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Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

JOE GQABI
DISTRICT MUNICIPALITY

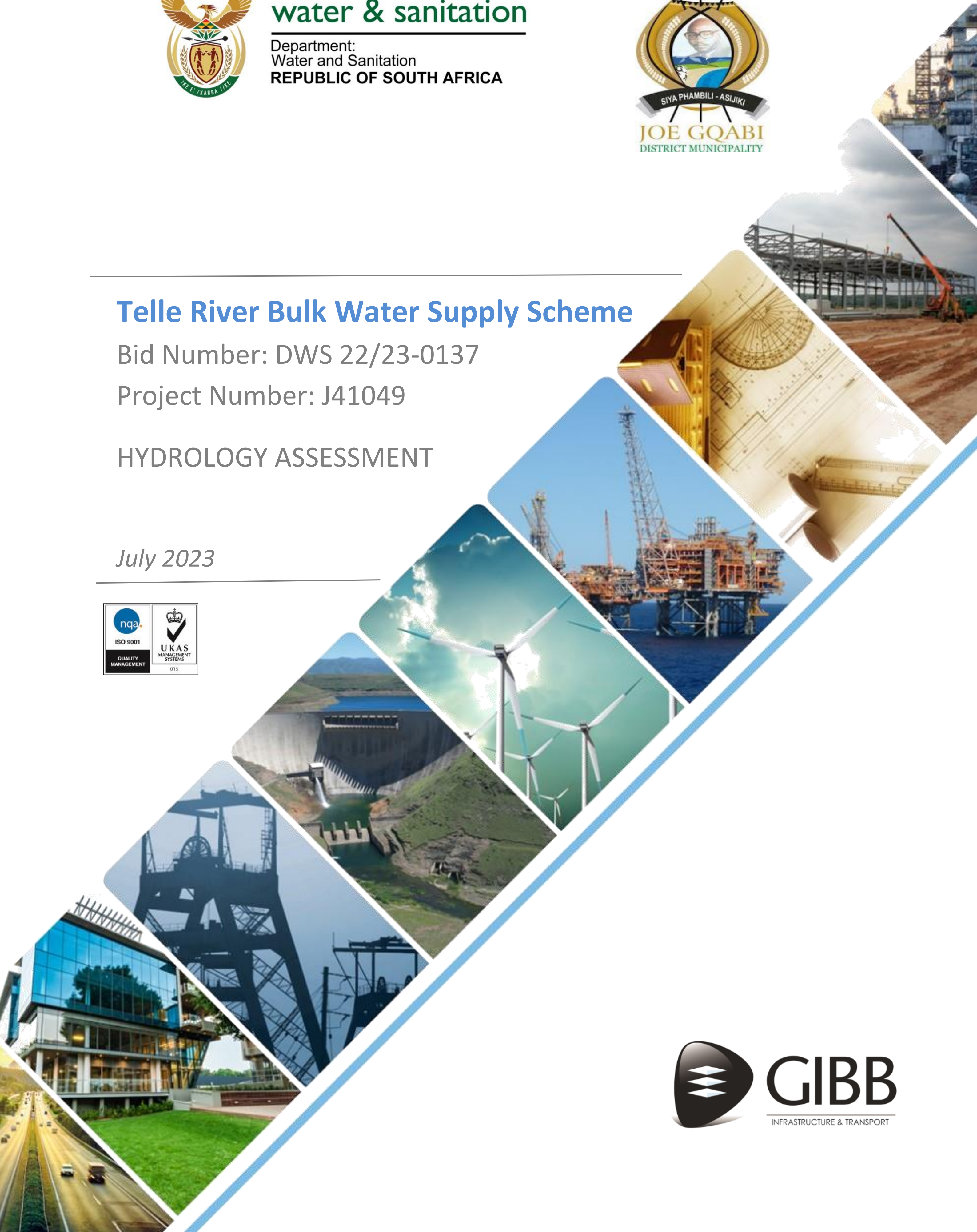
Telle River Bulk Water Supply Scheme

Bid Number: DWS 22/23-0137

Project Number: J41049

HYDROLOGY ASSESSMENT

July 2023



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Amendment Record

This document is reviewed to ensure its relevance. A record of contextual additions or omissions is given below.

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Abbreviations / Acronyms / Definitions

AMP	Asset Management Plan
BWSS	Bulk Water Supply Scheme
CFCs	Chlorofluorocarbons
CoGTA	Department of Co-operative Governance and Traditional Affairs
DEDEAT	Department of Economic Development, Environmental Affairs and Tourism
DWS	Department of Water and Sanitation
EAP	Economically Active Population
ECSECC	Eastern Cape Socio Economic Consultative Council
EIA	Environmental Impact Assessment

FS	Feasibility Study
FSR	Feasibility Study Report
GHG	Greenhouse Gases
GIS	Geographical Information System
IDP	Integrated Development Plan
IRR	Implementation Readiness Report
IRS	Implementation Readiness Study
ISD	Institutional and Social Development
ISO	International Standards Organisation
HDI	Human Development Index
JGDM	Joe Gqabi District Municipality
LM	Local Municipality
LoS	Level of Service
MWIG	Municipal Water Infrastructure Grant
NEAP	Non-Economically Active Population
O&M	Operation and Maintenance
PDR	Preliminary Design Report
PEP	Project Execution Plan
PE	Project Executive
PSC	Project Steering Committee
PSP	Professional Service Provider
RBIG	Regional Bulk Infrastructure Grant
SLM	Senqu Local Municipality
TR-BWSS	Telle River Bulk Water Supply Scheme
SMME	Small Medium and Micro Enterprises
WAR	Water Allocation Reform
WCDM	Water Conservation and Demand Management

WSA	Water Services Authority
WSP	Water Services Provider
WSDP	Water Services Development Plan
WUL	Water Use License

Acknowledgements

GIBB wishes to thank the Department of Water and Sanitation (DWS) and the Joe Gqabi District Municipality (JGDM) for their support in the delivery of this project.

1 Introduction

The study area is situated on the boundary of Lesotho and South Africa, near Sterkspuit, in Senqu Local Municipality. The Water Services Authority is Joe Gqabi District Municipality. The Senqu Local Municipality spans an area of 7 340 km^2 (see **Figure 1**). Full resolution versions of all the maps presented herein are included in **Appendix A**.

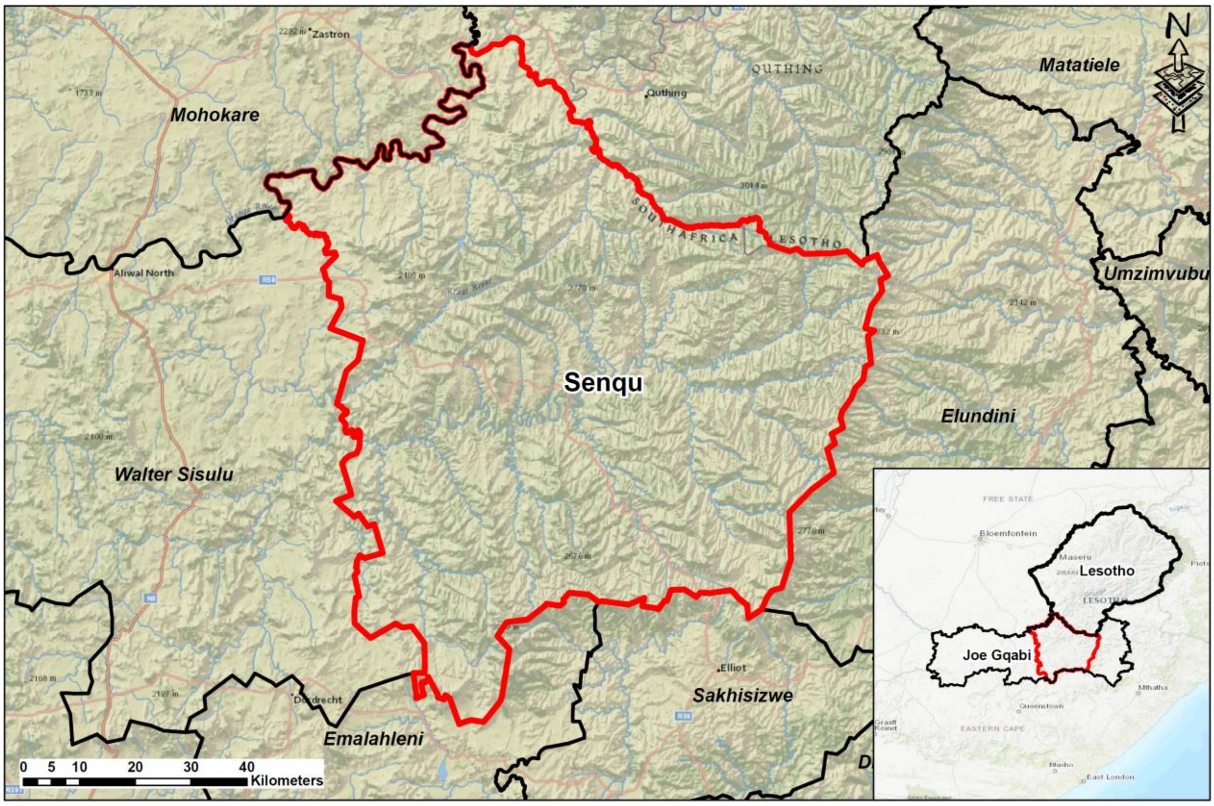

Figure 1: Senqu Local Municipality Boundary and locale.

The overall study area considers six (6) wards within the Senqu Municipality, namely Ward 1 to Ward 6 (see **Figure 2**). The relevant data for each ward in terms of population, population density, number of households and overall area is provided in **Table 1**.

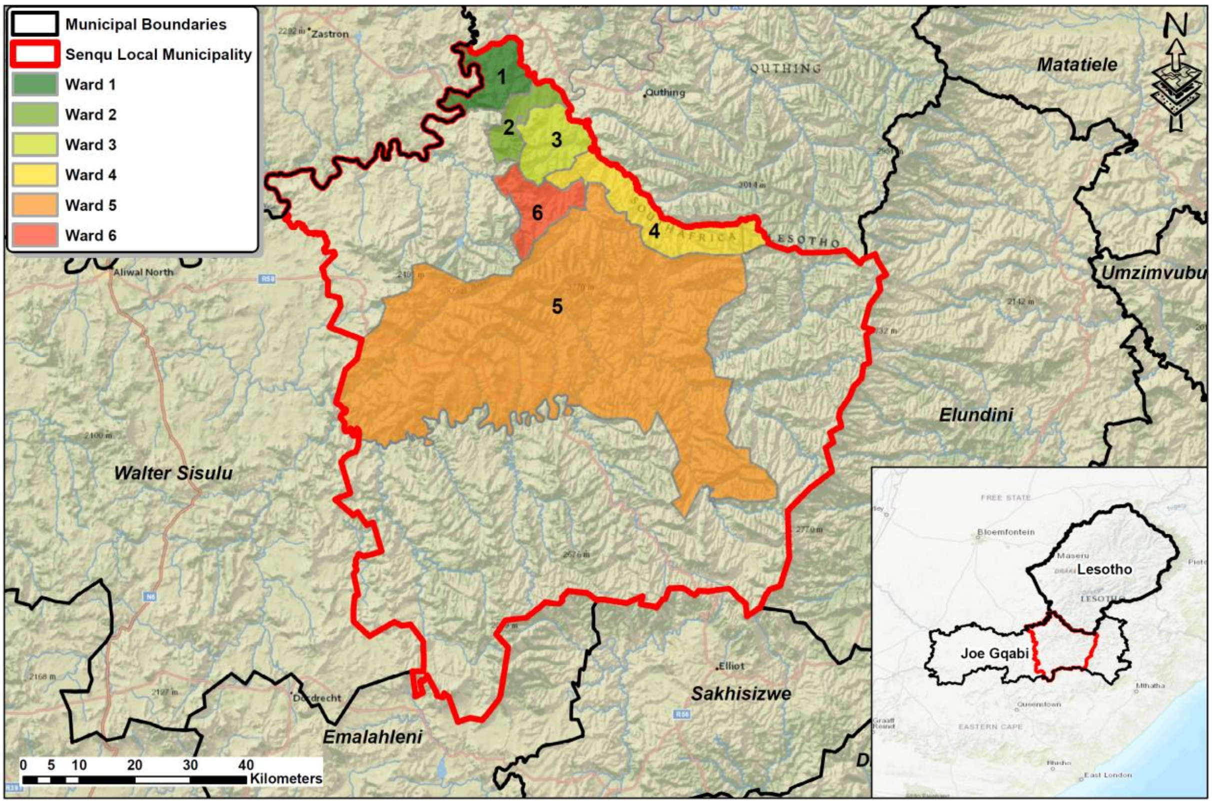

Figure 2: Wards 1 to 6 locality within Senqu Municipality.

Table 1: Villages in the Study Area

	Area	Census 2011		Population Density	HH Size
	km²	Population	No. of Households	People / km²	People / HH
Ward 1	125.3	8 713	2 378	69.5	3.7
Ward 2	81.3	18 080	4 993	222.4	3.6
Ward 3	131.9	7 764	2 108	58.9	3.7
Ward 4	223.8	6 945	1 735	31.0	4.0
Ward 5	2 206.8	4 342	1 267	2.5	3.4
Ward 6	123.0	7 199	1 994	49.4	3.6
Sum	2 892.1	53 043	14 475	-	-

It can be noted that Ward 2 population and population density figures stand out, as significantly larger compared to other Wards, with its population being about twice as large as the second largest Ward (Ward 1). A breakdown of the population distribution within each ward into the designated / identified settlements as per the information provided by the District Municipality would help shed more light on this. **Figure 3** presents a layout map showing the identified settlements / villages within all six (6) wards, while **Table 2** provides the relevant data inclusive of projected water demand for the year 2053.

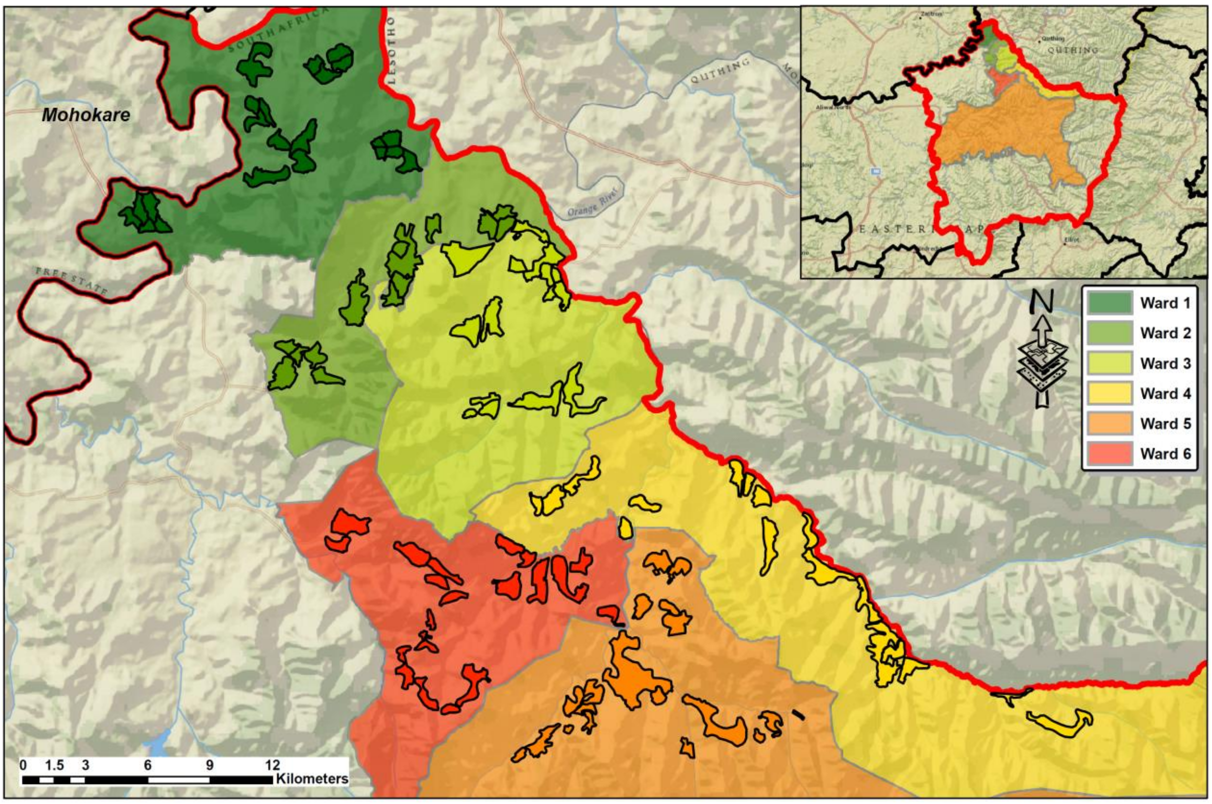

Figure 3: Settlements within Wards 1 to 6 in Senqu Municipality.

Examining the information listed in **Table 2** below, the following can be stated:

- By far, the largest settlement in terms of population (and as a result, water demand) is Senqu NU. This settlement is listed under Ward 2 as per the available information.
- Checking the 'Statistics South Africa' official database, this settlement is listed as follows:
  "Senqu NU includes all non-urban areas (farming areas and/or sparsely populated areas) within Senqu." (Source: SA Census 2022. [Main Place | Statistics South Africa (statssa.gov.za)]).
- Therefore, it is understood that the listing of this settlement does not suggest that there is an unusually high concentration people in that one physical locale in Ward 2, and so the data associated with this settlement should not skew the decisions made regarding the supplying of the area with water or other services.
- The nature of the topography in the Project Area is such that there is more than 530 m in elevation difference across the identified settlements / villages. (See **Figure 4** for a layout map that illustrates this point)
- The total daily average water demand for the design horizon year of 2053 is about 12 000 m^3/day, which translates to 4.4 million m^3/annum.

Table 2: Settlements / Villages in Wards 1 to 6 in Senqu Municipality with corresponding data.

Ward	Settlement	Census 2011		2053 Water Demand	Avg. Elevation
		Population	No. of HHs	m^3/day	(masl)
Ward 1	Ntatyana	366	100	73	1 487
	Mabalana	246	67	55	1 500
	N'Dofela	208	57	47	1 499
	Bikizana	334	91	56	1 507
	Mboleni	629	172	131	1 495
	Mdaweni	222	61	40	1 546
	Sqitini	425	116	104	1 520
	Ntaba-Kusuku	253	69	49	1 482
	Rayisini	177	48	37	1 546
	Dolosini	467	127	109	1 532
	Mayisela	331	90	88	1 560
	Mfiki	503	137	96	1 539
	Mbekweni	306	84	80	1 421
	Mpucukweni	200	55	51	1 440
	Quimera	174	47	50	1 460
	Babara	124	34	23	1 421
	Mjilweni	179	49	39	1 457
	Modapi	517	141	115	1 430
	Mrifi	430	117	73	1 433
	Platform	283	77	68	1 481
	Drayini	234	64	57	1 488
	Zwelitsha	2105	575	502	1 452
	SUM	***8 713***	***2 378***	***1 943***	-
Ward 2	Senqu NU	7021	1940	1856	1 497
	Sitoromo	1202	332	279	1 489
	Palmietfontein	1776	491	381	1 455
	Magalagaleni	491	136	99	1 482
	Gcina	555	153	125	1 505
	Mayireni	3175	877	658	1 509
	Ndingashe	1173	324	237	1 577
	Gumba-Gumba	377	104	73	1 566
	Rooiwal	634	175	135	1 600
	Makuyaze	375	104	62	1 567
	Dulcies Nek	182	50	44	1 610
	Mbini	389	107	93	1 582
	Mtsila	464	128	95	1 560
	Ngxingweni	266	72	42	1 639
	SUM	***18 080***	***4 993***	***4 179***	-

Ward	Settlement	Census 2011		2053 Water Demand	Avg. Elevation
		Population	No. of HHs	m^3/day	(masl)
Ward 3	Mdeni	882	239	207	1 456
	Henge	588	160	105	1 461
	Lower Telle	424	115	93	1 430
	Telle Mission	390	106	92	1 463
	Sikroxweni	445	121	109	1 436
	Qoboshane	301	82	76	1 452
	Magalagaleni	1690	459	348	1 535
	Hobeng	746	202	179	1 543
	Tlakong	426	116	91	1 573
	Era	452	123	83	1 600
	Tlankaneng	725	197	187	1 599
	Mpoki	263	71	55	1 648
	Musong	432	117	91	1 681
	SUM	***7 764***	***2 108***	***1 716***	-
Ward 4	Emqheyen	612	153	125	1 521
	White City	569	142	112	1 520
	Trappan	447	112	81	1 543
	Komkhulu	382	95	74	1 761
	Ntubeni	379	95	53	1 565
	Makumsha	384	96	87	1 544
	Mbango	190	47	47	1 559
	Mtunzini	1215	304	256	1 675
	Nothanda	215	54	51	1 619
	Blom	265	66	48	1 651
	Mfinci	333	83	85	1 750
	Juliwe	667	167	168	1 800
	Daweni	237	59	67	1 804
	Springkaanspoort	311	78	77	1 532
	Boomplaas	369	92	80	1 563
	Dangershoek	212	53	36	1 756
	Nomlengane	158	39	33	1 957
	SUM	***6 945***	***1 735***	***1 480***	-
Ward 5	Sidakaneni	231	67	57	1 578
	Blikana	622	182	146	1 649
	Mtsono	135	39	32	1 695
	Lusizini	371	108	65	1 554
	Sketsheni	331	97	77	1 730
	Ndungunya	435	127	107	1 594
	Pelandaba Mission	234	68	56	1 701
	Zingxangele	331	97	83	1 648
	Mahlathini	292	85	53	1 611
	Mhlabathini	263	77	57	1 695
	KwaMadume	346	101	63	1 661
	Emua Kwegolo	267	78	54	1 640
	Kusiphamo	136	40	16	1 670
	Ninakulu Mount	83	24	28	1 894
	Rock Cliff	265	77	68	1 816
	SUM	***4 342***	***1 267***	***962***	-

Ward	Settlement	Census 2011		2053 Water Demand	Avg. Elevation
		Population	No. of HHs	m^3/day	(masl)
Ward 6	Mlamli	1344	369	293	1 617
	Matafazaneni	430	118	81	1 770
	KwaMundu	191	52	49	1 838
	Mkhuzo	198	54	34	1 835
	Edwaleni	362	99	65	1 823
	Letsoesi	361	99	80	1 718
	eTyinindini	221	61	39	1 631
	Hillside	152	42	47	1 610
	New Hillside	880	241	254	1 586
	Ndunguyeni	463	127	99	1 580
	Mtere	488	134	99	1 618
	Mazizini	201	55	51	1 936
	Nxamagele	286	78	68	1 761
	KwaRob	149	41	36	1 920
	Mdlabona	192	53	48	1 887
	KwaRadebe B	48	13	12	1 880
	KwaRadebe A	105	29	27	1 876
	Fort Hook	1128	329	255	1 557
	SUM	***7 199***	***1 994***	***1 637***	**-**
TOTAL		**53 043**	**14 475**	**11 917**	**-**

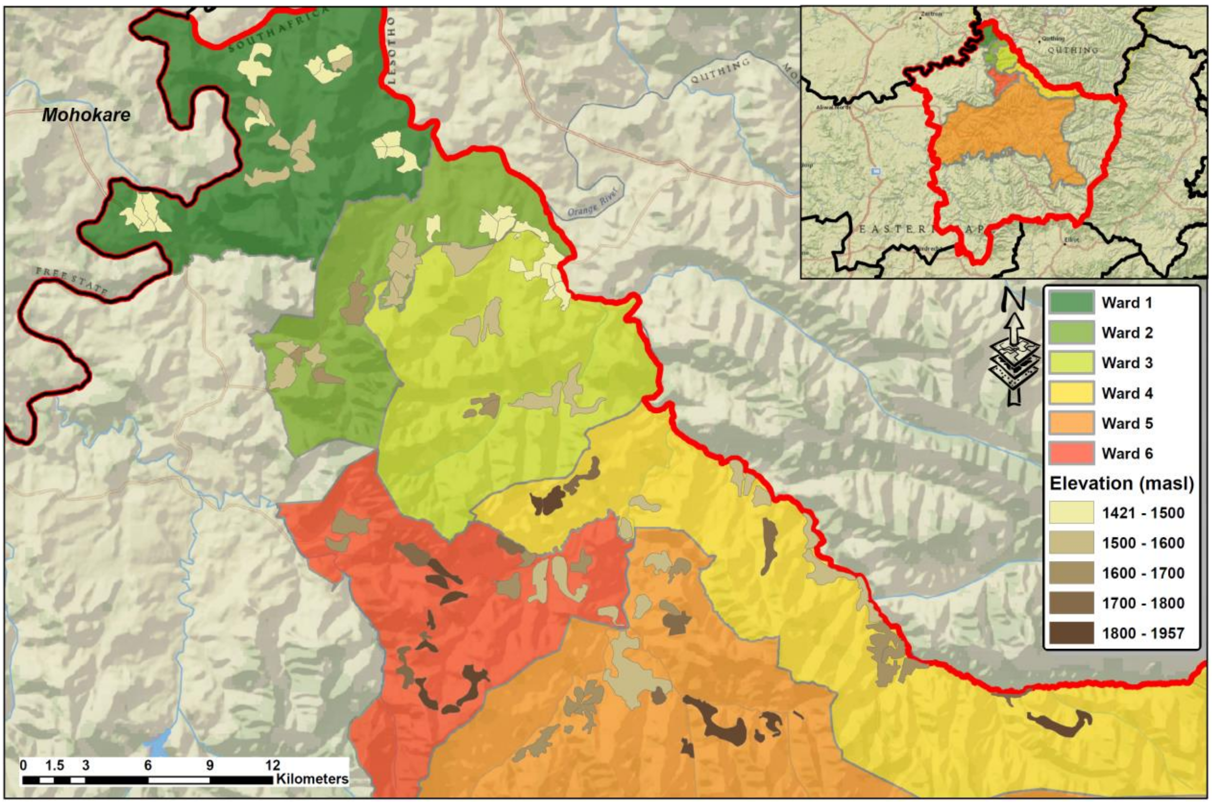

Figure 4: **Average Elevations at Settlements within Wards 1 to 6 in Senqu Municipality.**

2 Hydrological Assessment

2.1 Purpose

The purpose of the hydrological assessment is to assess the potential for abstracting surface water from a point along the river system within the Project Area with a minimum target volume of 4.4 million m^3/annum such that the abstracted water can be viably delivered to as many of the water demand centres as possible.

2.2 Scope

This hydrological assessment was carried out purely as a desktop study. As such, the quality and level of resolution of the available information limited the scope of the assessment and the corresponding output.

No detailed topographic surveys were obtained during this study. The 1:50 000 topographic maps were utilized as a result. The available historic rainfall, runoff and other relevant input data was utilized on 'as is' basis. No updates of such data were carried out. No detailed historic firm yield or stochastic yield curves were developed. Rather, a simple yield evaluation exercise was performed.

The assessment focused on the identification of potential abstraction point(s) while giving consideration to minimising the pumping head that would be required for water delivery.

The assessment also looked at a flood hydrology exercise to estimate the flood peaks for different return periods for the catchment area(s) in question.

2.3 Area of Interest

The main river system that runs through the Project Area consists of the Telle River, and couple of its tributaries. The Telle River runs along the Lesotho-South Africa border and drains into the Orange River (see **Figure 5**). The confluence with the Orange River is located to the east of Ward 2 at elevation 1 400 masl. While it is tempting to target an abstraction site downstream of this confluence, as water availability in terms of meeting the projected water demands would not be an issue, the fact remains that any water delivery system would then need to pump against a static head in excess of 400 m. Given the order of magnitude of water volumes to be abstracted, and the nature of the terrain in the area, this is deemed impractical. This argument holds if a central abstraction site is to be considered to supply all the identified settlements. However, should a decentralised approach be considered, where multiple pick-up weirs may become an option, then the area downstream of the confluence can be revisited.

Therefore, the area of interest for potential abstraction sites is mainly confined to the river system upstream of the Telle / Orange confluence. An abstraction site on the Telle River itself may be practical if it is situated in the higher reach (with ground elevations higher than 1 500 masl). Other options can consider the Blikana River, a tributary of the Telle River. The

Blikana River, like the Telle River, is perennial and the upper reach of this river has ground elevations higher than 1 500 masl as well.

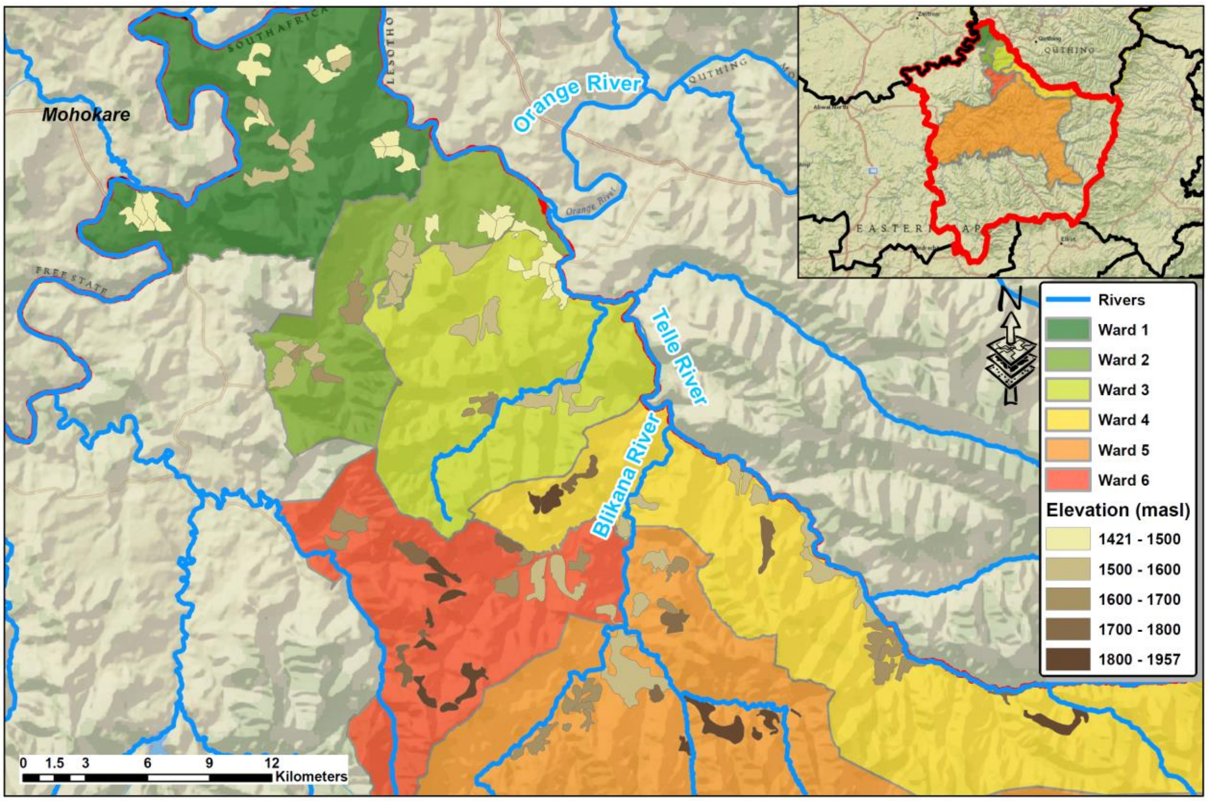

Figure 5: River Systems within the Project Area.

2.4 Physical and Hydrological Characteristics of Catchments

For the identified areas of interest, a hydrological assessment was carried out, starting with catchment delineation. Indicative outlet points on the river reaches of interest, following the above discussion were adopted as outlets for the catchments to be delineated. Physical characteristics like area, slope, centroid, longest watercourse, etc. are typical outputs of this process.

To arrive at these outputs, hydrologically correct Digital Elevation Models (DEMs) were created. This was done by sourcing topographical information from the 1:50 000 maps available for the area.

The contour data was converted into rasters within a Geographic Information System (GIS) environment such that one raster covers the extent of one project area. These raster datasets were georeferenced to the appropriate projected coordinate system (UTM Zone 35S).

To create a hydrologically correct DEM, pre-processing of the original raster dataset was performed. It was first verified that existing man-made lakes within data extent were mapped into the original raster. To achieve this, Google Earth images as well as the LIDAR imagery were used to trace these lakes.

This was followed by filling the depression cells in the DEM based on the elevation of the surrounding cells. These depression cells were present due to the inherent resolution of the raw DEM. This reduced the number of potential 'sinks' in the DEM and created what can be referred to as a 'hydrologically correct' DEM.

The developed DEM was then processed to evaluate the following:

- Flow direction: every cell was assigned a value corresponding to the flow direction of the steepest descent from that cell.
- Flow accumulation: Using the flow direction grid, the flow accumulation grid was created and it contained the accumulated number of cells upstream of a cell, for each cell in the input grid.
- Stream definition and segmentation: using the flow accumulation grid, it was then possible to define the streams network.
- Catchment grid delineation: This grid assigns each cell a value corresponding to the catchment it drains to.
- Catchment polygon processing: Based on the catchment delineation grid, an automatic tracing of the divides between catchments was saved into a polygon feature class.
- Drainage line processing: The stream grid, in conjunction with the segmented streams network, was translated into a line feature class depicting the mapped streams. Stream order process was also performed following the Strahler method.
- Adjoining catchment processing: In this process, aggregation of upstream catchments using the catchment feature class was carried out.
- Drainage point processing: The developed catchments were assigned a value corresponding to their respective outlet or drainage points.

Figure 6 shows visual representations of the analyses mentioned above for the Project Area.

The resulting set of data was then utilized to delineate all catchments. The delineated catchments were then analysed to extract their physical parameters to serve as input for the hydrological analysis where needed.

Figure 7 shows visual representations of catchment delineation output for the Telle River. Similar maps have been produced for other sub-catchments.

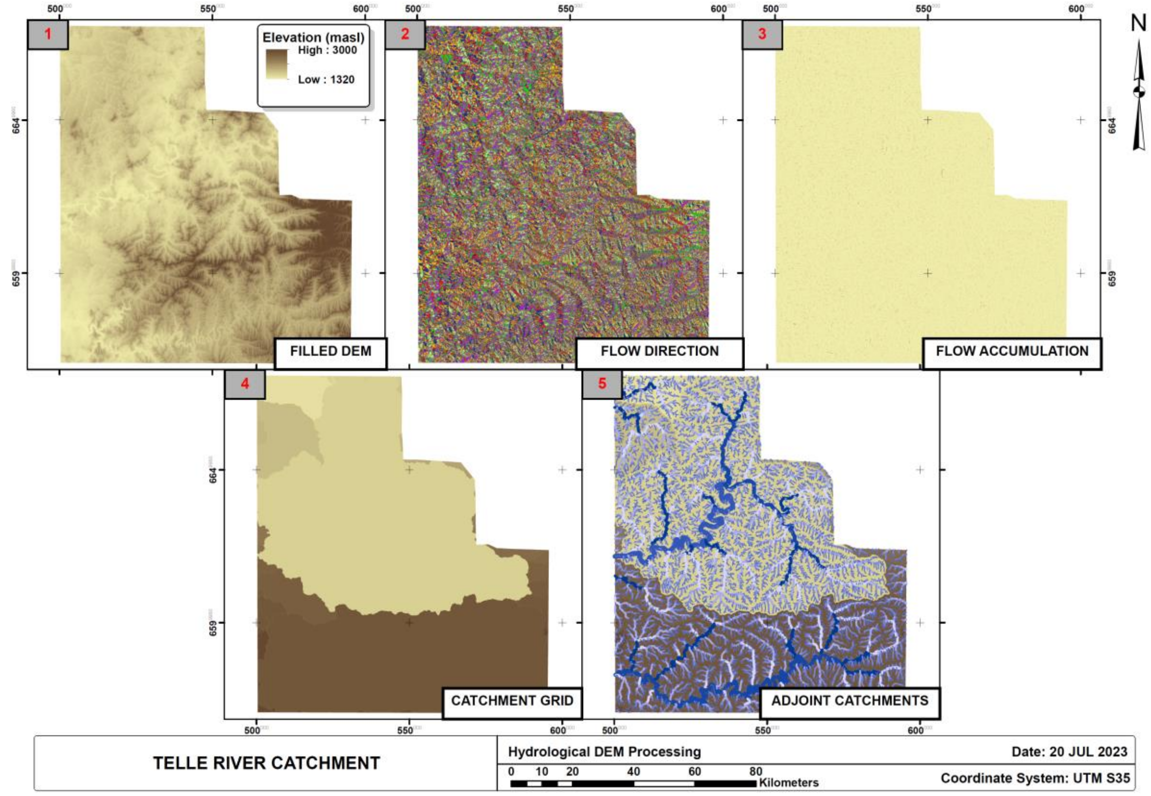

Figure 6: Hydrological Processing of Project Area.

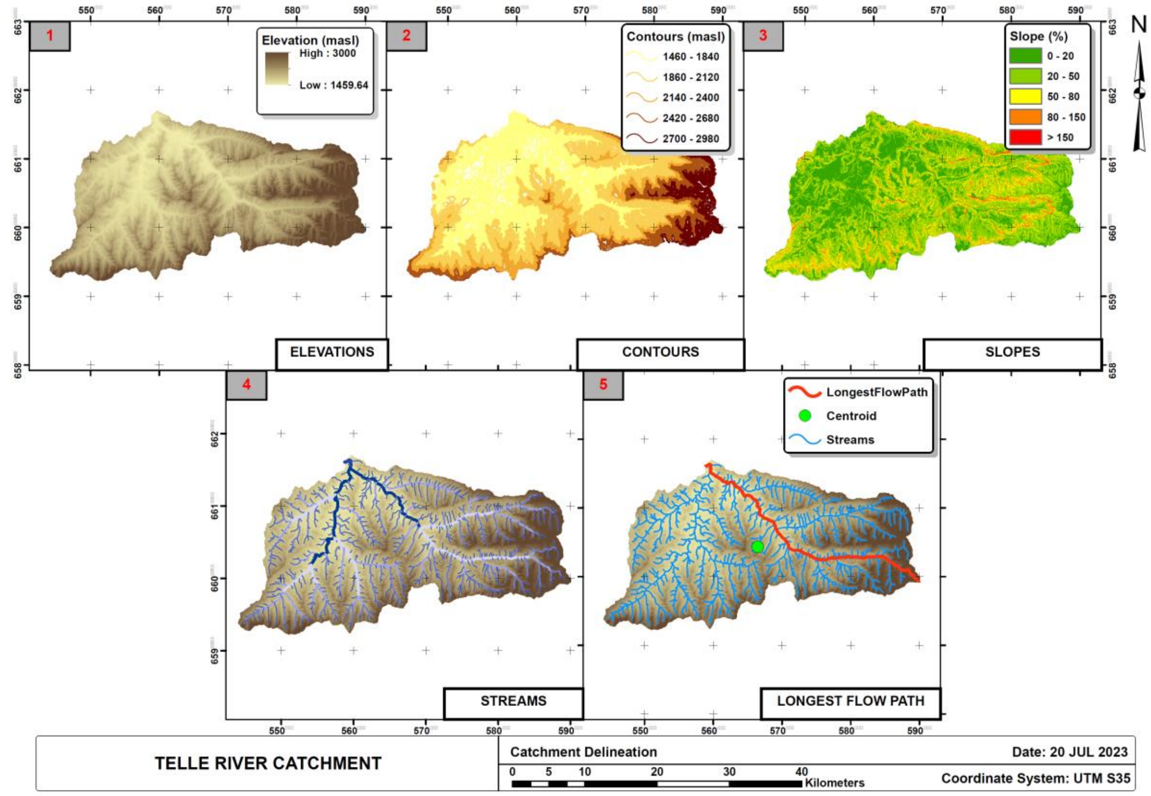

Figure 7: Telle River Catchment Delineation.

After delineating the catchments, a check was done to confirm that the extent of the delineated catchments conforms to the quaternary catchment boundaries (where and if applicable) as captured in the WR2012 database. Moreover, this is also done to extract the relevant information regarding rainfall stations, runoff gauges, Mean Annual Precipitation (MAP) and Mean Annual Runoff (MAR) applicable to these catchments.

Figure 8 shows an overall location map of the delineated Telle River catchment, with the WR2012 rainfall database overlayed.

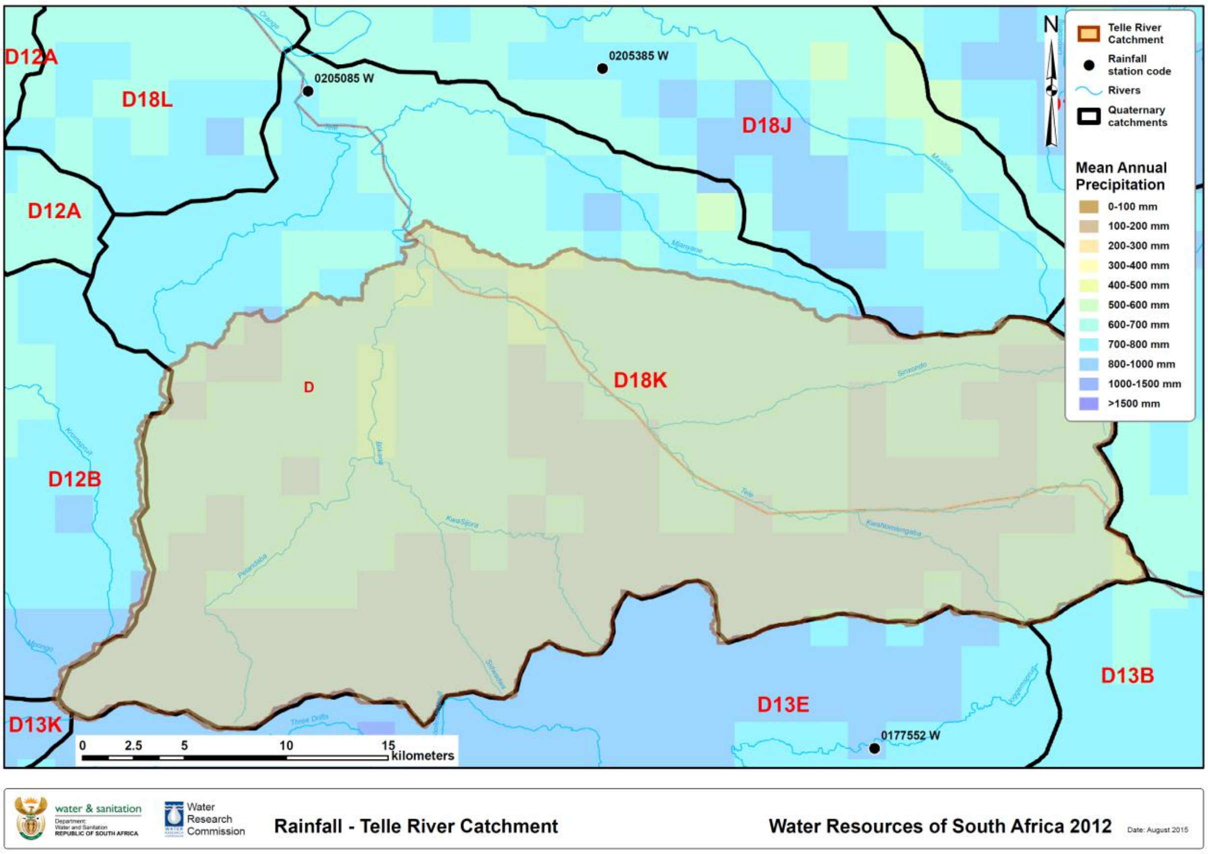

Figure 8: Telle River Catchment superimposed on WR2012 Rainfall Map.

It can be noted that the delineated catchment boundary correlates well with the relevant quaternary catchments. The Telle River catchment at the outlet of interest falls under quaternary catchment (QC) D18K. It makes up for 77% of the quaternary's catchment area. This quaternary catchment constitutes the full Telle River catchment area as its outlet drains at the confluence with the Orange River. **Figure 8** also shows the rainfall stations available in the area. No rainfall stations are located within the Telle River catchment of interest. However, a few rainfall stations lie within the D18K quaternary catchment.

Similarly, **Figure 9** shows an overall location map of the delineated Telle River catchment, with the WR2012 runoff database overlayed. Unfortunately, no stream flow gauges are available at or near the outlet of the D18K quaternary catchment. The nearest relevant stream flow gauge is station D1H006 located at Maghalee some 50 km downstream of the D18K quaternary catchment.

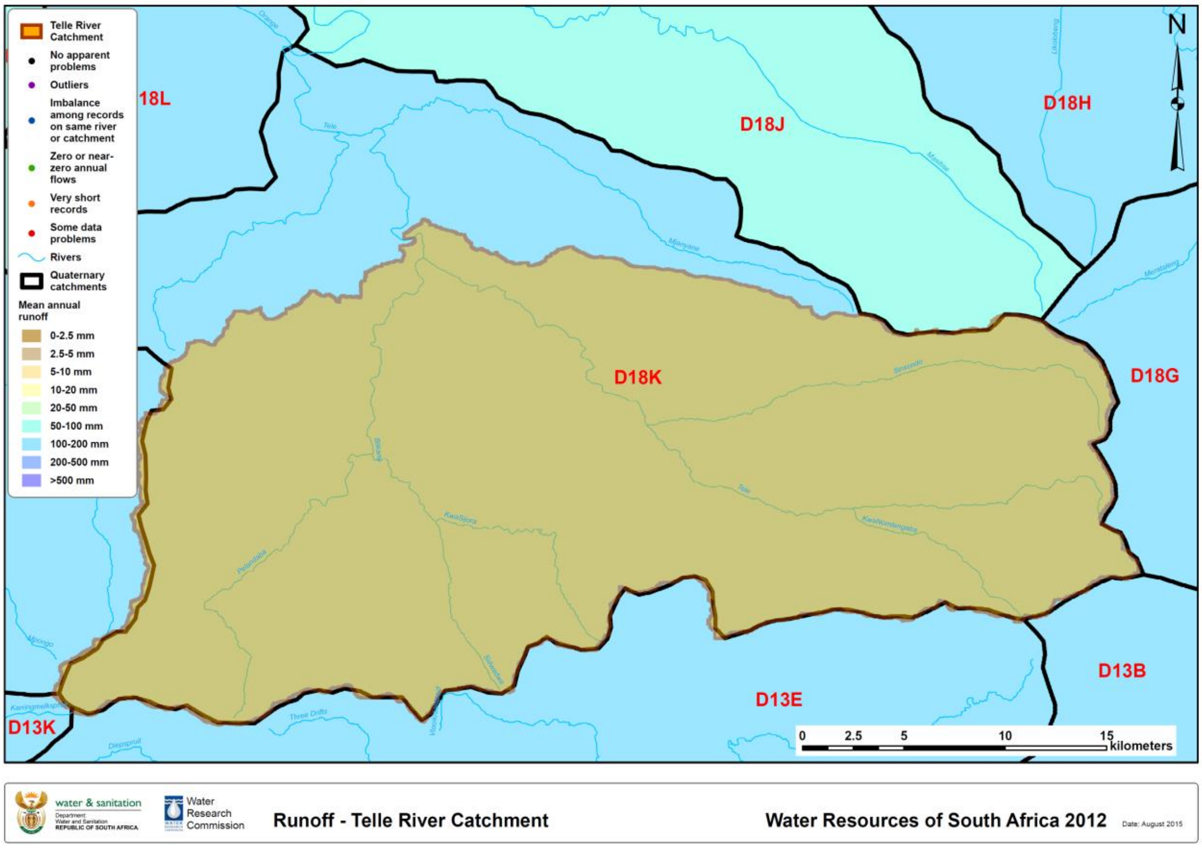

Figure 9: Telle River Catchment superimposed on WR2012 Runoff Map.

The main physical characteristics of the delineated catchments were extracted from GIS. The main hydrological parameters extracted include the Mean Annual Precipitation (MAP), time of concentration (T_c), lag time (T_L), and storm duration (SD). T_c and T_L were calculated following a series of equations that link the physical parameters of the said catchment to its hydrological response time. The storm duration was varied in relation to the computed catchment response times.

A summary of the main physical and hydrological characteristics of Telle River catchment is presented in **Table 3**.

Table 3: Summary of Physical and hydrological Characteristics of Telle River Catchment.

Catchment Area	L	L_c	S	C_S	MAP	MAR	Lag	T_c
km^2	km	km	m/m	m/m	mm	Mm^3/a	hr	hr
Telle River Catchment								
720	44.7	12.1	0.0196	0.3557	770	111	2.2	5.6

L: Longest watercourse length
L_c: Distance to catchment centroid
S: Watercourse slope
C_S: Catchment slope
MAP: Mean Annual Precipitation
MAR: Mean Annual Runoff
Lag: Catchment lag time
T_c: Time of concentration

2.5 Water Resources Assessment

Any potential abstraction site will have a catchment area that is a subset of the quaternary catchment D18K. Utilizing the available data from the Water Resources Simulation Model (WRSM2000), the calibrated model for the quaternary catchment was extracted and the simulated flows were captured. A high-level check was performed on rainfall patching and other input parameters such afforestation areas, irrigation schemes, etc. The modelling period, related to the available historic records, spans the years 1920 to 2009 (90 years).

The D18K quaternary catchment area is 935 km^2 with a Mean Annual Precipitation (MAP) of 774 mm (see **Figure 10**). The monthly rainfall series is shown in **Figure 11**.

The catchment's simulated runoff series was also extracted from the WRSM2000 model. This simulated runoff series was calibrated using calibration parameters from other nearby catchments with similar hydrologic characteristics. The D18K catchment has a Mean Annual Runoff of 144.5 million m^3/annum (an average of 0.15 Mm^3/a per km^2). The annual and monthly hydrographs are presented in **Figure 12** and **Figure 13**, respectively. The long-term mean monthly runoff is presented in **Figure 14**. **Table 4** presents a summary of the D18K catchment hydrology, along with a summary of the same parameters for the Telle River sub-catchment as presented in the previous section. The parameters were scaled down based on the first-order ratio of the corresponding catchment areas instead of the square root of that ratio as a conservative measure.

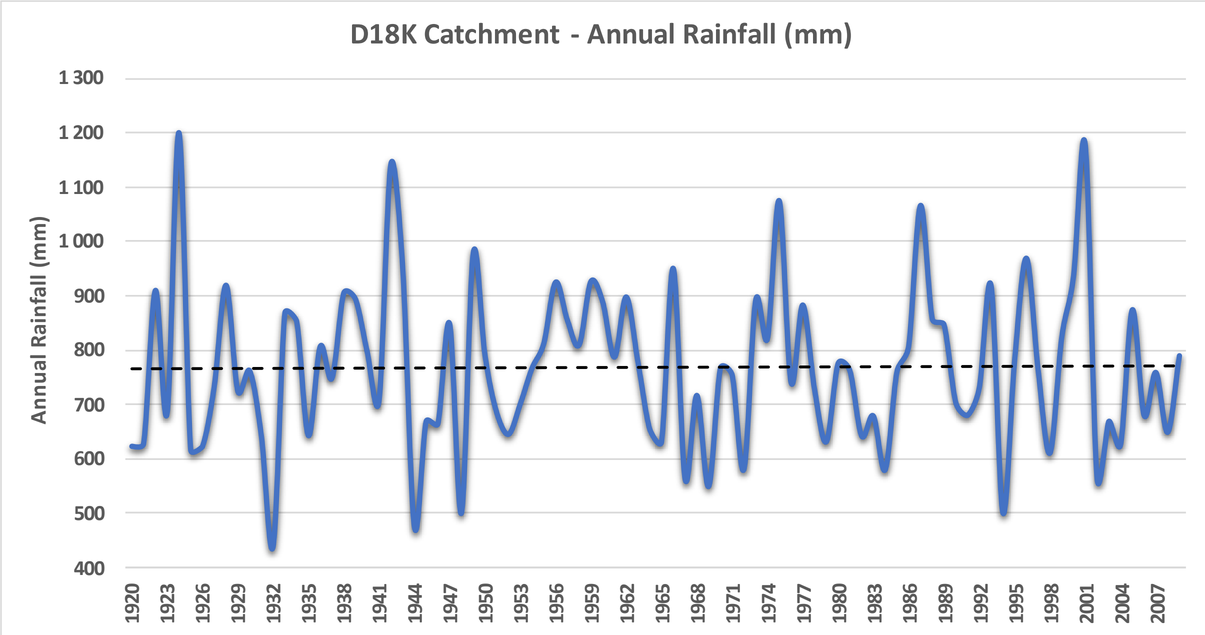

Figure 10: **Quaternary Catchment D18K – Annual Catchment Rainfall.**

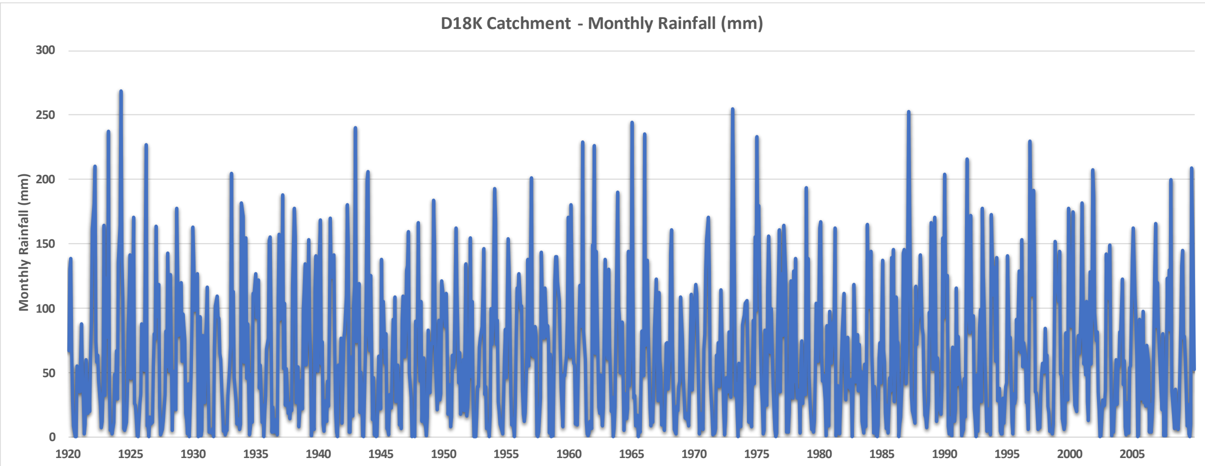

Figure 11: **Quaternary Catchment D18K – Monthly Catchment Rainfall.**

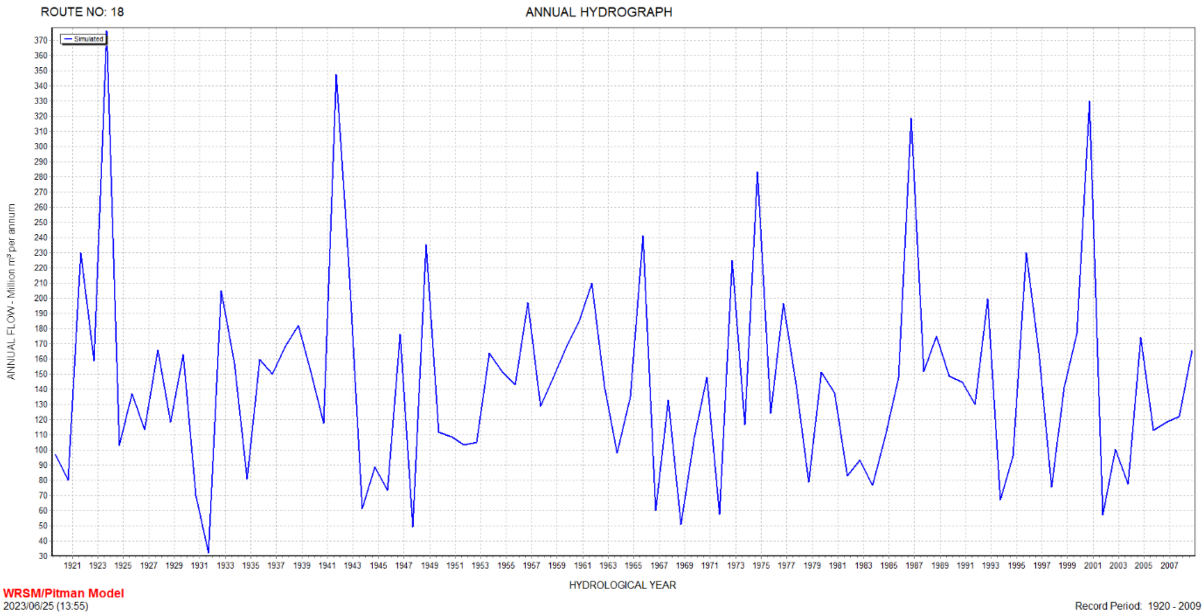

Figure 12: Quaternary Catchment D18K – Annual Hydrograph (WRSM).

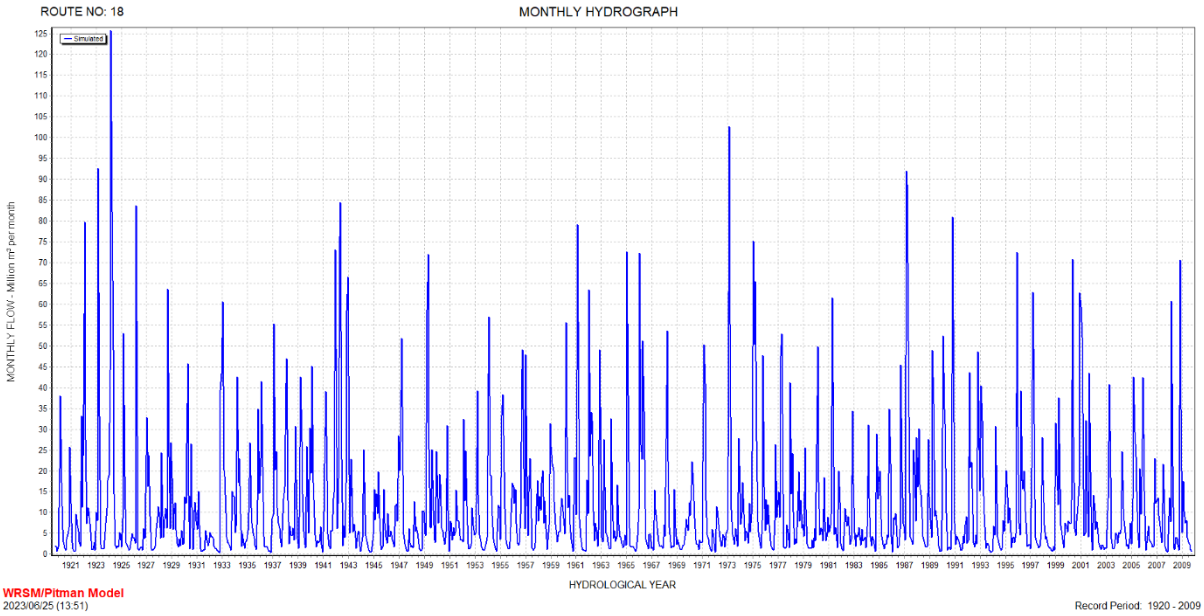

Figure 13: Quaternary Catchment D18K – Monthly Hydrograph (WRSM).

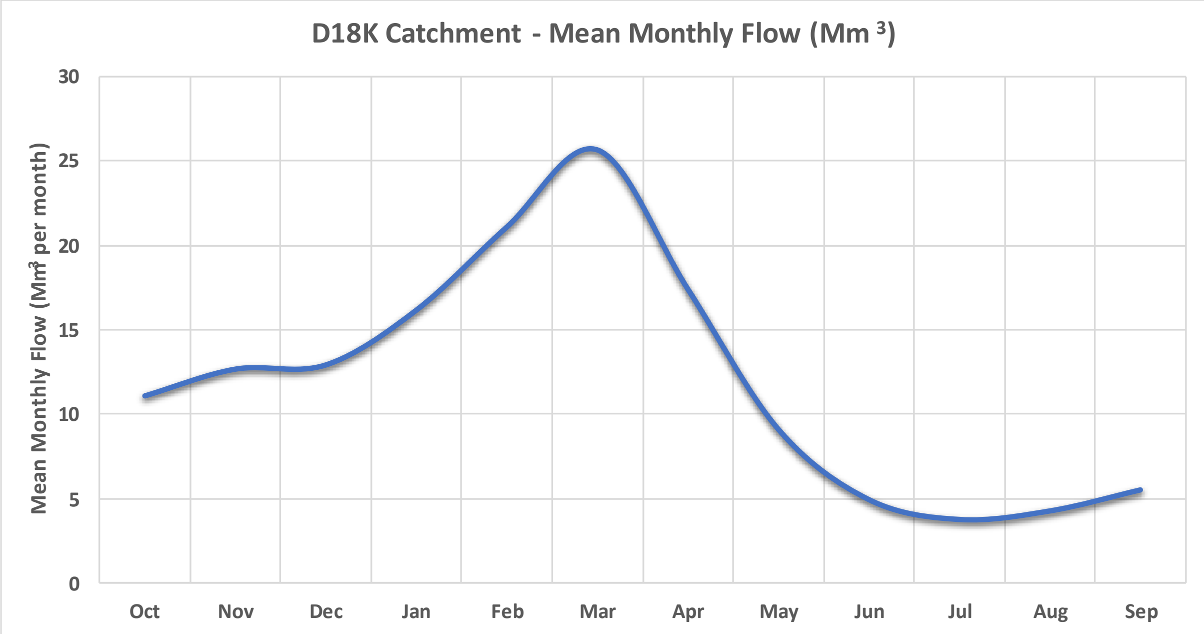

Figure 14: Quaternary Catchment D18K – Mean Monthly Hydrograph (WRSM).

Table 4: Summary of Rainfall-Runoff Parameters for D18K Quaternary Catchment and Telle River sub-catchment.

D18K Catchment											
Catchment Area			**MAP**			**MAE**			**MAR**		
km²			mm			mm			Mm³/a		
935			774			1 367			144.5		
D18K Catchment Mean Monthly Runoff (Mm³ per Month)											
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
11.07	12.67	12.92	16.17	21.12	25.70	17.42	9.09	4.91	3.73	4.23	5.48
Telle River Catchment											
Catchment Area			**MAP**			**MAE**			**MAR**		
km²			mm			mm			Mm³/a		
720			770			1 367			111.2		
Telle River Catchment Mean Monthly Runoff (Mm³ per Month)											
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
8.53	9.75	9.95	12.45	16.26	19.79	13.42	7.00	3.78	2.87	3.26	4.22

MAP: Mean Annual Precipitation
MAE: Mean Annual Evaporation
MAR: Mean Annual Runoff

Comparing the minimum target water volume of (4.4 million m³/a) to the catchment's MAR and to the long-term mean monthly runoff volumes indicates that the required abstraction volumes can be met, even when further deductions related to downstream users, environmental flow requirements, evaporation, etc. are accounted for. It also indicates that as long as the catchment area is big enough, then the type of the abstraction structure can be confined to either a weir or a dam with a maximum wall height of 10 m.

2.6 Potential Abstraction Sites

2.6.1 Scenario A: Centralized Abstraction Site

Should a single abstraction site be selected to serve as the sole surface water source for all the identified settlements within all six (6) wards, then such a site will need to be located in the higher reaches of the river system. Four (4) potential sites that can be considered have been identified and are shown in **Figure 15**.

Two (2) sites are identified along the Telle River, namely A-T1 and A-T2, and two (2) sites are identified along the Blikana River (A-B1 and A-B2).

An abstraction site along the Telle River itself has the advantage of providing access to higher assurance of supply compared to the sites on its tributary (Blikana River). This then can translate to potentially a smaller abstraction structure, which would reduce construction costs and reduce the footprint of the abstraction site. However, since the Telle River forms the border between Lesotho and South Africa, and since its catchment is split between the two countries, complications arise regarding the authorisations required to abstract water as well as construct the required infrastructure.

In contrast, the abstraction sites along the Blikana River would provide less assurances of supply, but the catchment area is entirely within South Africa. This simplifies the process required to obtain the necessary water abstraction and water use licenses. Furthermore, the two identified sites along the Blikana River are more closely positioned to the water demand centres (settlements) compared to those sites along the Telle River. The configuration of the envisaged abstraction structures can be adjusted to increase assurance of supply if needed.

All four of these potential sites have a disadvantage in needing to deliver at least some of the abstracted water against a static head up to 300 m. This will be required irrespective of the location of the abstraction site itself.

Given the above, the order of preference amongst the four identified sites is as follows:

1. Site A-B2
2. Site A-B1
3. Site A-T2
4. Site A-T1

Site A-B2 is recommended for further investigations should this scenario be adopted.

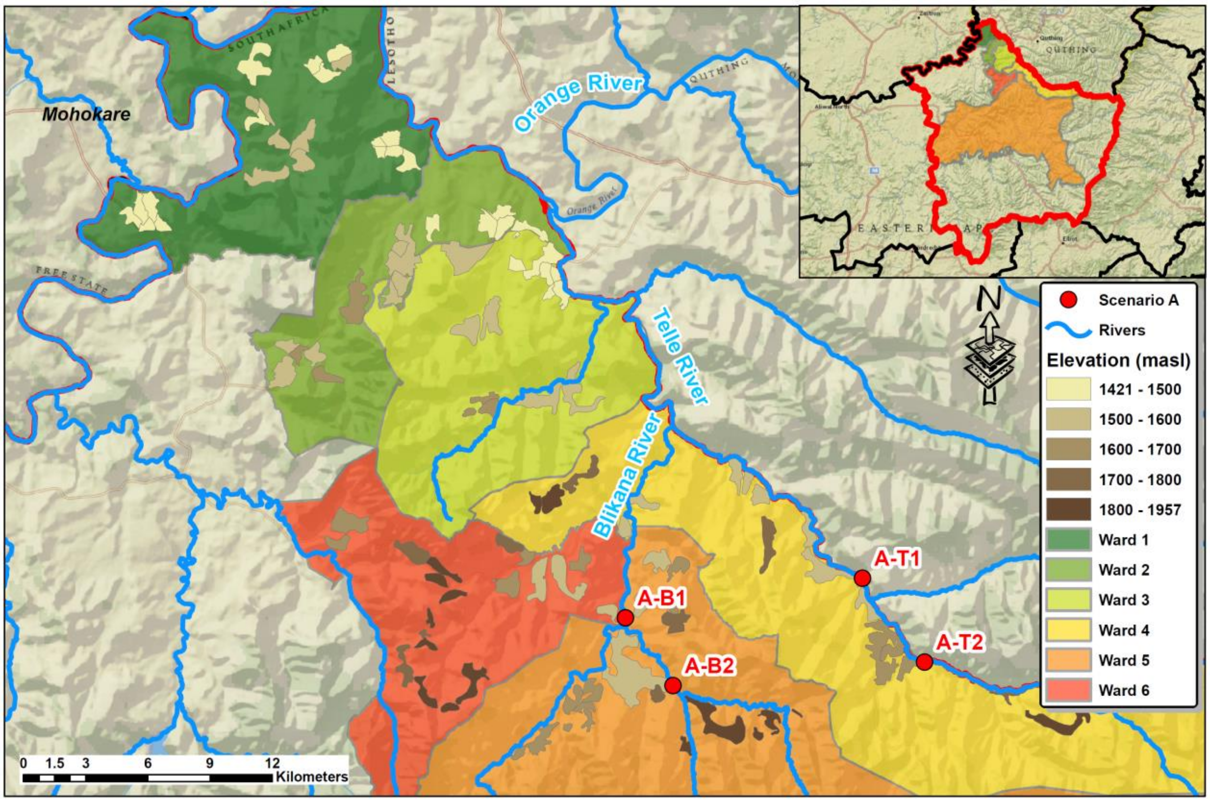

Figure 15: Potential Water Abstraction Sites – Scenario A.

2.6.2 Scenario B: De-centralized Abstraction Sites

This scenario allows for the inclusion of multiple abstraction sites such that water pumping is minimised. Each abstraction site with its water delivery system would be an independent water conveyance subsystem and would be sized / configured to meet the demand of those specific settlements / villages. It is key for this scenario to construct weirs as abstraction structures and eliminate the need for dam structures. Up to eleven (11) abstraction sites would be needed (see **Figure 16**). This scenario complicates the management, operation and maintenance of the proposed infrastructure. Given the order of magnitude of the water volumes involved, which is rather low, developing so many abstraction sites would be impractical. In order to deliver water to settlements in Ward 6 with minimal pumping arrangements, this scenario requires the utilization of a river system other than the Telle River, namely the Kromspruit River, which is a perennial river.

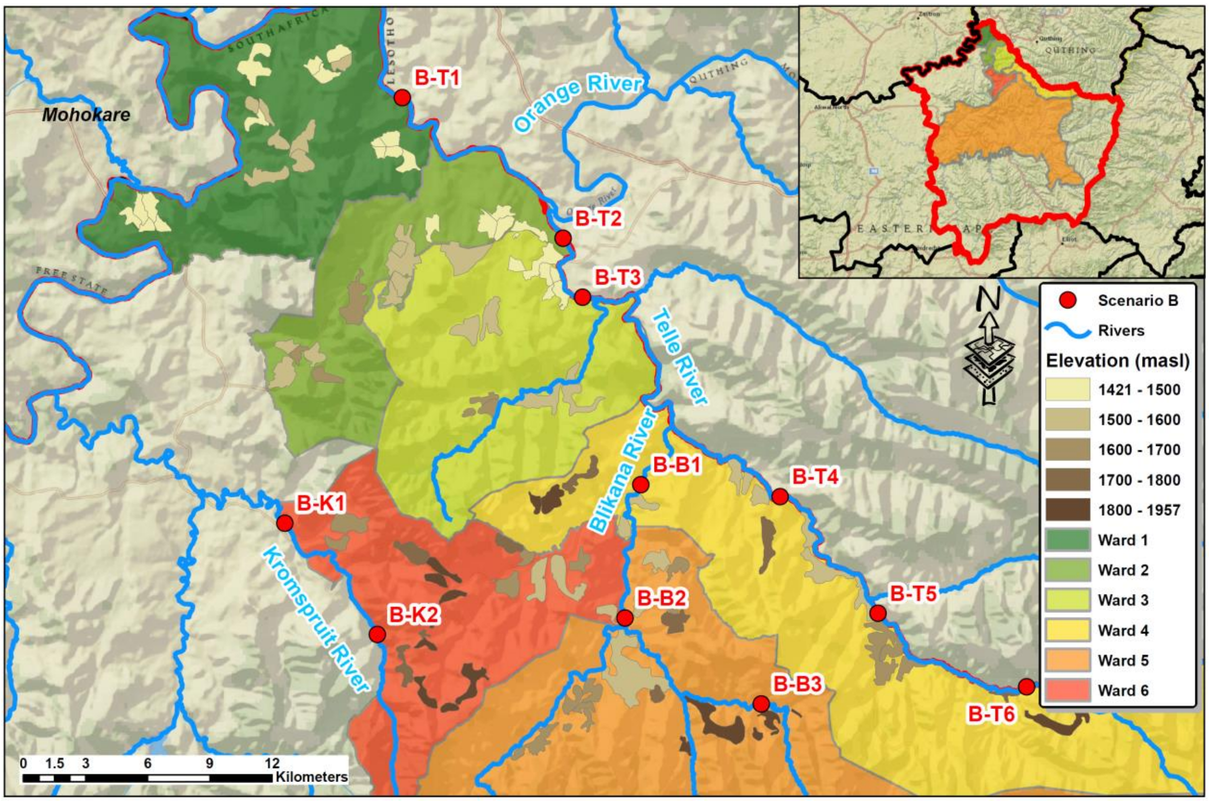

Figure 16: Potential Water Abstraction Sites – Scenario B.

2.6.3 Scenario C: Hybrid Abstraction Sites

This scenario considers the coupling of both Scenario A and Scenario B in order to reduce pumping costs while reducing the number of abstraction sites. A possible configuration to that end is to develop two (2) main abstraction sites in the higher river system reaches, with one (1) abstraction sites in the lower river system reaches, as shown in **Figure 17**. Depending on the finalised water delivery system costs per Ward, or per cluster of settlements, various configuration can be arrived at. This scenario offers a level of flexibility in the developed designs as long as the benefit / cost ratio for the adopted design is favourable. However, this scenario will likely call for the utilization of the Telle River itself and potentially even the Kromspruit River as well.

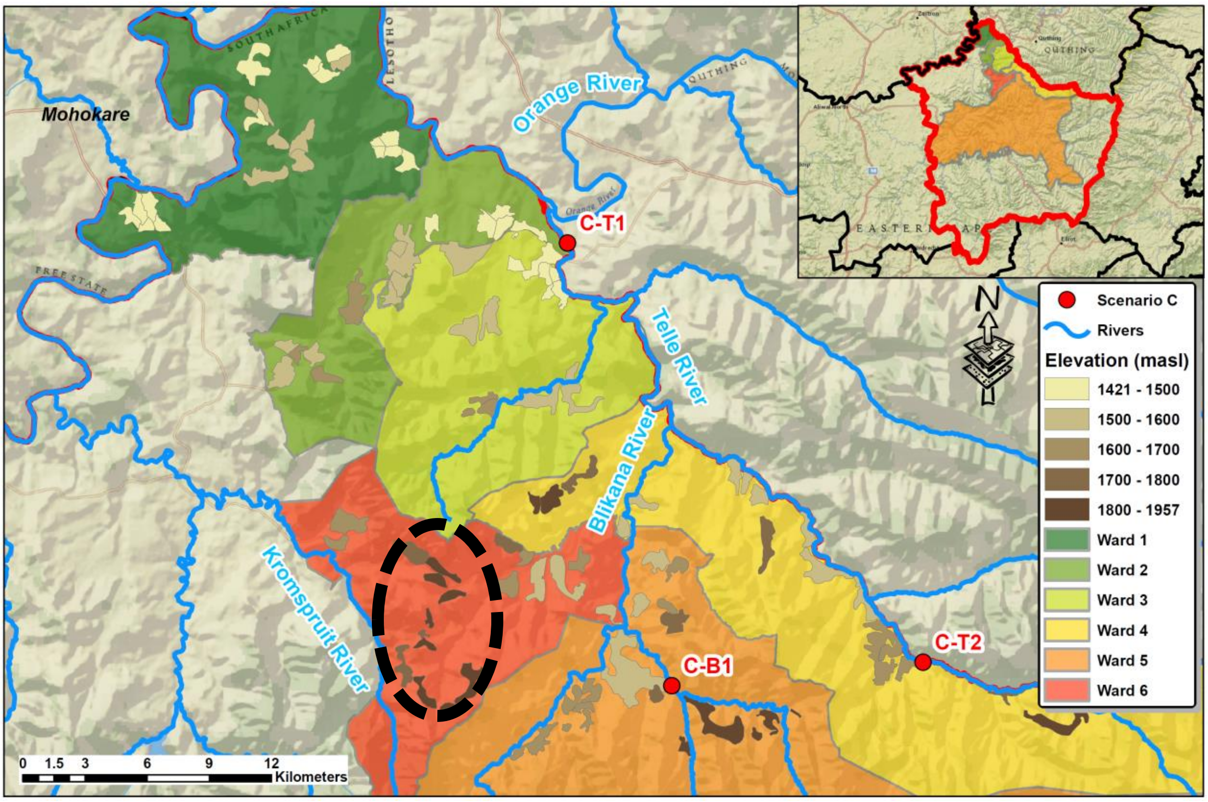

Figure 17: Potential Water Abstraction Sites – Scenario C.

2.6.4 Recommended Approach for Abstraction Sites

It is recommended to explore Scenario C further, with the starting point being site C-B1 (which is the same as site A-B2) and introduce additional abstraction points only when deemed necessary to do so. It is also recommended to engage with the relevant stakeholders in order to establish the extent of possible development on the Telle River itself. Should it be confirmed that such development can go ahead then sites C-T1 and C-T2 can be explored further as needed. At this stage, this approach is expected to improve the costing structure for the water delivery to Wards 1, 2, 3 and 4. It needs to be noted, however, that it may be required to exclude some of the settlements within Ward 6 due to the natural terrain and location which may render the cost of water delivery from the Telle River system to these settlements impractical. These settlements are listed in **Table 5** below and their location is indicated with a black circle in **Figure 17** above. It can be considered to supply these settlements via the Kromspruit River at site B-K2 indicated under Scenario B.

Table 5: List of Settlements within Ward 6 that may be excluded from current Scope.

Ward	Settlement	Census 2011		2053 Water Demand	Avg. Elevation
		Population	No. of HHs	m³/day	(masl)
Ward 6	Matafazaneni	430	118	81	1 770
	KwaMundu	191	52	49	1 838
	Edwaleni	362	99	65	1 823
	Mazizini	201	55	51	1 936
	Nxamagele	286	78	68	1 761
	KwaRob	149	41	36	1 920
	Mdlabona	192	53	48	1 887
	KwaRadebe B	48	13	12	1 880
	KwaRadebe A	105	29	27	1 876
	SUM	***1 964***	***538***	***437***	-

2.7 Yield Assessment

A yield analysis is required in order to determine the water volumes that can be abstracted sustainably. Input data into this analysis include, but not limited to, area-capacity curves for the proposed / existing water retaining structure (normally extracted from land or aerial surveys), naturalised stream flows, evaporation losses, irrigation and forestation demands, water demands imposed on the system downstream of the point of interest, etc. For this desktop study, where some of these input data are not available, a high-level yield assessment was carried out instead.

Given the required water demand to be abstracted, and comparing that demand with the Mean Annual Runoff (MAR) of the overall Telle River catchment, it is clear that demand can be met. However, water availability needs to be assessed as the abstraction point moves higher up the river system, thus reducing the catchment area.

The potential water abstraction site with the smallest catchment area that is also on a tributary of the Telle River rather than on the main river itself is site A-B2 (also labelled as site C-B1 under Scenario C). This abstraction site is located on the Blikana River and has an effective catchment area of 76 km^2. Following the same approach discussed in **Section 2.5**, the main rainfall-runoff parameters were estimated for this catchment and are presented in **Table 6** below.

Table 6: Summary of Rainfall-Runoff Parameters for D18K Quaternary Catchment.

Site A-B2 (Site C-B1) Catchment											
Catchment Area			**MAP**			**MAE**			**MAR**		
km^2			mm			mm			Mm^3/a		
76			740			1 367			11.7		
Mean Monthly Runoff (Mm^3 per Month)											
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
0.90	1.03	1.05	1.31	1.71	2.08	1.41	0.74	0.40	0.30	0.34	0.44

MAP: Mean Annual Precipitation
MAE: Mean Annual Evaporation
MAR: Mean Annual Runoff

It can be noted that while the Mean Annual Runoff of this catchment is still substantial compared to the required annual water demands, the mean monthly runoff volumes indicate the need for some storage capacity in order to supply the required demands.

A basic yield assessment was performed assuming a dam retaining structure with 10 m effective dam height; from Natural Ground Level (NGL) to Full Supply Level (FSL). An effective storage volume of 2 million m^3 and a dead storage volume of 0.25 million m^3 was assumed. The corresponding dam lake surface area at FSL was estimated to be 0.25 km^2.

The monthly rainfall series, monthly evaporation values and monthly stream flow series were then used to evaluate a Historic Firm Yield (HFY) estimate assuming minimal afforestation and irrigation development in the catchment. A HFY of 4.4 million m^3/annum was arrived at as a result.

This indicates that given the assumptions listed above, this potential abstraction site can meet the required water demands for all settlements in all six (6) wards. Keeping to the assumptions listed above in terms of the dam size, and considering it as the maximum limit for this project, it can then be concluded that developing an abstraction site on the Blikana River that is higher up in the catchment than site A-B2 is not recommended. As discussed previously, targeting abstraction sites along the upper reaches of the river system would be beneficial in terms of reducing the static head needed to deliver the abstracted water to the different demand centres. There is a trade-off between the reduction of pumping costs and the number, size and configuration of the abstraction site(s) and the associated dam / weir structures. Moving the abstraction site higher up the river beyond site A-B2 would yield diminishing returns given those considerations.

It should be noted that should this site be developed as a weir with minimal or no effective storage capacity, then the corresponding theoretical yield would be in the order of 1 million m^3/annum.

Applying the same set of assumptions listed above to site C-T2, which has a catchment area of 121 km^2, a historic firm yield of 4.4 million m^3/annum can be arrived at with a dam structure that is 8 m high with an effective storage capacity of 1.4 million m^3. Developing a weir at this site would give a theoretical yield of about 1.25 million m^3/annum.

For site C-T1, which is effectively the entire D18K quaternary catchment, no storage capacity would be required, as constructing a weir at this site can deliver the full 4.4 million m^3/annum water demand.

It is envisaged that all weirs / dams are to of gravity type with mass concrete as the construction material of choice. A central spillway section is to be provided. These structures are expected to frequently spill.

A summary of the yield assessment findings is provided in **Table 7**.

Table 7: Summary of Yield Assessment Results.

Site A-B2 (Site C-B1)				
X	**Y**	**Ground Elevation**	**HFY - Dam**	**HFY - Weir**
UTM S35		masl	Mm^3/a	
559 683.9	6 612 660.5	1 570	4.4	1.0
Site A-T2 (Site C-T2)				
X	**Y**	**Ground Elevation**	**HFY - Dam**	**HFY - Weir**
UTM S35		masl	Mm^3/a	
571 822.4	6 613 792.3	1 600	4.4	1.25
Site C-T1				
X	**Y**	**Ground Elevation**	**HFY - Dam**	**HFY - Weir**
UTM S35		masl	Mm^3/a	
554 649.8	6 634 033.2	1 410	-	4.5

The locations indicated on the maps and in **Table 7** above are approximate. A reconnaissance site visit should be carried out and refined positions of these abstraction sites should then be decided depending on site conditions.

It must be stressed that these findings are high-level assessments that are based purely on a desktop study. As such, it is recommended to conduct the necessary field investigations including topographic surveys, geotechnical investigations carry out corresponding analyses thereafter. An assessment of the environmental flow requirements needs to be carried out as well.

2.8 Flood Peaks Estimation

Deterministic, empirical and statistical methods (where applicable) have been applied to arrive at a range of estimated flood peaks for the three (3) potential abstraction sites under Scenario C. These methods vary in scope of applicability to the study area and the catchments under consideration. Some judgement was applied to arrive at the adopted values. Flood peaks up to and including the Regional Maximum Flood (RMF) were estimated. A summary of the adopted flood peaks is presented in **Table 8**.

Table 8: Summary of Estimated Flood Peaks.

Site	Flood Peaks (m^3/s) at Return Period (Years)							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**RMF**
C-T1	250	500	720	960	1 250	1 500	2 000	3 380
C-T2	35	70	95	130	170	200	270	460
C-B2	20	45	60	80	110	130	170	290

Appendix A: Supporting Maps