Floodline Delineation of a Reach of the T-Goob se Laagte River for the proposed Pella Bulk Water Pipeline Project

Pella, Northern Cape, South Africa

January 2020

Client

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Report Name	**Floodline Delineation of a Reach of the T_Goob se Laagte River**	
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Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2017. We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principals of science.	

The horseshoe reservoir, the endpoint of the pipeline (January 2020)

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Declaration

I, Russell Tate declare that:

- I act as the independent specialist in this study;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the project;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this study, including knowledge of the Act, regulations and any guidelines that have relevance to the study;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the study;
- I undertake to disclose to the client and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the study by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Russell Tate

MSc. Aquatic Health

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12/01/2020

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1 Introduction

The Biodiversity Company was appointed by SLR Consulting (South Africa) (Pty) Ltd to undertake a baseline floodline determination in watercourses associated with the Pella bulk water pipeline. The scope of work considered in this study included the delineation of watercourses from the Pelladrift Water Treatment Plant in the north west of the project area ending at the Horseshoe Reservoir near Aggeneys. The remaining extent of the bulk water pipeline which enters the Black Mountain Mining concession was not assessed, as this will form part of the Smelter Project Environmental Impact Assessment.

An existing pipeline runs the servitude that will be used for the new pipeline. It will be located, within the existing 30m reserve of the existing above-ground pipeline. The existing pipeline received General Authorization (27/2/1/D182/1/3/4/5) in terms of section 39 of the National Water Act, 1998 (Act NO. 36 of 1998) for water use activities to be undertaken by Sediberg Water for the upgrading of the existing water supply pipeline (51km) from the Orange River to Aggeneys, Pella, Pofadder and local landowners. The proposed pipeline route will be crossing the same 8 watercourses listed in the existing pipeline authorisation and were considered in this floodline determination.

The legal definition of the extent of a watercourse is defined in the amendment of the General Authorisation for section 21 (c) and (i) water uses. The extent of the watercourse is defined as:

- A river, spring or natural channel in which water flows regularly or intermittently "within the outer edge of the 1 in 100 year floodline or riparian habitat measured from the middle of the watercourse from both banks";
- Wetlands and pans "within 500 m radius from the boundary (temporary zone) of any wetland or pan".

An example of the watercourse extent is provided in Figure 1. The aim of this study was therefore to derive the estimated flood peaks and conduct a modelling exercise which will determine the extent and height of the anticipated peak flows for the 100 year return period.

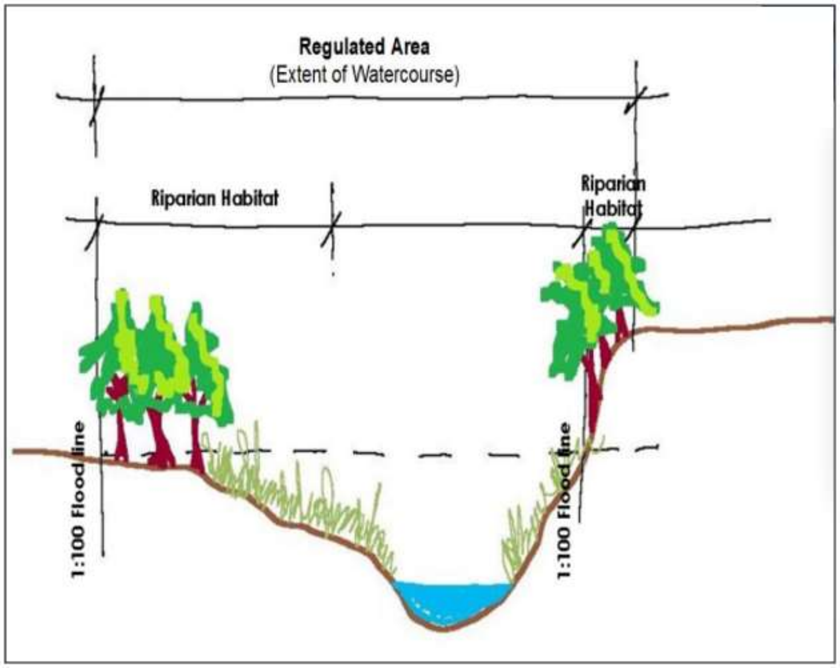

Figure 1: The extent of a watercourse (DWA, 2012)

2 Project Area

The project area, or Area of Interest (AOI), was derived to be between the Pelladrift Water Treatment Plant 39 km north east of the town of Aggeneys, running south west ending in the Horseshoe Reservoir. The project area is located within the Lower Orange Water Management Area (WMA) in the D81G and D82A quaternary catchments. The Sub Quaternary Reaches (SQR's) of concern for this determination are the ephemeral 3rd order 20 km long T-Goob se Laagte River (D81G – 03731 - SQR) and associated tributaries. The T-Goob se Laagte River is a largely natural (class B) river with a moderate ecological status and sensitivity (DWS, 2020). The remaining watercourses of concern are tributaries of the ephemeral D81G – 03840 SQR and a tributary of the ephemeral D82A – 03779 SQR (Mik River). It is noted that within the drainage area assessed during this study, some areas were observed to have endoreic (inward draining) minor catchments, this may present a limitation in the delineations of the catchment areas.

An assessment of the available data regarding the hydrology of the watercourse was made on the Department of Human Settlements, Water and Sanitation (DHSWS) database. There were, however, no gauging stations on any watercourses of concern in the project area.

In order to facilitate the development of the peak flow, the considered catchment area was separated into respective sub catchments as indicated in Section 5.1 of this report.

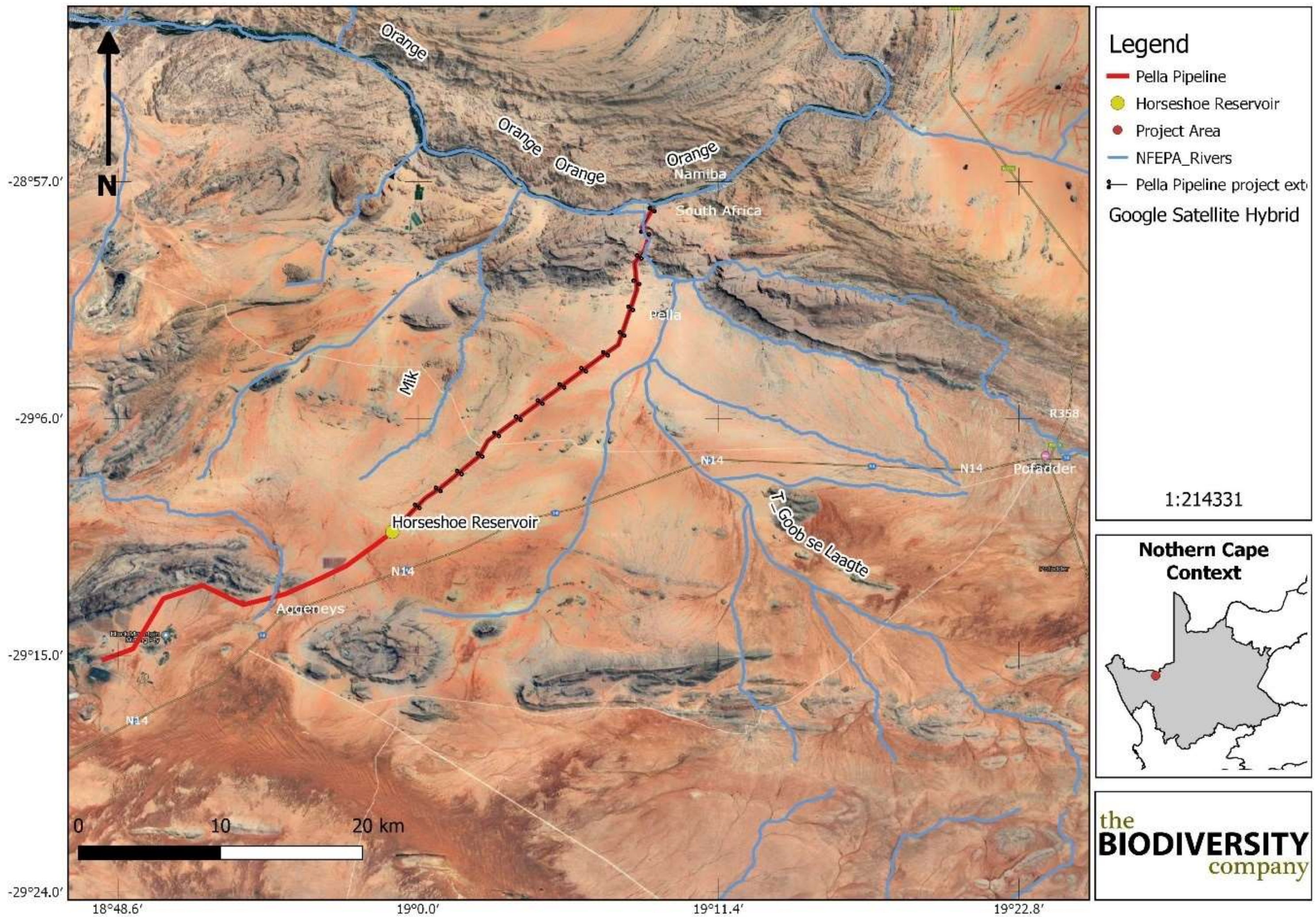

Figure 2: Locality map illustrating the project area (January 2020)

3 Methodology

3.1 Survey

A single site visit was completed for this determination. The site visit was completed from the 14th to17th of January 2020.

3.2 Flood Hydrology

The hydrological assessment completed in this determination was set out in line with the standards and methods stipulated in the SANRAL drainage manual (SANRAL, 2013). Based on the practical guidelines for the relevant catchment areas the following inputs were required for the peak flood calculations:

- Catchment Area;
- Slopes;
- Run-off characteristics;
- Land use, land type and underlying lithology;
- Mean annual precipitation; and
- Local hydraulic structures.

The supporting software Utility Programs for Drainage was utilised for the calculations of the various flood peaks in the appropriate 1:50 and 1:100 return periods.

3.2.1 Storm Rainfall Depths

Through the available software, Design Rainfall Estimation in South Africa (ver 3), the storm rainfall depths were derived with data presented in Smithers and Schulze (2002). The method makes use of the rainfall stations near the project area. The storm rainfall depths for various return periods and storm durations were then calculated for the project area using the abovementioned software.

3.2.2 Elevation Data and Catchment Area

Topographic factors such as catchment size, slope, stream patterns and shape are known to have an impact on the nature of flood events. Steeper catchments may have higher flood peaks over a shorter critical duration, whereas a gentle catchment topography produces longer duration flood peaks (SANRAL, 2013).

Relief data was obtained for the 2731CC Quarter Degree Square from the Department of Rural Development and Land Reform. The contour interval for this data was presented at 10m. The clipped contour data was used to create a Triangular Irregular Network (TIN) which was used to create a Digital Elevation Model (DEM). Standard ARCGIS 10.5 hydrology tools were then used to generate the basin and watersheds for the specific watercourse considered in this determination.

The various catchment characteristics were defined based on the ARCGIS methods stipulated in Gericke and du Plessis (2012). These characteristics included catchment slope, watercourse length and slope, longest path and catchment centroid.

3.2.3 Land Cover and Soils

Land cover types and lithology affects the rates of infiltration and runoff within a catchment. Land cover and soil coverages were used during the peak flow calculations. The land cover of the immediate catchment area upstream of the lowest point in the modelled river was assessed during the determination. In addition, land cover classes from the 2013 – 2014 South African National Land-Cover dataset (Geoterraimage, 2015) and Google Earth imagery was also utilised to calculate the overall catchment land use coverages. Generalised soil coverages for the catchment area were derived based on the Land Type and Capability dataset from the Agricultural Resource Council – Institute for Soil, Climate and Water (ARC-ISCW).

3.2.4 Manning's n Roughness Coefficients

The Manning's n roughness coefficients are values that are used to model the instream channel, the riverbanks and adjacent floodplains resistance to flow. The Mannings roughness was assessed during the site visit. The instream channels are ephemeral in nature and consisted of a wide, flat channel with sandy to rocky substrate and little to no vegetation (Figure 3). The riparian area on the banks are limited and comprised of rocky embankments or bare sandy to rocky substrate with isolated patches of vegetation (shrubs and grasses) (Figure 4 and Figure 5). Based on these observations, a Mannings n roughness coefficient of 0.025 was estimated for the channel and 0.035 for the banks from Chow (1959) as well as Arcement and Schneider (1989).

Figure 3: The watercourses of the project area (January 2020). Note the sand substrates with intermittent rocky areas

Figure 4: The largest watercourse near the pipeline source at the Orange River (January 2020). Note the slope of the embankments and isolated riparian area.

Figure 5: Riparian area of a drainage line comprised of patches of vegetation within bare soils (January 2020)

3.2.5 Hydraulic Structures

The considered river reach was assessed on the site investigation for the presence of any hydraulic structures (bridges, weirs and culverts) that may have an influence on the hydraulic condition in the watercourse.

3.2.6 Peak Flow Calculations

Peak flow calculations were completed through the Utility Drainage Programme software. Rational Method, Rational Method (alternative), Unit Hydrograph, Standard Design Flood (SDF) and Empirical methods were used to assess the peak discharge for the 1:100 and 1:50 flood periods (SANRAL, 2013).

3.2.7 Mean Annual Runoff

The most appropriate method for calculating the Mean Annual Runoff (MAR) is the SCS- SA method (Bosznay 1989). According to SANRAL (2013) the formula for the calculation is:

$$Q = \frac{(P-Ia)^2}{P-Ia+S}$$

Where

Q = Storm depth (mm)

P = Daily rainfall depth (mm)

S = Potential maximum soil water retention (mm)

$$= \frac{25400}{CN} - 254$$

CN = Curve Number

I_a = Initial losses (abstractions) prior to the commencement of stormflow (mm) – 0,1S in South Africa

The storm depth is then divided by 365 to calculate the daily MAR.

3.2.8 Software Used

- ARCGIS 10.5 is a Geographical Information System (GIS) software programme used to view, edit, create and analyse geospatial data. ARCGIS was used to view spatial data and to create maps. Its extension 3D Analyst was used for terrain modelling purposes, for converting the elevation data into Digital Elevation Model (DEM) grid format;
- HEC GEORAS utilises the ARCGIS environment and is used for the preparation of geometric data (cross-sections, river profile, banks and flow paths) for input into the HEC-RAS hydraulic model. It is further used in post processing to import HEC-RAS results back into ARCGIS, to perform flood inundation mapping;
- Design Rainfall Estimation in South Africa (ver 3);
- Utility Programme for Drainage (Van Vuuren and Van Dijk) Version 1.1.0; and
- HEC-RAS 5.0.7 (Brunner, 2010) was used to perform hydraulic modelling. HEC-RAS is a programme used to perform one/two-dimensional calculations for a range of applications.

3.2.9 Hydraulic Model Setup

Development of the hydraulic model included the following steps:

- Preparation of geometric data (cross-sections, stream centre lines, bank lines and flow paths) in HEC-GEORAS and RAS-Mapper (Figure 6);
- Importing of geometric data into HEC-RAS;
- HEC-RAS setup by inserting the appropriate roughness coefficient values at the selected cross-sections;

A 2-D Unsteady flow analysis of the peak flows using a simple triangular flow hydrograph over a 21 hour period was conducted on the established geometry and upstream boundary conditions. The peak of the hydrograph matching that of the outputs of the respective utility drainage software.

- Exporting GIS shapefiles was completed via HEC-RAS and HEC-GEORAS.

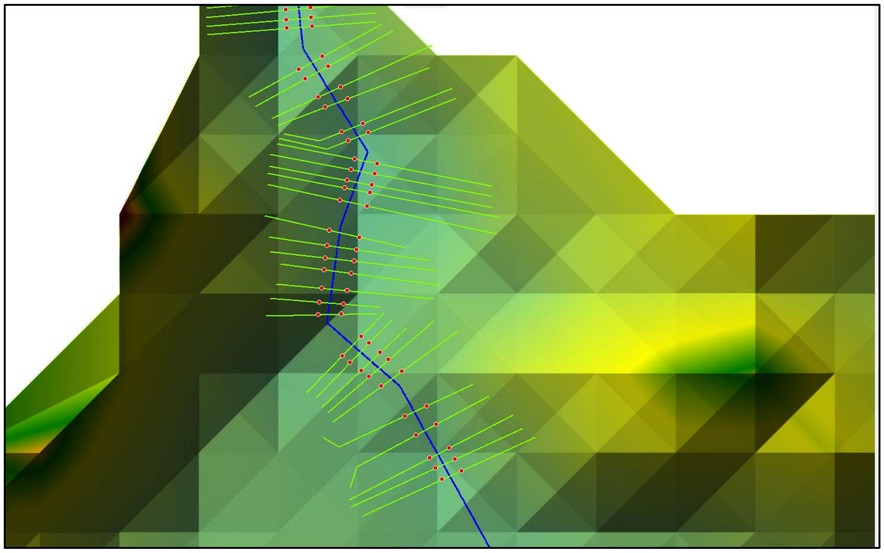

Figure 6: An excerpt of the HEC-RAS geometry model of the watercourse used for the floodline delineation

4 Limitations

The following is applicable:

- No storage facilities (dams) were modelled upstream or downstream of the project area;
- No flood protection infrastructure was modelled;
- The floodline presented should only be used for indicative and environmental planning purposes, and not for detailed engineering designs, unless signed off by a suitably qualified and registered engineer;
- No detailed contour data (<1m) was available for the modelling of the catchment areas and watercourse channels considered in this study. Considering the flat topography of the region, the absence of such data presents a significant limitation to the effective modelling of the smaller watercourses located in the upper catchment in the study area. Based on this limitation, the only floodline delineated was that associated with the lower reaches of the T-Goob se Laagte River (D81G – 03731 - SQR).
- The floodline of the Orange River was not considered in this study.
- Given the low accuracy of the available contour data, no hydraulic structures were modelled;
- The initial conditions of the HECRAS model made use of the water surface profile in the available contour data. However, based on field observations it is assumed that the initial discharge in the watercourse was below 0.1 m^3/s.
- The floodline areas modelled in this assessment should be interpreted with caution; and

- No impact/risk assessment or mitigation actions are provided in this determination.

5 Results

5.1 Catchment Description

5.1.1 Rainfall

Daily rainfall depths were extracted from DHSWS Hydrological Services website. The closest weather station was the Pella Mission @ Pella Pump Station (D8E005-MET) which is approximately 1 km north of the project area along the Orange River. The data for this station is for the period of 1983-2019.

The Mean Annual Precipitation (MAP) of the weather station was 144 mm. The climate of Pella is considered a "desert" classified as BWh in the Köppen-Geiger climate classification. The average temperature in Pella was 21 °C.

The total average monthly rainfall is indicated in Figure 7. This is the average from 1983 to 2019 and includes flood events. Normally, in May the precipitation is at its peak. The driest month was August, with 2.3 mm of rain.

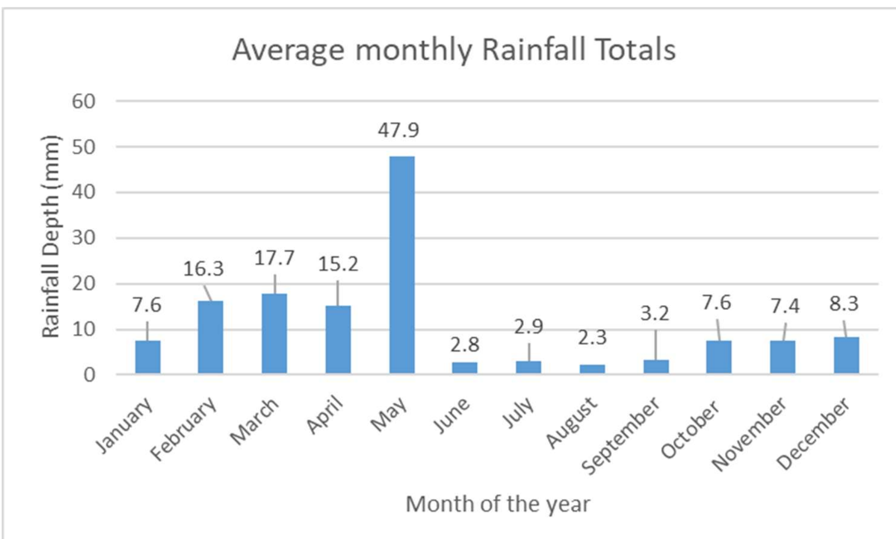

Figure 7: Total annual rainfall per month for the project area (DWS Hydrological Services, 2020)

5.1.2 Storm Rainfall Depths

The storm rainfall depths for the centre position of the project area were extracted from the Design Rainfall Estimation in South Africa software programme (Smithers and Schulze, 2002). The programme uses the six closest rainfall stations the specified project area. The rainfall stations used for this project area are indicated in Table 1. The gridded storm rainfall depths for the contributing catchment at the various return periods and storm durations are indicated in Table 2.

Table 1: Six Closest rainfall stations to the project area

Station Name	Station No.	Distance (km)	Record (Years)	Latitude	Longitude	MAP (mm)	Altitude (mamsl)
PELLA	0247242_W	24.2	79	29°01'S	19°09'E	50	484
POFADDER;ON SEEPKANS.	0279497_A	52.6	41	28°47S	19°17'E	78	500
ONSEEPKANS (POL)	0279497_W	56.9	47	28°44S	19°17'E	80	420
SKUITKLIP	0280351_W	84.6	47	28°51S	19°42'E	90	840
GOODHOUSE	0277386_A	86.5	21	28°56S	18°13'E	57	441
HENKRIESFON TEIN	0277177_W	98.2	29	28°057S	18°06'E	72	356

Table 2: Storm Rainfall Depths for the Catchment

Storm Duration	Return Period / Storm Rainfall Depth (mm)						
min / hr / day	**1:2 yr**	**1:5 yr**	**1:10 yr**	**1:20 yr**	**1:50 yr**	**1:100 yr**	**1:200 yr**
5 min	6.5	10.1	12.8	15.7	19.7	23	26.5
10 min	9.7	15.2	19.2	23.4	29.4	34.4	39.7
15 min	12.2	19.2	24.3	29.6	37.2	43.5	50.2
30 min	15	23.6	29.9	36.4	45.8	53.4	61.7
45 min	17	26.6	33.7	41.1	51.6	60.3	69.6
1 hr	18.5	29	36.7	44.8	56.2	65.7	75.8
1.5 hr	20.8	32.7	41.4	50.5	63.5	74.1	85.6
2 hr	22.7	35.6	45.1	55.1	69.1	80.7	93.2
4 hr	26	40.8	51.6	63	79.1	92.4	106.6
6 hr	28.1	44.1	55.8	68.1	85.6	99.9	115.4
8 hr	29.7	46.6	59	72	90.5	105.6	122
10 hr	31	48.7	61.7	75.2	94.5	110.3	127.4
12 hr	32.1	50.4	63.9	77.9	97.9	114.3	132
16 hr	34	53.3	67.5	82.4	103.5	120.8	139.5
20 hr	35.5	55.7	70.5	86.1	108.1	126.2	145.7
24 hr	36.8	57.7	73.1	89.2	111.9	130.7	151
1 day	30.2	47.4	60.1	73.3	92.1	107.5	124.1
2 day	35.8	56.2	71.2	86.9	109.1	127.4	147.1
3 day	39.6	62.1	78.6	95.9	120.5	140.7	162.4
4 day	41.7	65.4	82.8	101.1	126.9	148.2	171.1
5 day	43.4	68.1	86.3	105.3	132.2	154.3	178.2
6 day	44.9	70.4	89.2	108.8	136.6	159.5	184.2
7 day	46.1	72.4	91.7	111.9	140.5	164.1	189.4

5.1.3 Evaporation

The closest weather station was the Pella Mission @ Pella Pump Station (D8E005-MET) which is approximately 1 km north of the site. The data for this station is for the period of 1983-2019. The average evaporation for the region is displayed in Table 3.

Table 3: Symon's Pan and open water evaporation for the project area (DWS Hydrological Services, 2019)

Month	Pella Mission @ Pella Pump Station (D8E005-MET) (mm)
January	552.5
February	449.4
March	410..9
April	297.6
May	209.4
June	149.9
July	165.8
August	224.7
September	299.4
October	405.2
November	468.6
December	527.2
Total	**4296.8**

5.1.4 Mean Annual Runoff

MAR was calculated using the SCS-SA method where all input values as well as the resultant MAR can be found in Table 4 below. The formula was altered to calculate annual runoff opposed to daily runoff by using MAP instead of daily rainfall. Potential maximum soil water retention was calculated as an average of the dominant soil types in the catchment to get the initial curve number for the selected land cover data (SANRAL, 2013).

Table 4: All parameters required for MAR as well as the calculated MAR

Input values	
P (mm)	97
CN	68
S(mm)	119.53
I_a (mm)	11.95
Q (mm\year)	35.35

5.1.5 Topography, Drainage and Contributing Catchment

The project area lies directly within the D81G and D82A quaternary catchments. The overall study basin was delineated into 3 sub-catchment areas. For the purposes of this study, the pipeline structure is situated at the head of sub catchment 1 and 3 with the Mik River in catchment 1 not being significantly impacted on by the pipeline route. Further, considering that the pipeline was in the headwater zone of catchment 1, no derived channels could be delineated with the available 10m contour data. Thus, catchment 1 was not subjected to peak flow delineations in these watercourses. In order to address this limitation, buffer zones of 30m were applied to the delineated ephemeral watercourses as presented in Figure 19. The infrastructure was noted to be in proximity to the delineated discharge outlets of catchment 2 and 3. Thus, the receiving environment of sub catchments 2 and 3 were assessed in this study and a watercourse extent delineated. The longest watercourse in catchment 2 flows from west to east and is 4.9 km long. Catchment 1 had the longest main watercourse channel from the south east to north west for a distance of 46.25km.

The overall basin has an average annual precipitation rate of 97 mm. The topography of the delineated catchments varied from 370 Metres above mean sea level (mamsl) in the region near the confluence with the Orange River, to 1200 mamsl in mountainous inselbergs in the southern section of the catchment. The catchment surrounding the southern region of the catchments was indicated to be proximate to 977 mamsl. It is noted that the steepest portions of the catchments were located in proximity to the Orange River where the outlet of the catchment for the T-Goob se Laagte River (D81G – 03731 - SQR) occurs through a kloof with steep, high rocky banks. The catchment as a whole was sloping to the north east, with an average catchment slope of approximately 2% indicating a flat topography in the majority of the catchment area.

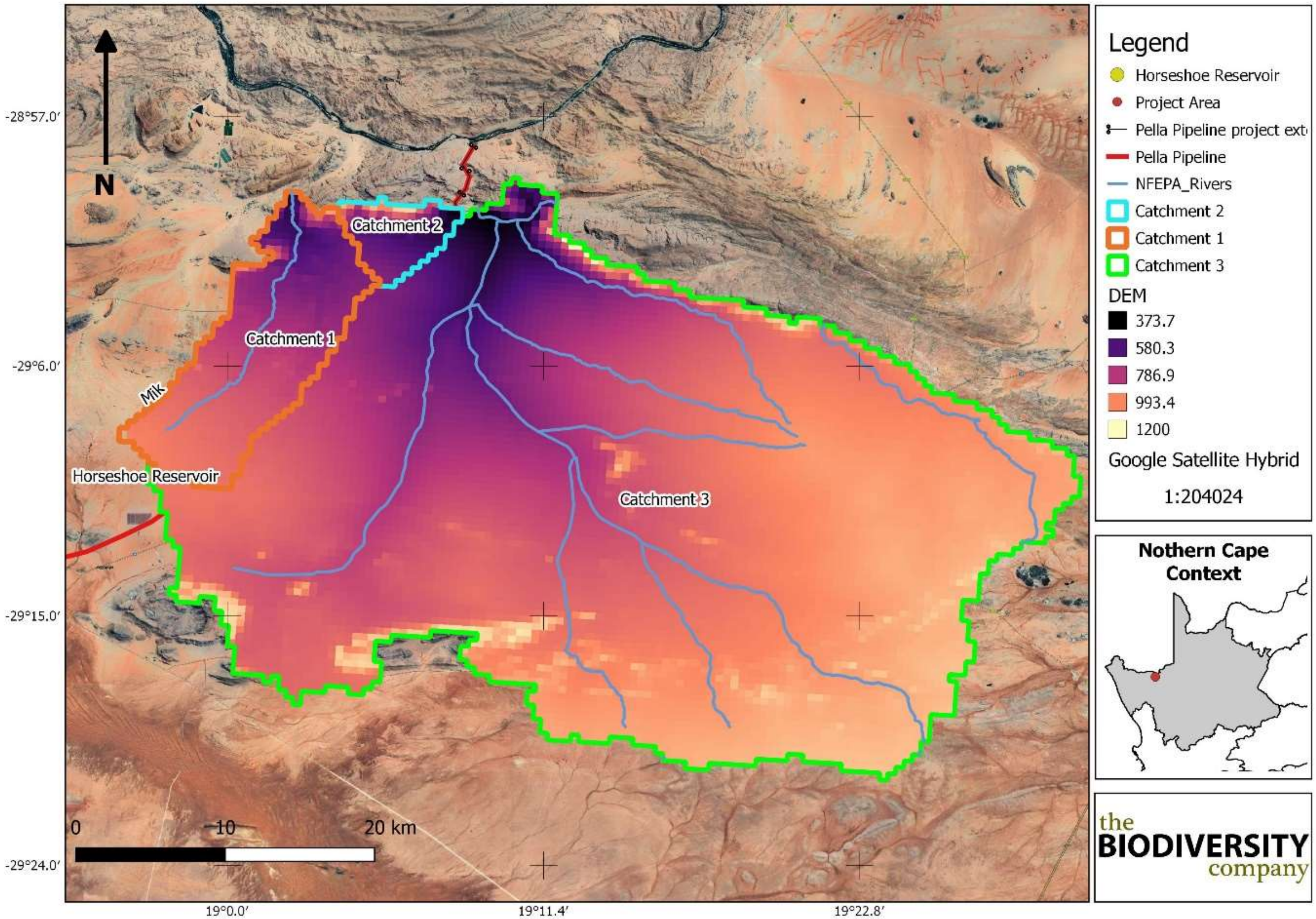

Figure 8: Digital Elevation Model for the respective catchments considered in this determination (January 2020)

5.1.6 Land Cover and Soils

The land cover associated with the catchment area is characterised by loose rocks, coarse sands and gravels. Limited vegetation cover was observed or derived to be located in the delineated catchment areas. The hydrological soil group of the region was classified as Group A, indicting high infiltration rates.

As noted in the methods component of this determination, the data presented in this section was obtained from Geoterraimage (2015). The landuse for the catchment is dominated by bare soil (54.60%) followed by grassland (44.79%). The remaining land use is comprised of mining (0.149%), thick bush (0.209%),urban built-up (0.24) and plantations (0.006%) as seen in Table 5 and Figure 9. The catchment for the project area considered is large and therefore is comprised of a wide variety of geology, land and soil types. Soils are a key natural regulator of catchment hydrological response due the capacity that soils have for absorbing, retaining and releasing water (Schulze, 1989). The soils within the catchment are varied throughout the uniform elevation. The soils are comprised of Ag soils (69.02%), Ae soils (17.55%) and Ic soils (7.56%) with the remaining population comprised of Af and IB soils as seen Figure 10. Ag soils within the catchment are freely drained, red-yellow apedal, with high base status < 300 mm deep comprised of Portsmouth (Hu35), Moriah (Hu32), Vergenoeg (Hu45), Dundee (Du10) and Quaggafontein (Hu42) in the B horizon. Ae soils in the catchment are freely drained red-yellow apedal, with high base status > 300 mm deep (no dunes), comprised of Moriah (Hu32), Zwartfontein (Hu34), Portsmouth (Hu35) Gaudam (Hu31) in the B horizon. Ic soils are comprised of miscellaneous land classes; comprised of 90% rocks and roots as well as Mispah (Ms10) in the A horizon.

These soil types belong to the S2 (87.30%) and less so S16 (12.69%) soil classes (Figure 10). S2 soils are freely drained, structureless soils with favourable physical properties however have restricted soil depths, low natural fertility and are easily eroded. S16 soils are non-soil land classes which are water intake areas with restricted land use options.

The soil patterns of the project area fall within four types namely LP2 (70.07%), AR2 (17.58%), R (10.90%) and the remaining 0.89% is comprised of AR1. LP2 are shallow soils with minimal development on hard or weathering rock, with lime generally present in part or most of the landscape. AR2 are red and yellow, well drained sandy soils with high base status. R is rock with limited soils. AR1 is red, excessively drained sandy soils with high base status, mainly dunes.

The Soil Conservation Services method for Southern Africa (SCS-SA) uses information of hydrologic soil properties to estimate surface runoff from a catchment based of the soil permeabilities. Deep, well-drained soils generally have high rates of permeability and thus resulting in greater infiltration. Consequently, highly impermeable soils therefore have a much higher runoff potential due to low potential infiltration (Macfarlane, *et al.*, 2015). The soils of the catchment are comprised of class A/B (79.35%) soils followed by class A (8.89%), B (8.23%), C (3.53%) soils (Figure 13). Class A/B soils have infiltration rates of 0.15 - 0.45 in/hr which represent moderate to high infiltration rates from sands and gravels with minor coarse silts These are well drained to semi permeable soils.

The geology of the catchment (Figure 14) is comprised of gneissic granite and other ultrametamorphic rocks of the Namaqualand Metamorphic Complex which are overlain in places covered by pedisediment materials (Early Tertiary) and older sands and deflation residues on dorbank and calcrete.

Table 5: Catchment land-use by area and percentage.

Landuse	Area (m^2)	Area (%)
Bare Soil	797482108	54.596
Thick Bush	3059254	0.209
Grassland	654227821	44.789
Mining	2177100	0.149
Plantation	98100	0.006
Urban Built-Up	3627900	0.24
Total	1460672283	100

Table 6: Catchment soil/land-type by area and percentage

Landtype	Area (m^2)	Area (%)
Ae	251547064	17.550
Af	10556469	1.067
Ag	989263372	69.021
Ib	73568617	5.133
Ic	108351665	7.560
Total	1460672283	100

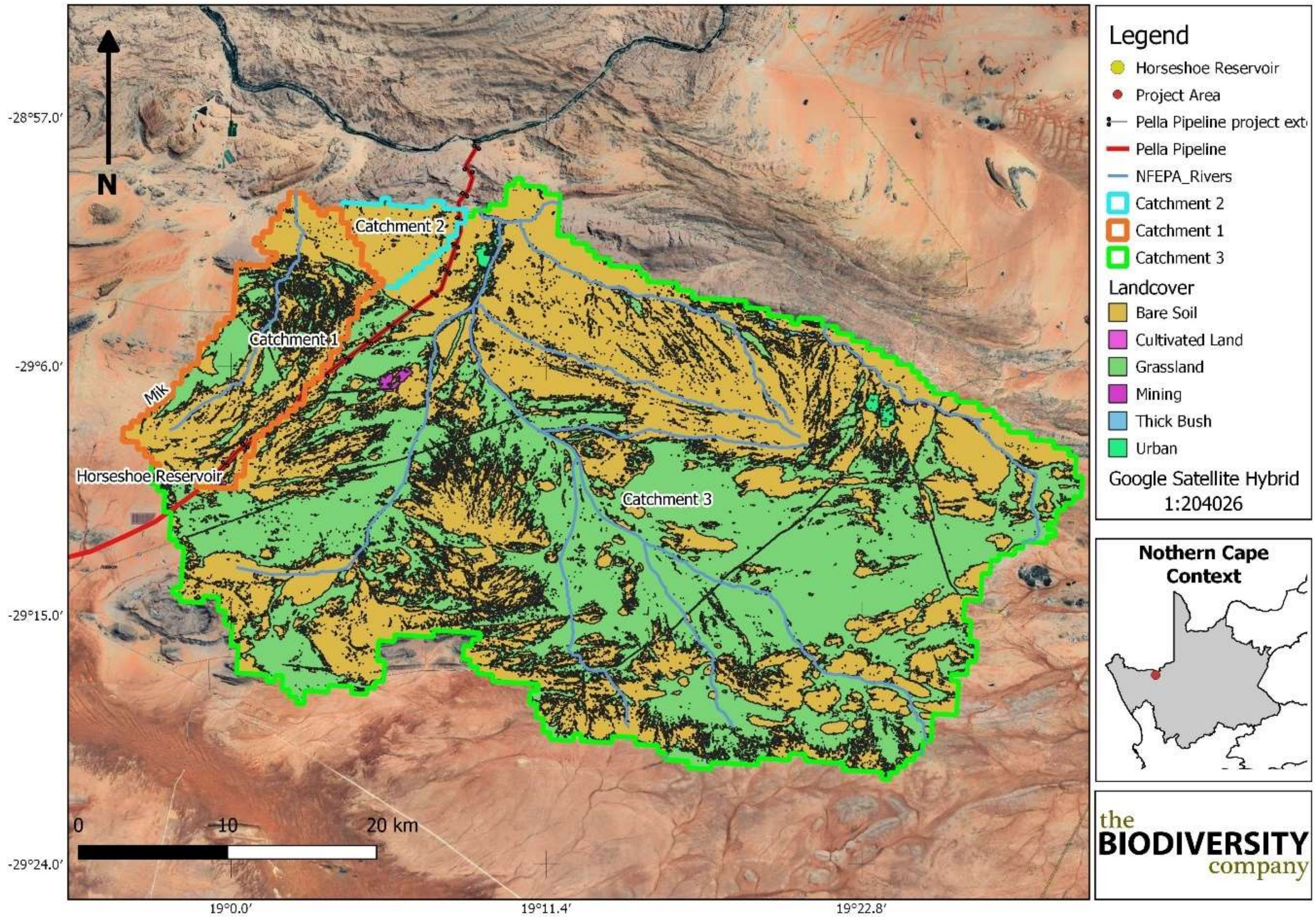

Figure 9: Landcover Map for the respective catchment considered in this determination (January 2020)

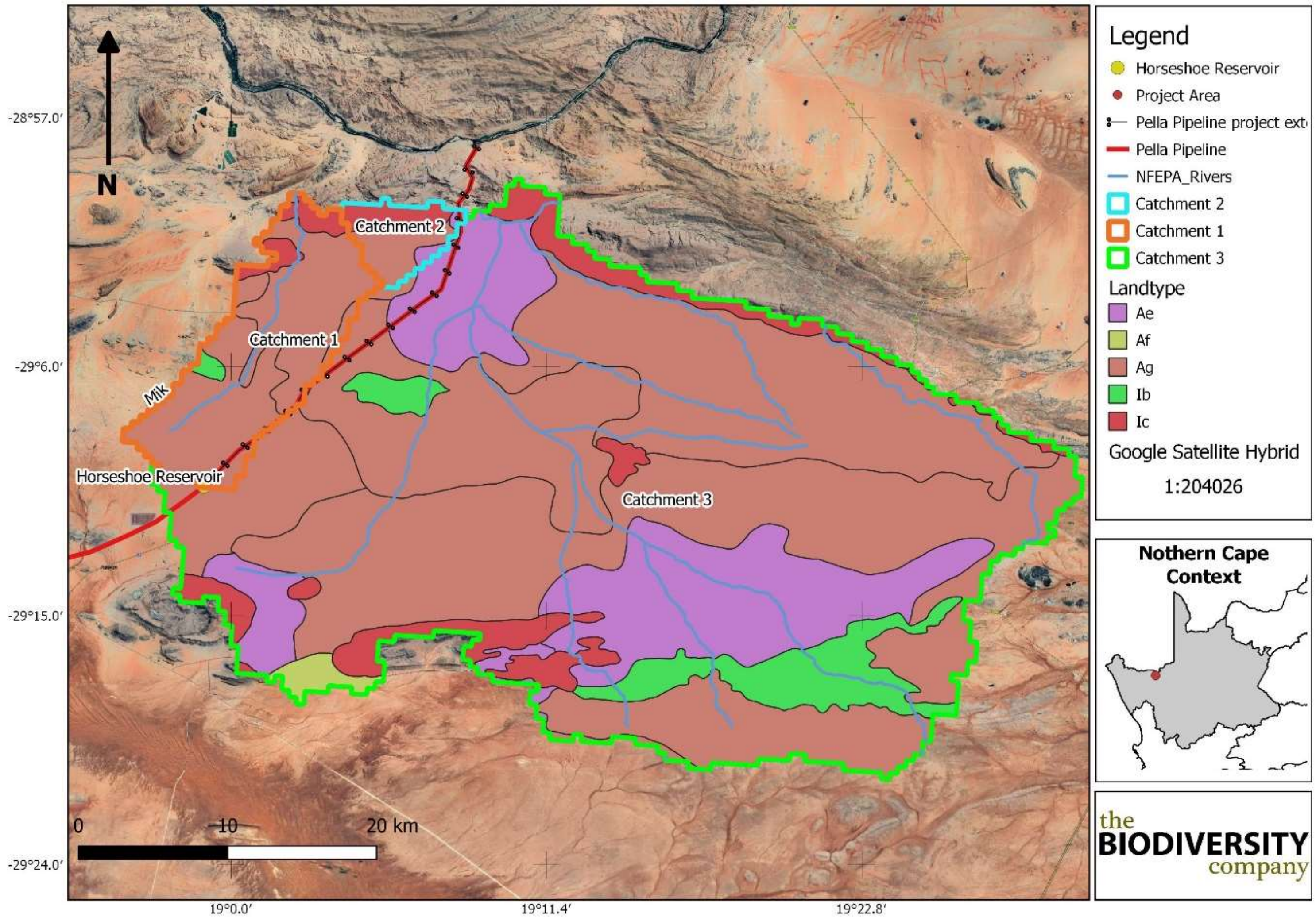

Figure 10: Soil type map for the respective catchment considered in this determination (January 2020)

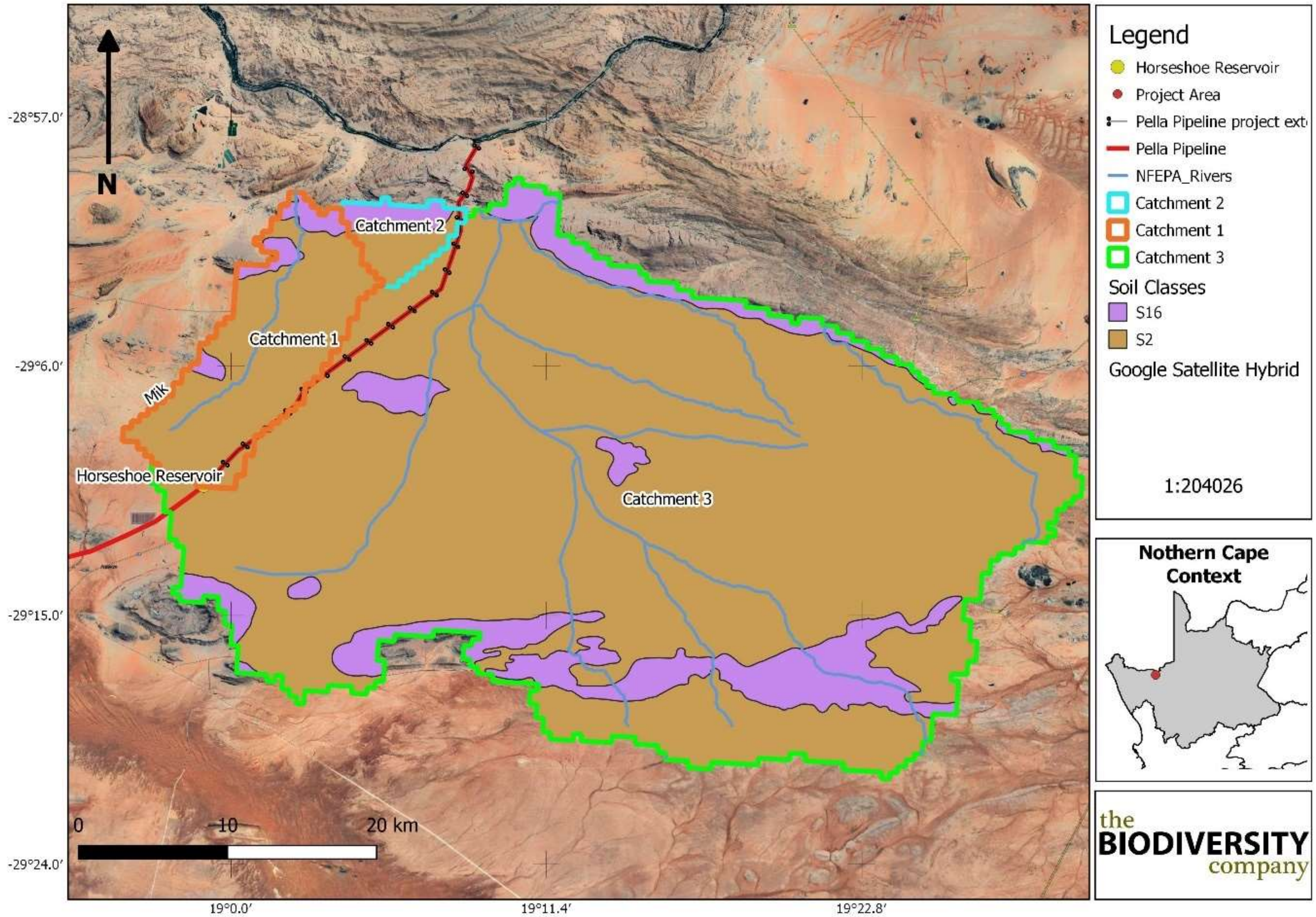

Figure 11: Soil class for the respective catchment considered in this determination (January 2020)

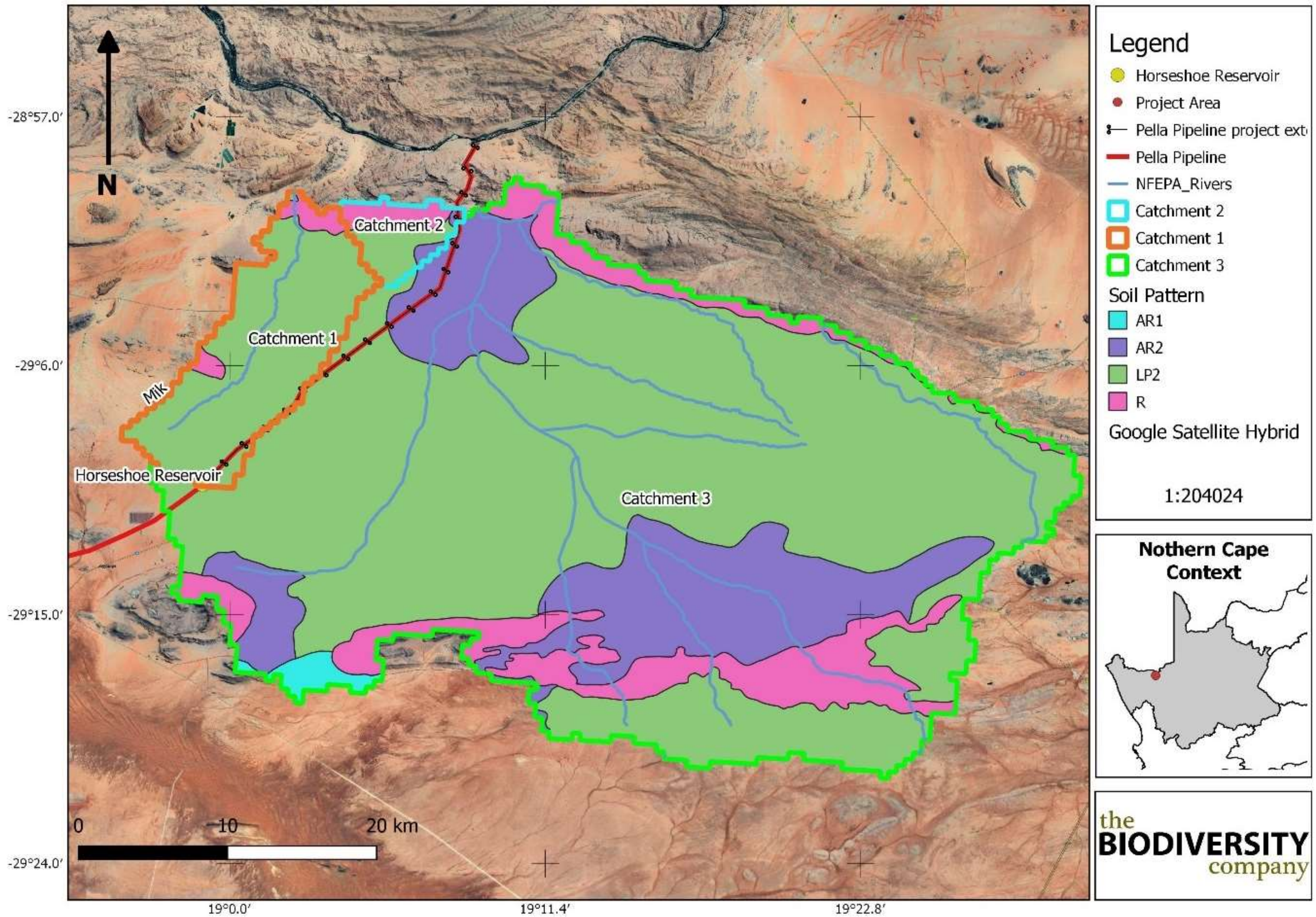

Figure 12: Soil patterns map for the respective catchment considered in this determination (January 2020)

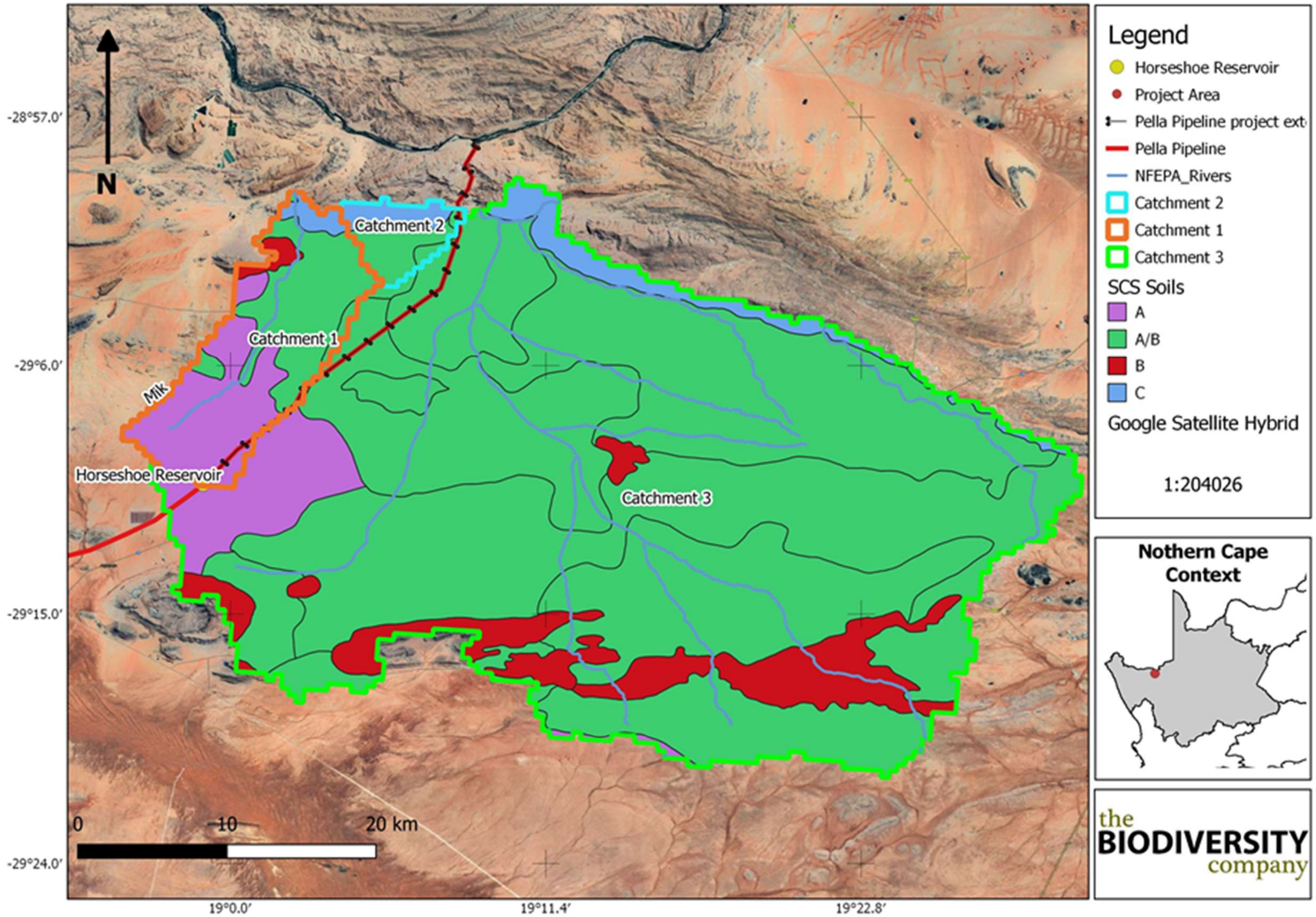

Figure 13: SCS soils for the respective catchment considered in this determination (January 2020)

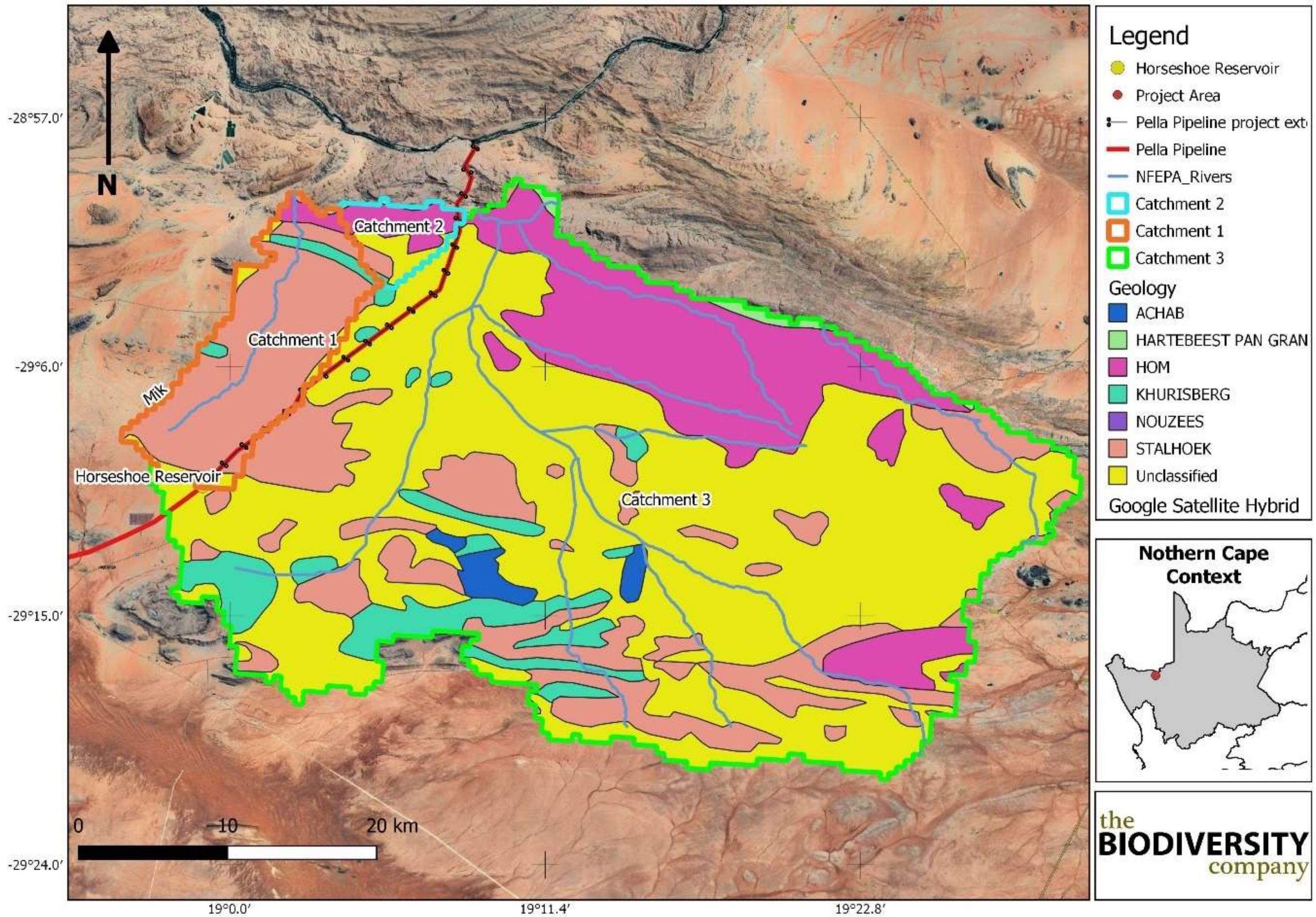

Figure 14: Geological map for the respective catchment considered in this determination (January 2020)

5.2 Hydraulic Structures

The catchment of consideration for the proposed underground pipeline had no associated hydraulic structures that included culverts. The associated infrastructure utilised for maintenance of the pipeline included an adjacent dirt road running the length of the pipeline. Where the road intersected with the watercourses, the roadway would pass over the watercourse and at times, gabions would be used to stabilise the roadway. An example of this is seen in Figure 15. All pipeline crossings can be seen in Table 7 and Figure 16. Figure 17 represents all delineated watercourses within the catchment area. Sites were named according to the river on which they fall, T1, T2, T3, T4, T5, T6, T7, T8 and T9 fall along the Te Goob se Laagte River and sites M1 and M2 are on the Mik River.

Figure 15: Ephemeral river crossing the dirt road (January 2020)

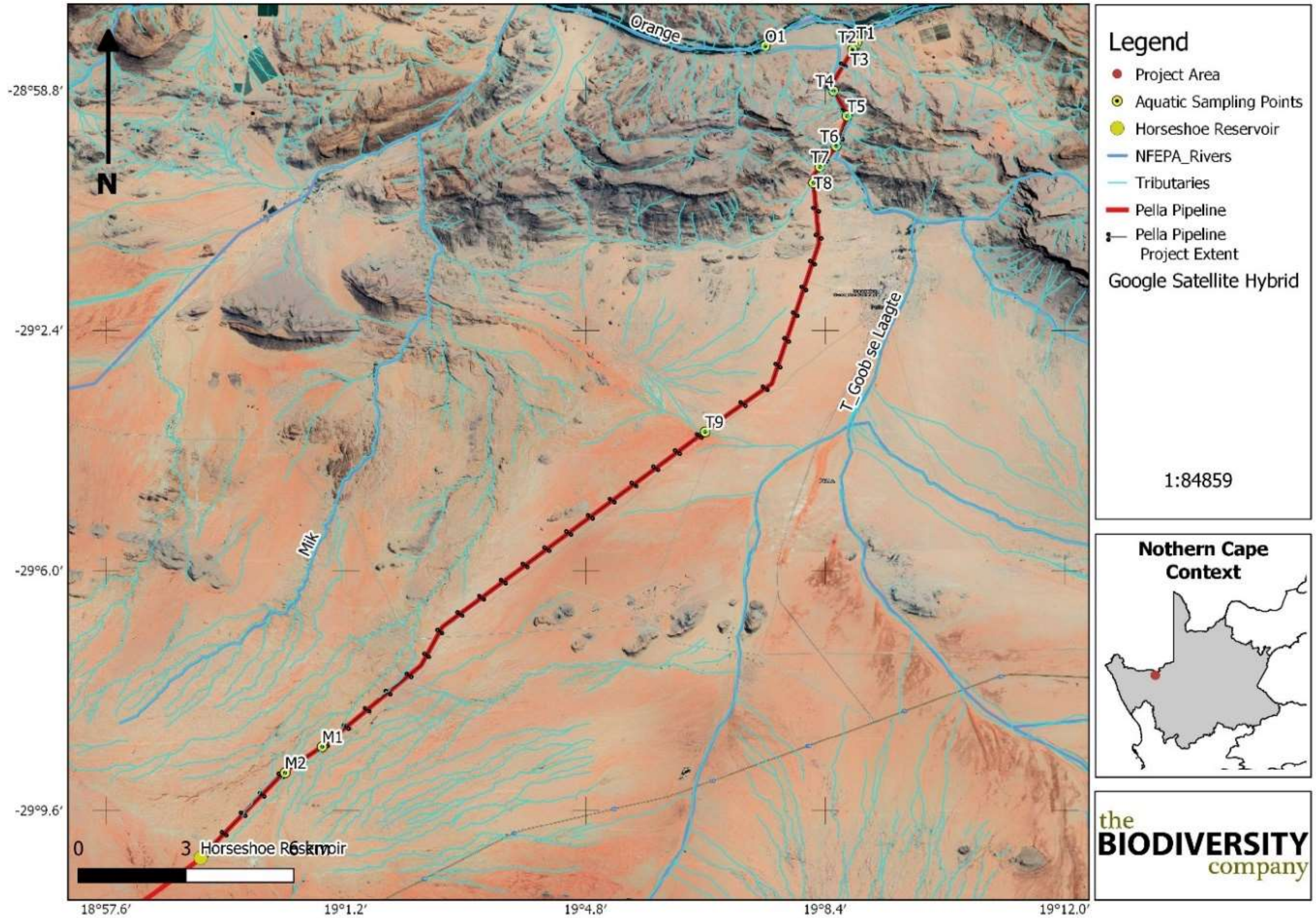

Figure 16: The location of the proposed pipeline and identified watercourse crossings (January 2020)

Table 7: Photos and co-ordinates for the sites sampled (January 2020)

	Upstream	Downstream
T4		
GPS	28°58'48.33"S 19° 8'31.45"E	
T5		
GPS	28°59'10.79"S 19° 8'43.47"E	
T6		
GPS	28°59'37.92"S 19° 8'33.63"E	

	Upstream	Downstream
T7		
GPS	28°59'56.58"S 19° 8'19.06"E	
T8		
GPS	29° 0'11.15"S 19° 8'13.32"E	
T9		
GPS	29° 3'55.07"S 19° 6'35.62"E	
M1		
GPS	29° 8'38.45"S 19° 0'50.44"E	

	Upstream	Downstream
M2		
GPS	29° 9'1.82"S 19° 0'17.04"E	

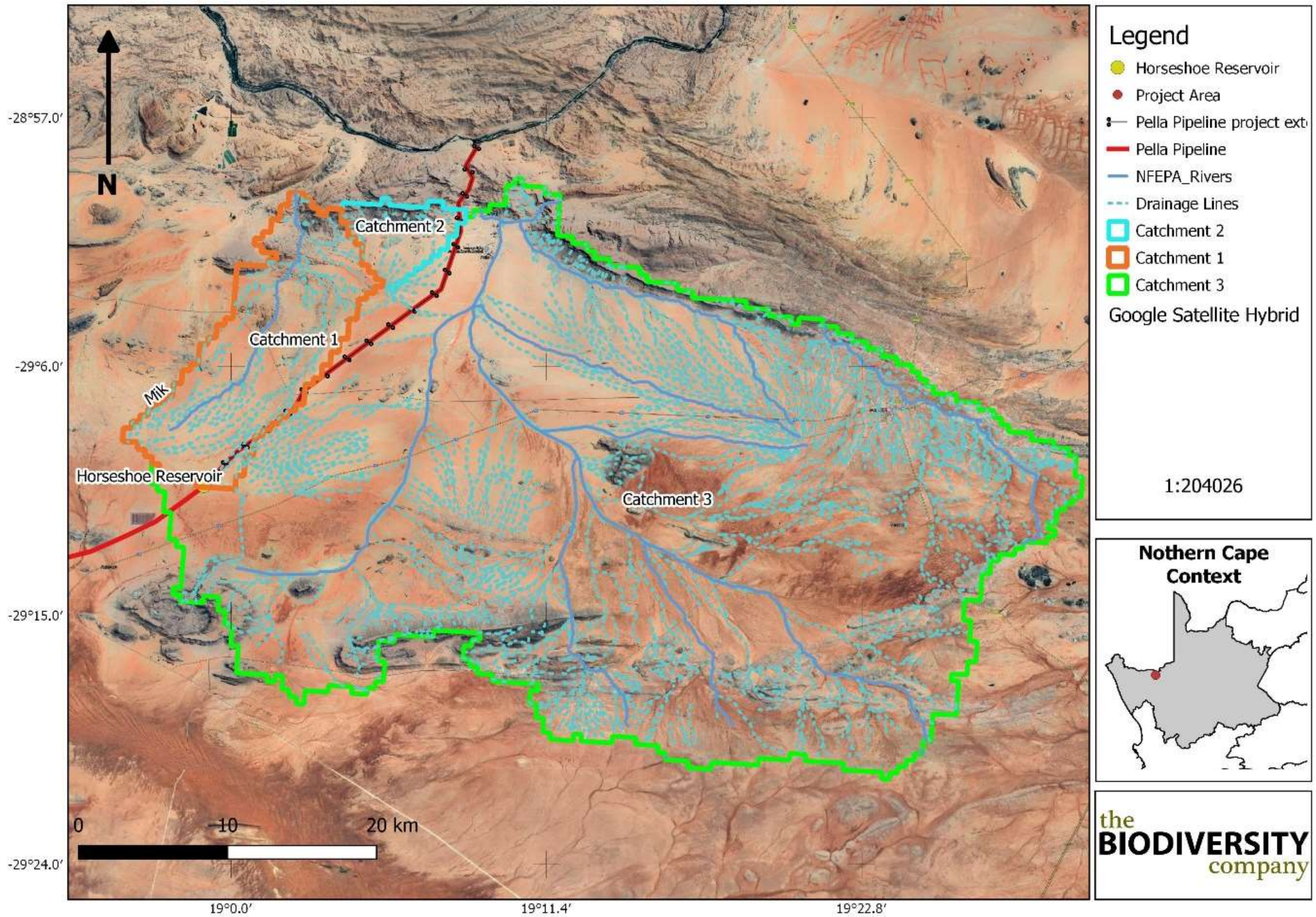

Figure 17: Watercourses within the project area (January 2020)

5.3 Peak Flow

The parameters and calculated peak flows using the peak discharge methods are summarised in Table 8, Table 9 and Table 10 respectively, with the most appropriate peak flow for the study site provided in blue highlight. When determining peak flow, it is suggested that multiple methods are considered, and the hydrologists digression is used to consider which is most appropriate. The SDF method was considered first and compared with the other methods (SANRAL, 2013). The SDF model was run first as the SDF model can achieve effective results over variable project settings, allowing for models to be simulated for any catchment size. The SDF method has modelled peak flows which occur at the upper range for the five methods used. The rational, alternative rational and SDF methods all estimated peak flows which were considered to be either over or under-estimated for the considered catchment. This over or under estimation was due to the limitation of the size of the considered catchment, where the rational and alternative rational models are typically applied to catchments below 15 km^2)(SANRAL, 2013). Therefore, the most appropriate peak flow considered was the unit hydrograph method as the method applied for catchments between 15 to 5000 km^2 (SANRAL, 2013). Catchment 1 was not considered for this assessment due to its channel size with low resolution of contour data. As a result, a sensitivity area was modelled.

Table 8: Parameters used to calculate Peak Flow

Method	Catchment 2	Catchment 3
MAP (mm)	97	97
Catchment Area (km^2)	26.7592	1276.286
Longest Watercourse (km)	4.9	46.248
H0.10L (mAMSL)	510	880
H0.85L (mAMSL)	408	495
Height Difference Along 10-85 slope (m)	102	385
Average Slope of Longest Watercourse (m/m)	0.01	0.015
Distance to catchment centroid (km)	4.339	25.365
Number of days per year thunder is heard	20	20
Veld type region	6	6
SDF Basin number	14	14
Kovacs K-region	K6	K6

Table 9: Calculated Peak flows for Catchment 2 using the different available methods (m^3/s)

Period/Method	Rational	Rational (alternative)	Unit Hydrograph (m^3/s)	SDF	Empirical
1:2 year	18.47	27.99	4.196	8.899	-
1:5 year	26.74	50.37	7.323	25.84	-
1:10 year	35.85	70.01	11.35	41.21	12.52
1:20 year	46.69	91.58	16.68	58.41	17
1:50 year	63.71	121.03	26.45	83.82	23.54
1:100 year	82.08	146.8	37.54	105	29.89

Table 10: Calculated Peak flows for Catchment 3 using the different available methods (m^3/s)

Period/Method	Rational	Rational (alternative)	Unit Hydrograph (m^3/s)	SDF	Empirical
1:2 year	105.64	228.65	16.81	71.23	-
1:5 year	153.44	406.45	30.12	206.81	-
1:10 year	206.33	563.25	46.91	329.88	112.75
1:20 year	269.71	736.38	68.99	467.58	153.14
1:50 year	370.1	973.95	109.69	670.97	212.04
1:100 year	479.48	1183.61	156.49	840.46	269.25

5.4 Floodlines and Watercourse Extents

The 1:50 and 1:100 year floodlines are indicated on Figure 18. Appropriate modelled sensitive areas are indicated in Figure 19.

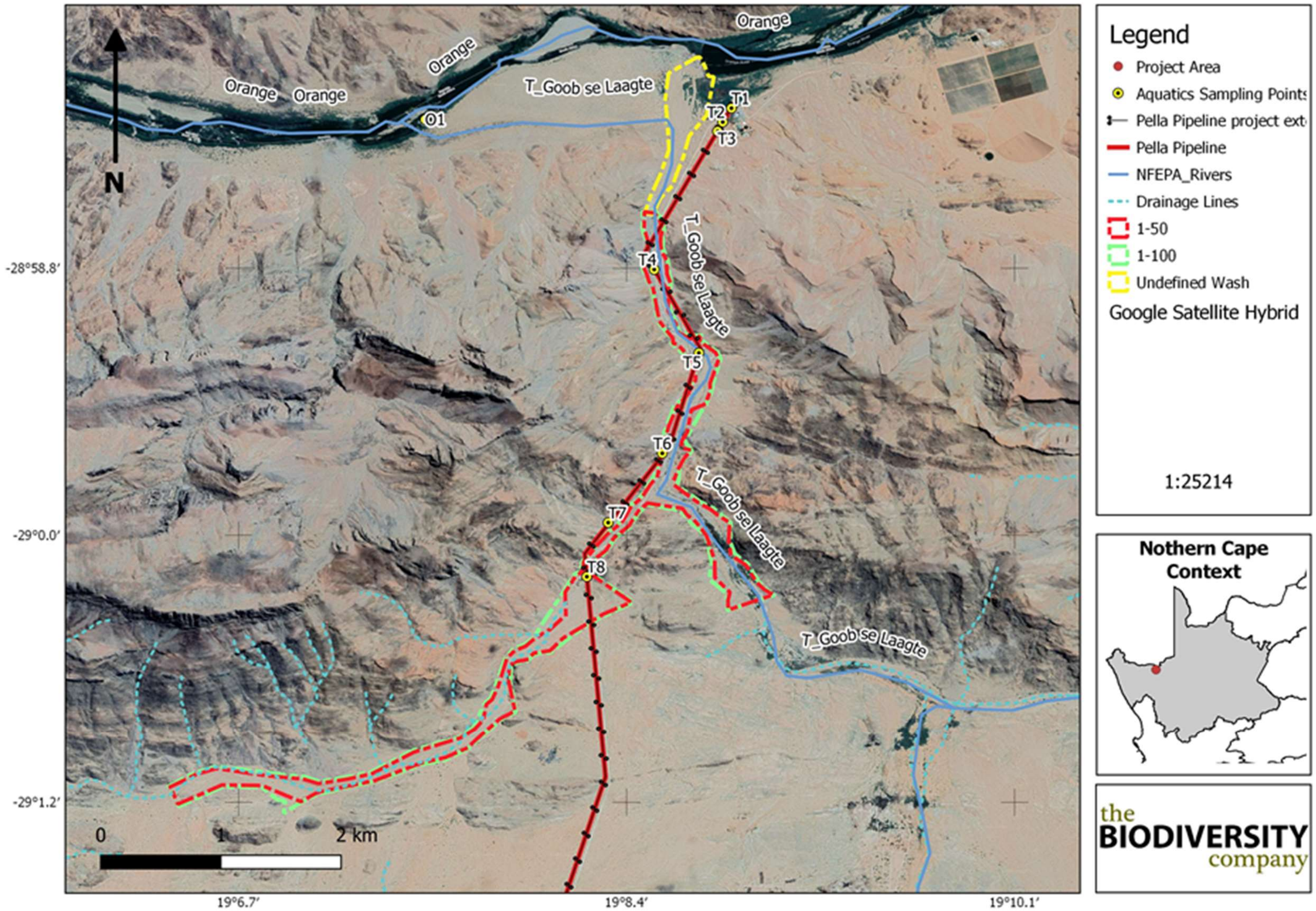

Figure 18: Modelled 1-50 and 1-100 year floodlines for the project area (January 2020)

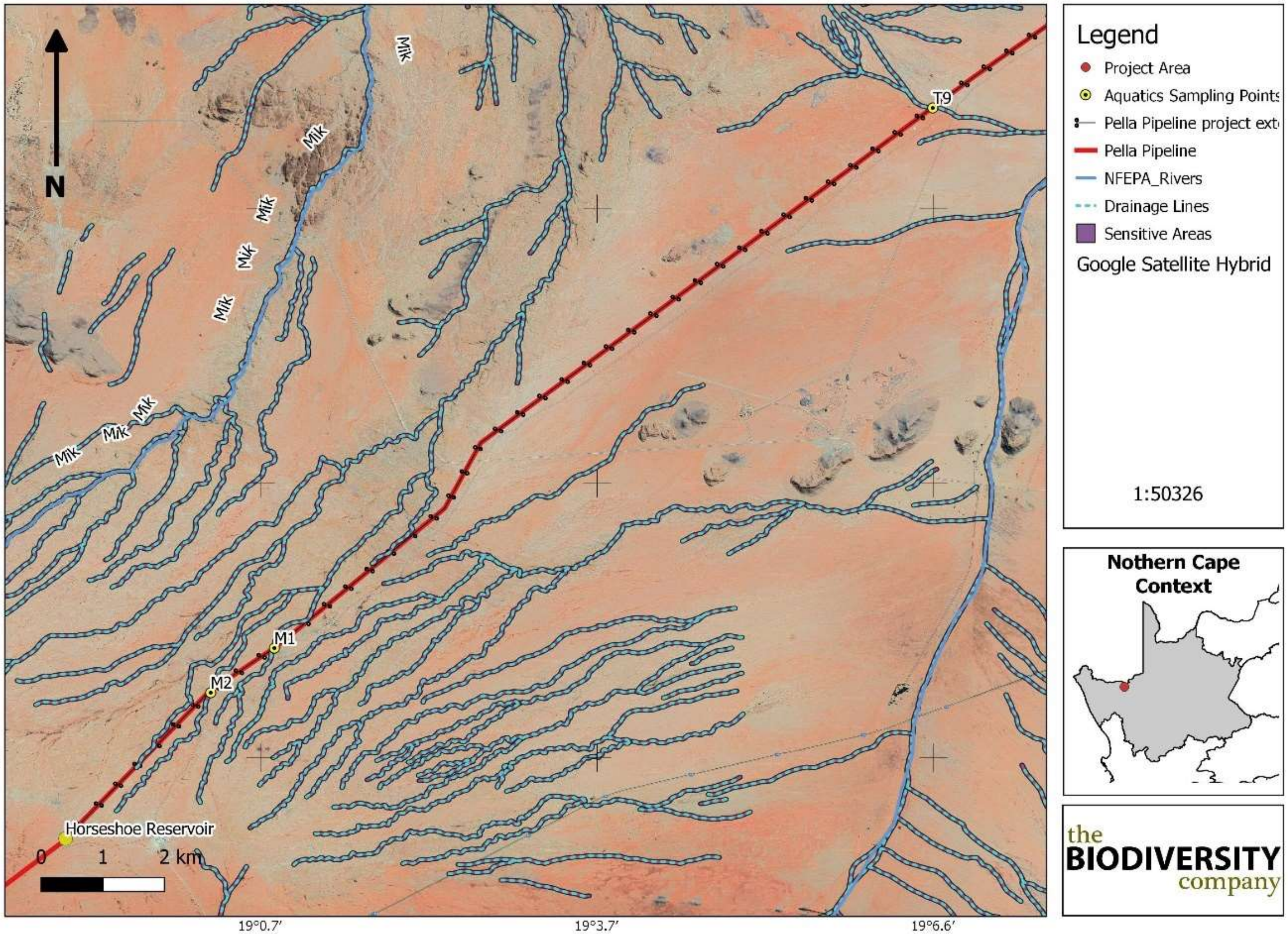

Figure 19: Modelled sensitive areas for the project area (January 2020)

6 Conclusion

As indicated in the limitations of this study, elevation data resolution was poor. Furthermore, the terrain in the study area was derived to be flat with limited undulations where drainage occurs, particularly in the source zones. The effective delineation of the floodlines of the ephemeral streams/drainage lines was therefore not possible. To address this, the drainage lines were modelled using the available elevation and topographical data. These modelled drainages were then ground truthed via the survey and aerial imagery. In order to effectively illustrate, and cover the location of these features, a 30m buffer zone was applied to the watercourse centreline. This buffer was then verified via aerial imagery and was derived to be suitable.

The lower reaches of the watercourses considered in this study were effectively modelled and the sensitive areas delineated. The proposed infrastructure is located directly within the modelled floodlines. Considering this, infrastructure should design to mitigate potential flood damage to the structure and downstream riverine habitats. The effective mitigation applicable can be obtained from the aquatic ecology report.

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