6.59	420.18	281.12	1.29
HN1	16791	50year	1165.52	1383.56	1385.76		1385.9	0.002003	2.37	744.51	391.49	0.51
HN1	16791	100year	1415.92	1383.56	1385.98		1386.14	0.002164	2.62	831.32	408.1	0.54
HN1	16600	50year	1165.52	1383.56	1384.69	1384.69	1385.18	0.018445	4.63	385.42	397.05	1.38

HN1	16600	100year	1415.92	1383.56	1384.84	1384.84	1385.38	0.01788	4.92	442.17	407.4	1.39
HN1	16422	50year	1165.52	1381.63	1383.6		1383.79	0.003578	2.9	625.72	389.32	0.67
HN1	16422	100year	1415.92	1381.63	1383.83		1384.04	0.003463	3.08	718.72	401.19	0.67
HN1	16264	50year	1165.52	1380.6	1383.09		1383.29	0.003031	3.16	615.01	330.87	0.64
HN1	16264	100year	1415.92	1380.6	1383.31		1383.54	0.003157	3.41	688.42	337.54	0.66
HN1	15926	50year	1165.52	1380.5	1382.7		1382.85	0.00262	2.7	692.2	396.18	0.58
HN1	15926	100year	1415.92	1380.5	1382.9		1383.08	0.002764	2.95	774.46	407.79	0.61
HN1	15764	50year	1165.52	1380.41	1381.47	1381.47	1381.97	0.019321	4.52	377.09	383.83	1.4
HN1	15764	100year	1415.92	1380.41	1381.62	1381.62	1382.18	0.01852	4.82	432.79	391.89	1.4
HN1	15595	50year	1165.52	1378	1380.36		1380.56	0.003129	3.09	603.71	322.03	0.64
HN1	15595	100year	1415.92	1378	1380.64		1380.86	0.003027	3.28	695.15	333.31	0.65
HN1	15441	50year	1165.52	1377	1379.78		1380.05	0.003644	3.7	549.79	299.84	0.71
HN1	15441	100year	1415.92	1377	1380.08		1380.36	0.003547	3.91	641.05	321.16	0.72
HN1	15275	50year	1165.52	1376.08	1379.32		1379.56	0.0028	3.6	582.1	275.82	0.64
HN1	15275	100year	1415.92	1376.08	1379.61		1379.87	0.002889	3.87	663.44	291.95	0.66
HN1	15110	50year	1165.52	1376.11	1378.9		1379.1	0.003115	3.46	636.73	372.77	0.66
HN1	15110	100year	1415.92	1376.11	1379.24		1379.43	0.002695	3.47	763.35	391.25	0.63
HN1	14942	100year	1415.92	1374.5	1379.11		1379.21	0.000769	2.4	1097.74	379.27	0.36
HN1	14789	50year	1165.52	1374	1378.67		1378.76	0.000725	2.35	940.15	334.25	0.35
HN1	14789	100year	1415.92	1374	1378.98		1379.09	0.000802	2.58	1046.94	351.4	0.37
HN1	14593	50year	1165.52	1373.95	1378.55		1378.65	0.000762	2.39	923.24	333.77	0.36
HN1	14593	100year	1415.92	1373.95	1378.85		1378.96	0.000844	2.62	1024.97	348.72	0.38
HN1	14414	50year	1165.52	1373.9	1378.31		1378.49	0.00142	3.17	716.9	297.3	0.48

HN1	14414	100year	1415.92	1373.9	1378.58		1378.78	0.001587	3.48	798.24	314.04	0.51
HN1	14253	50year	1165.52	1373.85	1378.28		1378.34	0.000442	1.77	1077.24	321.31	0.27
HN1	14253	100year	1415.92	1373.85	1378.54		1378.62	0.000521	2	1161.3	327.53	0.29
HN1	14061	50year	1165.52	1373.8	1378.04		1378.21	0.002016	3.68	823.12	545.18	0.57
HN1	14061	100year	1415.92	1373.8	1378.32		1378.48	0.001751	3.58	977.41	547.86	0.54
HN1	13903	50year	1165.52	1373.75	1377.57		1377.82	0.003189	4.31	641.83	410.57	0.7
HN1	13903	100year	1415.92	1373.75	1377.88		1378.13	0.003024	4.42	777.31	472.45	0.69
HN1	13733	50year	1165.52	1373.65	1377.27		1377.42	0.001957	3.26	749.74	400.89	0.55
HN1	13733	100year	1415.92	1373.65	1377.59		1377.75	0.00186	3.36	883.57	432.53	0.54
HN1	13529	50year	1165.52	1373.6	1377.06		1377.19	0.001151	2.43	790.46	321.39	0.42
HN1	13529	100year	1415.92	1373.6	1377.37		1377.53	0.001208	2.63	892.57	336.41	0.43
HN1	13174	50year	1165.52	1373.55	1376.97		1377.04	0.000722	1.9	999.16	377.29	0.33
HN1	13174	100year	1415.92	1373.55	1377.28		1377.36	0.00077	2.08	1117.5	390.96	0.34
HN1	13007	50year	1165.52	1373.5	1376.75		1376.88	0.001481	2.64	766.75	340	0.47
HN1	13007	100year	1415.92	1373.5	1377.05		1377.2	0.001523	2.84	868.76	354.14	0.48
HN1	12845	50year	1165.52	1373.2	1376.22		1376.53	0.003891	4.08	515.63	263.93	0.75
HN1	12845	100year	1415.92	1373.2	1376.48		1376.82	0.004064	4.4	584.37	277.85	0.78
HN1	12696	50year	1165.52	1373.15	1375.74		1375.97	0.003221	3.35	577.08	302.52	0.66
HN1	12696	100year	1415.92	1373.15	1375.98		1376.24	0.003385	3.63	649.09	314.64	0.69
HN1	12541	50year	1165.52	1373.13	1375.35		1375.5	0.002738	2.78	688.1	401.24	0.6
HN1	12541	100year	1415.92	1373.13	1375.58		1375.76	0.00274	2.98	783.67	414.66	0.61
HN1	12383	50year	1165.52	1372.61	1374.94		1375.1	0.002552	2.73	690.56	399.99	0.58
HN1	12383	100year	1415.92	1372.61	1375.17		1375.35	0.002667	2.97	781.85	418.42	0.6

HN1	12196	50year	1165.52	1372.22	1374.05	1373.83	1374.44	0.008555	4.25	448.64	343.15	1.02
HN1	12196	100year	1415.92	1372.22	1374.3	1374.01	1374.69	0.007614	4.37	534.69	359.38	0.98
HN1	12044	50year	1165.52	1371.2	1373.82		1373.92	0.001412	2.23	864.43	431.48	0.44
HN1	12044	100year	1415.92	1371.2	1374.06		1374.17	0.001509	2.44	968.08	449.47	0.46
HN1	11842	50year	1165.52	1371.2	1373.58		1373.68	0.001742	2.32	817.38	438.35	0.48
HN1	11842	100year	1415.92	1371.2	1373.79		1373.92	0.00184	2.53	914.53	451.58	0.5
HN1	11689	50year	1165.52	1370.69	1373.14		1373.31	0.003559	3.35	668.82	461.21	0.69
HN1	11689	100year	1415.92	1370.69	1373.35		1373.54	0.003482	3.5	767.51	476.65	0.69
HN1	11528	50year	1165.52	1370.58	1372.58	1371.91	1372.77	0.003676	2.97	627.74	401.2	0.68
HN1	11528	100year	1415.92	1370.58	1372.77	1372.06	1372.99	0.003826	3.23	707.35	415.44	0.7
HN1	11376	50year	1165.52	1369.92	1371.16	1371.16	1371.67	0.018755	4.82	375.75	374.31	1.41
HN1	11376	100year	1415.92	1369.92	1371.31	1371.31	1371.87	0.017975	5.11	432.54	385.08	1.41
HN1	11223	50year	1165.52	1365.42	1369.12		1369.33	0.002289	3.58	641.38	308.53	0.59
HN1	11223	100year	1415.92	1365.42	1369.45		1369.67	0.002272	3.77	744.78	331.54	0.6
HN1	11072	50year	1165.52	1365.42	1368.9		1369.04	0.001443	2.73	774.2	349.57	0.47
HN1	11072	100year	1415.92	1365.42	1369.23		1369.38	0.001448	2.9	891.75	371.43	0.47
HN1	10920	50year	1165.52	1365.42	1368.74	1367.29	1368.83	0.001157	2.36	903.3	420.08	0.41
HN1	10920	100year	1415.92	1365.42	1369.07	1367.46	1369.17	0.001126	2.49	1046.97	444.18	0.42
HN1	10905		Culvert									
HN1	10769	50year	1165.52	1365.4	1368.33		1368.48	0.00227	3.05	744.82	439.33	0.57
HN1	10769	100year	1415.92	1365.4	1368.56		1368.73	0.002403	3.3	850.53	471.85	0.59
HN1	10616	50year	1165.52	1365.4	1367.91		1368.08	0.003039	3.17	689.48	462.37	0.64
HN1	10616	100year	1415.92	1365.4	1368.12		1368.31	0.003136	3.4	790.1	495.87	0.66

HN1	10440	50year	1165.52	1364.98	1367.32		1367.53	0.004469	3.67	621.77	462.57	0.77
HN1	10440	100year	1415.92	1364.98	1367.54		1367.76	0.00431	3.82	724.91	490.75	0.77
HN1	10286	50year	1165.52	1364.02	1366.36		1366.77	0.005355	3.97	508.54	383.74	0.84
HN1	10286	100year	1415.92	1364.02	1366.56		1367.01	0.005451	4.23	584.22	405.18	0.86
HN1	10128	50year	1165.52	1363.47	1365.75		1366.02	0.004237	3.47	594.82	437.27	0.74
HN1	10128	100year	1415.92	1363.47	1365.94		1366.24	0.004306	3.69	678.67	455.56	0.76
HN1	9977	50year	1165.52	1362.65	1364.76	1364.61	1365.18	0.00717	4.28	480.62	387.46	0.95
HN1	9977	100year	1415.92	1362.65	1364.97	1364.77	1365.41	0.006897	4.47	561.22	409.41	0.95
HN1	9809	50year	1165.52	1361.14	1363.25	1363.25	1363.9	0.009937	4.99	386.13	298.37	1.12
HN1	9809	100year	1415.92	1361.14	1363.45	1363.45	1364.16	0.009773	5.27	448.16	316.56	1.13
HN1	9569	50year	1165.52	1359.12	1361.78		1361.96	0.00189	2.6	729.02	418	0.51
HN1	9569	100year	1415.92	1359.12	1362.14		1362.32	0.001659	2.65	884.31	454.8	0.49
HN1	9350	50year	1165.52	1357.5	1360.49	1360.49	1361.41	0.006515	5.12	345.83	202.83	0.96
HN1	9350	100year	1415.92	1357.5	1360.77	1360.77	1361.79	0.00659	5.47	406.65	229.05	0.98
HN1	9180	50year	1165.52	1357.04	1360.5		1360.75	0.001658	2.78	631.97	305.21	0.49
HN1	9180	100year	1415.92	1357.04	1360.8		1361.09	0.001672	2.97	728.11	321.03	0.5
HN1	9021	50year	1165.52	1356.88	1359.83		1360.32	0.005425	4.69	448.55	263.27	0.88
HN1	9021	100year	1415.92	1356.88	1360.23		1360.68	0.004474	4.63	557.72	290.16	0.81
HN1	8810	50year	1165.52	1355.27	1359.66		1359.92	0.001153	2.66	640.15	259.44	0.43
HN1	8810	100year	1415.92	1355.27	1360.03		1360.32	0.00118	2.86	739.75	279.39	0.44
HN1	8646	50year	1165.52	1355.15	1359.53		1359.72	0.001257	2.96	697.51	262.48	0.45
HN1	8646	100year	1415.92	1355.15	1359.89		1360.12	0.001299	3.18	797.61	279.25	0.47
HN1	8479	50year	1165.52	1355.15	1359.46		1359.58	0.00052	1.89	874.78	289.47	0.29

HN1	8479	100year	1415.92	1355.15	1359.82		1359.97	0.000558	2.06	982.73	302.9	0.3
HN1	8314	50year	1165.52	1355.15	1358.41	1358.41	1359.32	0.006091	4.72	331.22	189.97	0.92
HN1	8314	100year	1415.92	1355.15	1358.69	1358.69	1359.69	0.006002	5	386.48	201.64	0.93
HN1	8156	50year	1165.52	1353.95	1357.71		1357.96	0.001604	3.03	656.01	295.55	0.5
HN1	8156	100year	1415.92	1353.95	1358.01		1358.29	0.001688	3.27	746.98	314.48	0.52
HN1	7974	50year	1165.52	1353.95	1357.68		1357.74	0.000768	2.08	1073.52	474.54	0.34
HN1	7974	100year	1415.92	1353.95	1357.99		1358.06	0.000774	2.2	1224.37	493.94	0.35
HN1	7614	50year	1165.52	1353.95	1356.58	1356.58	1357.41	0.006375	4.24	329.81	247.08	0.91
HN1	7614	100year	1415.92	1353.95	1356.88	1356.88	1357.73	0.005719	4.37	411.99	299.66	0.88
HN1	7310	50year	1165.52	1349.92	1353.2	1352.99	1353.91	0.006822	5.62	372.81	196.56	1
HN1	7310	100year	1415.92	1349.92	1353.62	1353.27	1354.3	0.005793	5.62	459.4	216.55	0.94
HN1	6986	50year	1165.52	1348.85	1353.15		1353.4	0.001264	2.83	625.22	227.15	0.45
HN1	6986	100year	1415.92	1348.85	1353.54		1353.83	0.001277	3.03	717.96	239.1	0.46
HN1	6753	50year	1165.52	1348.22	1353.22		1353.27	0.000245	1.43	1292.38	345.83	0.2
HN1	6753	100year	1415.92	1348.22	1353.62		1353.68	0.000266	1.57	1435.52	356.2	0.22
HN1	6477	50year	1165.52	1348.22	1353.14		1353.22	0.000362	1.72	1040.09	287.63	0.25
HN1	6477	100year	1415.92	1348.22	1353.53		1353.63	0.000391	1.88	1155.94	294.55	0.26

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