BIOPHYSICAL MONITORING: REPORT 1 OF THE UPPER TSITSA RIVER CATCHMENT (T35 A-E)

TSITSA PROJECT

Huchzermeyer, N; Schlegel, P; van der Waal, B

August 2019

TSITSA PROJECT

environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

RHODES UNIVERSITY
Where leaders learn

DISCLAIMER

This report has been reviewed and approved by the Department of Environment, Forestry and Fisheries: Environmental Programmes – Natural Resource Management Programmes (NRM), Directorate – Operational Support and Planning. Approval does not signify that the contents necessarily reflect the views and the policies of DEFF, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

The research has been funded by Department of Environment, Forestry and Fisheries: Environmental Programmes – Natural Resource Management Programmes (NMR), Directorate – Operational Support and Planning

EXECUTIVE SUMMARY

The Tsitsa Project strives to restore functional landscapes to the benefits of local and downstream users. It prioritises its limited resources for the maintenance of functioning, but threatened, ecological infrastructure overly severely degraded systems in order to avoid further degradation.

The Tsitsa Project is currently engaging with sustainable land management and restoration work in Quaternary Catchment T35 A-E. This targets the upper Tsitsa River catchment and is the current focus area for the biophysical monitoring. In order to gain an understanding of the physical processes at play in the Catchment and the success of different rehabilitation processes it is imperative to conduct biophysical baseline and monitoring surveys to guide effective and adaptive management. This report follows on the Biophysical Monitoring Plan (Schlegel *et al.,* 2019) and Biophysical Monitoring Methods (Huchzermeyer *et al.,* 2019b) set out by the Tsitsa Project.

This report focuses on the main results for the Biophysical Monitoring done to date for the Tsitsa Project and includes details on monitoring sites, the condition of each site and relevant data and observations. In-depth interpretations of the data will follow in an updated report.

The current monitoring accesses rainfall, water quality and quantity, river, wetland and veld condition in Catchment T35 A-E. Figure 1 summarises the current condition of the Tsitsa Catchment as per the results of the biophysical monitoring up until April 2019.

Rainfall:

A total of 11 self-logging tipping rain gauges are currently managed by the biophysical monitoring team. The location, magnitude, duration and extent of rainfall plays an important role in the effects of different catchment processes. The rainfall data presented in this report can be used to help aid the interpretation of catchment processes and can be linked to spikes in hydrology, increased sediment yields etc. Annual rainfall in the catchment has increased from 2015 with a general trend showing higher average rainfall at higher altitudes particularly closer to the Drakensberg escarpment. Rainfall at monitoring sites higher up in the catchment receive annual rainfall of greater than 700 mm/year (T35 A, B, C, F). Sites in the lower and middle catchment receive rainfall between 500-600 mm/year (T35 D, E, G, H, J, K). The highest intensity rainfall events are found in the North-western part of the catchment. Maximum 5 minute rainfall events at Catchment T35 A, B & D exceeded 13 mm/5 minutes (156 mm/hour). Catchment C, E & G exceeded 10 mm/5 minutes (120 mm/hour) and Catchment F, H, J & K exceeded 6 mm/5 minutes (72 mm/hour).

Hydrology and River Monitoring:

The health of rivers are an important indicator of the catchment processes occurring in the catchment in which the river is situated. There are currently 11 river monitoring sites at which a combination of hydrology, water quality and geomorphic (habitat) condition are being monitored. Discharge and flow velocities play an important role in sediment mobility and the stability of beds. All the sites show similar trends in discharge fluctuations with total discharge increasing further down the catchment. Months with little or no rainfall generally have low discharge values. Discharge peaked during summer months due to heavy rains in the catchment. Local rainfall events can increase the discharge significantly, particularly at the start of the rainy seasons. Snowmelts (e.g. August 2016) can also cause spikes in discharge during the winter months. Peak discharges at the start of the monitoring period (2016) were well below average but have been rising with increased rainfall in the catchment in subsequent summer months. The peak discharge in 2019 exceeded the 10 year flood indicating very high discharges for the season.

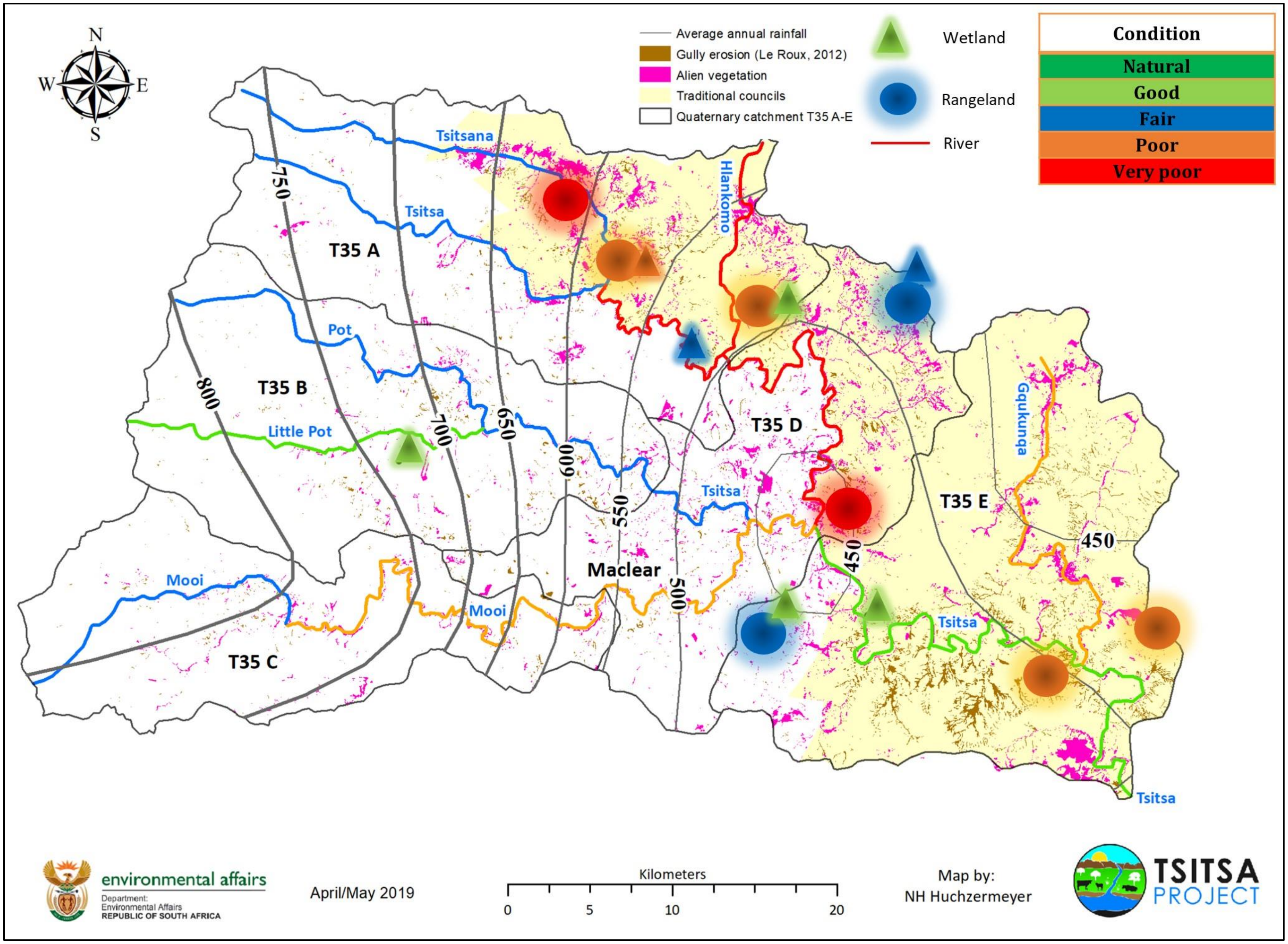


FIGURE 1: CONDITION OF THE TSITSA CATCHMENT FOLLOWING FIELD SURVEYS IN APRIL 2019

Monitoring water quality variables gives an indication of the health of aquatic habitats. Five variables were identified for a short-term habitat assessment, namely dissolved nitrogen and phosphate concentrations, pH, electrical conductivity (EC), dissolved oxygen (DO) content and water temperature.

Overall the water quality indicated a balanced system with the exception of increased phosphate levels and turbidity and the reduction in clarity due to high suspended sediment concentrations in flood waters. Phosphate levels for April 2019 ranged from 0 - 0.6 across all the sites. The highest levels were measured during a flooding event and levels of phosphate dropped with the reseeding flood. Concentrations of phosphates need to be considerably higher than those found in the rivers to have a significant impact on biotic health (Dallas & Day, 2004). The health effects of drinking water with phosphates are not well documented. Natural levels of nitrates are generally <1mg/l. Concentrations of >10 mg/l are seen as detrimental to aquatic life and human consumption. Most of the sites exhibit Nitrate levels of <1 mg/l in April 2019 with the exception of Site T2 on the Tsitsa River which was 1.6 mg/l. This is not seen as being detrimental to the health of the river at the site. DO levels ranged between 98 -114%. None of the DO concentrations fell below 50%, which is defined as sub-lethal to aquatic organisms (DWAF, 1996). Therefore, concentrations of DO were not expected to have any significant impacts on biotic health in the rivers. A well buffered South African river will be expected to have a pH ranging between 6 and 8, but fluctuations occur due to a changes in temperature, photosynthetic activity or biotic respiration and decomposition of organic matter (DWAF, 1996; Dallas & Day, 2004). Measured pH at most of the sites in April 2019 ranged from 7.3 - 8.0. Site T4 on the Tsitsa River exhibited a higher pH value of 9.6. According to Dallas & Day (2004) very little information is available on the tolerance of aquatic organisms to increased conductivity. The rate of change rather than the absolute change is important in assessing the effects on organisms. EC ranged from 20-60 µS/cm for April 2019. Turbidity increased and clarity decreased progressively with higher discharges and further down the river system. This can be linked to an increase in erosion and transport soil and sediment. Increased suspended sediment (greater turbidity and reduced clarity) has a significant effect on water and habitat quality particularly during the summer months. This is possibly the largest water quality issue for local livelihoods as the river water cannot be used for household purposes during a large part of the summer months.

Macroinvertebrates provide barometers of river health as they are the first to register ill effects of negative impacts on a river system. River health, in terms of water quality, can be rapidly assessed by looking at the taxa richness of macroinvertebrate species sensitive to water quality (Dickens & Graham, 2002). A score derived using the South African Scoring System (SASS) (Dickens & Graham, 2002), a widely used technique in South African Rivers, was calculated for each site as a time integrated assessment of water quality. This gave a measure of river health at the site scale. The average score per taxa (ASPT) is the total sensitivity score for all the families found, divided by the number of families found.

The SASSv5 scores are reported for each monitoring sites for April/May 2019 and give an indication of the ecological condition of the river at the monitoring site and the river upstream of the site. The ASPT score for April/May 2019 ranged from 4.9 - 7.5 across all the monitoring sites indicating ecological conditions ranging from very poor to good (Figure 1). A reduction in the ASPT scores and ecological conditions at each site can be attributed to the lack of habitat (mostly due to the embeddedness of coarse substrates) at these sites (due to erosional catchment processes and bed gradient) and high flows with turbid waters experienced during the monitoring survey. Site T4 on the Tsitsa River (ASPT score: 4.9) and Hlankomo River (ASPT score: 5) exhibited a very poor ecological condition. The Gqukunqa River (ASPT score: 5.8), Inxu River and the Mooi River (ASPT score: 6) exhibit a poor ecological condition. The Tsitsana River and Pot River (ASPT score: 6.7) exhibit a fair ecological condition. The Little Pot River (ASPT score: 7.1), the Tsitsa River at lower sites T3 and NH3 (ASPT score: 7.2) and the Tsitsa River at Site T2 (ASPT score: 7.5) exhibit a good ecological condition. Figure 1 shows the location of river monitoring sites and their condition in the context of Catchment T35 A-E.

A review of the common macroinvertebrate families of the upper Tsitsa River Catchment and their associated habitats with an emphasis on fine sediment accumulation can be found in the report. The following trends were observed and documented in the Tsitsa River. Shallow pool areas and areas of reduced flow are highly embedded with high concentrations of sediment drape and commonly not suitable for many families of macroinvertebrates that prefer some sort of coarse substrate or aquatic vegetation to cling onto. In areas where flow velocity was sufficient to wash away fines (eg. cobble riffles), macroinvertebrate abundance and diversity increased and the river maintained a more natural condition. Macroinvertebrates seek refuge in aquatic and marginal vegetation during highly turbid flows. Presence of vegetation in sites containing fine sediment deposits increased the macroinvertebrate diversity. Lack of vegetation, low flows and depths and high concentrations of fine sediment with a low substrate diversity decreased macorinvertebrate diversity. In rocky habitats in the Tsitsa River, the presence of diverse macroinvertebrate families was found to be mainly affected by substrate diversity. The more diverse the substrate the more habitats are available for colonisation by macroinvertebrate families. However, excessive deposition of fine sediment on the bed of the river decreased the substrate diversity and available habitats, in turn reducing the number of macroinvertebrate families present that were sensitive to sediment drape and in some cases increasing the number of less sensitive families. In habitats dominated by fines macroinvertebrate families that were less sensitive to fine sediment drape become more abundant. In patches where fine sediment accumulation was excessive, such as on thick silt deposits, macroinvertebrate abundance was observed to decrease. Excessive sedimentation in a river system has a direct impact on various aquatic trophic levels. Macroinvertebrates that naturally occur in rocky habitats decreased in abundance with an increase in fine sediment accumulation, due to a reduction of habitats through the filling of interstitial spaces and rocky substrates becoming draped by fine sediment. Macroinvertebrates that naturally occur in sandy habitats and crawl along substrate or are air breathers, diving in the water column or thriving on the surface of the water, are less affected and are possibly benefited by an increase in fine sediment accumulation.

Terrestrial Biophysical Monitoring:

Land cover/use, landscape connectivity and ecosystems have been mapped using a combination of medium-resolution satellite imagery, higher-resolution aerial imagery and field verification (Huchzermeyer *et al*., 2018a; Huchzermeyer, *et al*., 2018b & Schlegel *et al*., 2018a). A base-line map, classifying land cover at a catchment-scale, of the catchment was generated. Mapping of these ecosystem components will be mapped on a ≥ 5 yearly interval. These datasets are used by catchment managers for integrated planning and prioritisation.

Landscape connectivity over the past 100 years has been enhanced by the formation of gullies, livestock tracks and roads (Van der Waal & Rowntree, 2017). The downslope and across slope connectivity is monitored by mapping connectivity features such as gullies, livestock paths, and roads and calculating a percentage increase or decrease in connectivity. Cross-slope or horizontal drainage features such as roads, jeep tracks and livestock tracks drain, concentrate and route overland flow directly into drainage networks, preventing water infiltration and sediment storage. Livestock tracks were by far the most dense and extensive, whereas main roads were high in urban centres, but limited in spatial extent. Down-slope connecters, such as gullies are not as widespread throughout the catchment, but are very effective at draining areas that can store sediment (low angled slopes) and routing sediment to the larger channels. Increases in hydrological and sediment connectivity were largest around villages on communal land.

Snyman (2019) is using LANDSAT imagery to extract burn scars in Catchment T35 A-E. A time-series analysis is being used to calculate fire frequency and MODIS/VIIRS point data is used to monitor the timing and intensity of fires. This data can then be used to help interpret catchment processes and aid management interventions. Preliminary findings show that:

- there is a decrease in the area of fire scars over the past 30 years,
- fire scars are larger in the upper catchment and smaller in the middle and lower catchment, especially in the traditional council areas,
- fire frequency is highest in the upper catchment,
- fire intensity is highest in the upper catchment.

Veld Condition Assessment:

The Tsitsa river catchment vegetation is dominated by grassland (Mucina & Rutherford, 2006). Grasslands are an important resource for the people living within the catchment. However, grasslands in the Tsitsa Catchment are characterised by many symptoms of veld degradation with the most prominent being large-scale and severe erosion and the encroachment of alien vegetation.

One of the driving forces behind this degradation is the lack of grazing and fire management systems. To assess the current veld condition, veld monitoring sites were chosen that represent different land-use areas, geology, elevations and vegetation types. Phase 1 of the veld condition assessment is focused in the traditional council areas. A total of 8 sites were chosen for monitoring. This report unpacks the veld condition for each site and includes dominant grass species, biomass, veld condition and grazing capacity Sites classified as having a very poor veld condition (Site 4 & 8) occur on abandoned cultivated lands were the soil structure has been previously disturbed and not given enough time to recover. These sites are heavily utilized and have low biomass values (> 960 $kg.ha^{-1}$) and only poor grazing grass species are present with large areas of bare ground. These sites are also located on the mudstones of the Elliot and Molteno geological formation. These mudstones are highly erodible particularly when the vegetation cover is inhibited.

Sites classified as having a poor veld condition (Site 1, 2, 5 & 6) are heavily grazed with biomass ranging from 1 000-2 000 $kg.ha^{-1}$. Higher biomass values are present because the sites are located in lower gradient areas where water accumulates stimulating plant growth (e.g. close to wetlands, on alluvial deposits next to rivers or mid-slopes). There is less bare ground visible than in the sites classified as having a very poor veld condition.

Two sites were classified as having a moderate veld condition (Site 3 & 7). Site 3 is located in a managed grazing camp on a private farm and exhibits grasses that provide good grazing despite lower levels of grass biomass than other sites (1 592 $kg.ha^{-1}$). Site 5 is located on a valley bottom close to a wetland and exhibits the highest biomass of all the sites (2 667 $kg.ha^{-1}$). Both sites exhibit good grass cover with minimal bare ground and occur at altitudes of greater than 1 350 meters above sea level.

Biomass readings of 4 000 kg.ha-1 or more exhibit high biomass and only then would they benefit from a prescribed burning. Many of the sites are nowhere near this goal for biomass requiring up to 4.5 times the amount of biomass before pre-scribed burning should be considered. Overgrazing is commonly not a function of intensity but rather a function of frequency. Because the catchment is dominated by mudstones that are highly erodible it is important to maintain healthy vegetation cover throughout the catchment. All the sites would benefit by prolonged rest periods to allow for the stabilization of grass and other important plant population through re-growth and full seed production.

Wetland Monitoring:

Over 2 800 wetlands were identified covering a total area of over 7 600 ha, ranging from larger valley bottom wetlands to smaller hillslope seep wetlands (Schlegel *et al.,* 2018). A range of wetlands (7 sites) was chosen to investigate their current condition, species composition and look at their effectiveness as sediment buffers in the landscape at a course scale. Most of the investigated wetlands were found to be in a good to fair condition and are acting as important sediment sinks in the landscapes. The biggest risks to the wetlands are alien vegetation, erosion at the toe of the wetlands and potential incision of drainage lines that will reduce the buffering function of the wetland floodplain and enter the main river channels directly.

Forests (Huchzermeyer *et al.,* 2018a)

Indigenous vegetation (both forests and other smaller woody species) are important **biodiversity hot spots** that also provide a variety of building materials and are important for cultural (fighting sticks and bark for medicine) and spiritual values (Geldenhuys *et al.,* 2016; Ngwenya, 2016). The indigenous forests occur in fire shadow areas of ravines and steep south facing slopes that are commonly protected by cliffs. Assessments of forests pointed to a healthy population structure, but fire and alien pressures do threaten the outer limits of the forests (Geldenhuys *et al.* 2016). Restoration and management are needed to improve the quality and sustainability of indigenous forests.

Alien Vegetation (Huchzermeyer *et al.,* 2018a; Huchzermeyer *et al.,* 2019a)

Alien plant species are those species that are considered non-indigenous to an ecosystem. South Africa has a long history of problems with Invasive Alien Plants (IAPs) and corresponding research and management of biological invasions.

A total of 37 dominant alien woody species were identified in Catchment T35 A-E of which 7 species (silver wattle, black wattle, green wattle, poplar, eucalyptus, pine and Mauritius thorn) are invading hillslopes, riparian zones and indigenous vegetation on a large scale. Approximately 51% of the area covered by alien woody vegetation occurs on hillslopes, 43% in the riparian zones and the remaining 6% are spreading from drainage lines, plantations, gardens and woodlots. 56% of the alien vegetation category was verified in the field. From the alien vegetation category verified in the field only 3% was noted to be actively used and harvested to such an extent that it was no longer spreading. This is particularly evident within close walking distance of villages.

The main alien species in Catchment T35 A-E can be detailed as follows:

- **Silver wattle:** A total of 6 955 patches (uncondensed area of 5 502 ha). Of those 3 671 (3 326 ha) of the patches consist of 50 percent and above Silver wattle.
- **Black wattle:** A total of 280 patches (uncondensed area of 262 ha). Of those, 246 (239 ha) of the patches consist of 50 percent and above Black wattle.
- **Green wattle:** A total of 441 patches (uncondensed area of 222 ha). Of those, 243 (97 ha) of the patches consist of 50 percent and above Green wattle.
- **Black and Green wattle co-existing:** A total of 6 675 patches (uncondensed area of 5 398 ha).
- **Mauritius thorn:** A total of 60 patches (uncondensed area of 3.8 ha). However, there might be a higher abundance as they are difficult to identify off aerial photographs and commonly occur in drainage lines and gullies where remote sensing techniques are limited.
- **Eucalyptus species:** A total of 1 028 patches (uncondensed area of 1 293 ha) occur outside of the plantation areas. Of those, 331 (343 ha) of the patches consist of 50 percent and above Eucalyptus species.
- **Pine species:** There are a total of 228 patches (uncondensed area of 137 ha) occur outside of the plantation areas. Of those, 39 (21 ha) of the patches consist of 50 percent and above Pine species.

- **Poplar species:** A total of 917 patches (uncondensed area of 1 099 ha). Of those 190 (160 ha) of the patches consist of 50 percent and above of Poplar species.

Data management:

The Tsitsa Project Biophysical Monitoring Group is a steward of the data that is a product from our inventory and monitoring work in the Tsitsa River Catchment. While this information is useful and crucial today, it will become even more valuable in the years and decades to come. From planning, to field work, and through to analysis, priorities are placed on:

- Data Accuracy.

  The quality of the biophysical data we collect is paramount. Analyses to detect trends or patterns require data with minimal error and bias.

- Data Security.

  Data is protected against loss.

- Data Longevity.

  Data sets need to be cared for. Processing documentation will accompany all data sets.

- Data Accessibility.

  Data will be made available in a variety of formats to any interested and affected stakeholders through the TP knowledge hub.

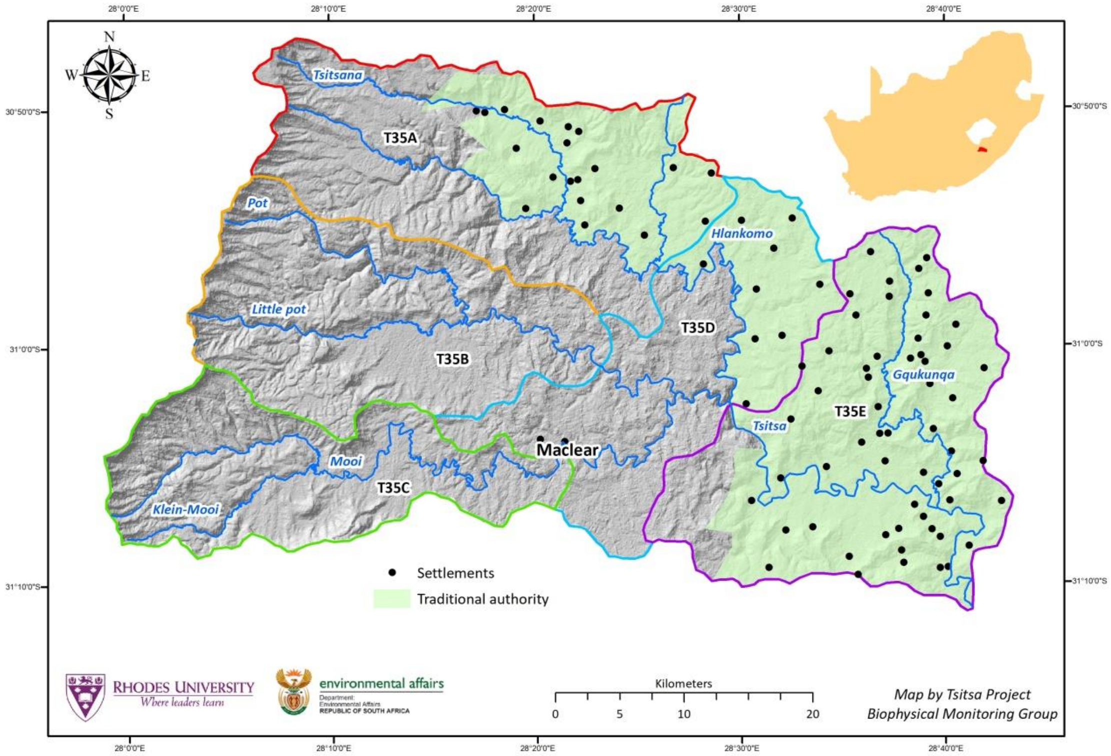
- Student data collection warrants an embargo period in which a full dataset cannot be shared until the student has published and released their data.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. UPPER TSITSA RIVER CATCHMENT AT A GLANCE



The upper Tsitsa River Catchment (T35 A-E) is in the Eastern Cape province of South Africa. The catchment receives summer rainfall and is characterised by steep topography, with the prominent Drakensburg Escarpment forming the headwaters, followed by a second smaller escarpment in the lower catchment. Soils become increasingly more erodible as you move down the catchment, evidenced by the formation of large gullies.

AREA

~200 000 ha
(Catchments T35 A-E)

POPULATION

~45 000 Residents

MAIN LAND COVER/ USE for 2011

72% Grasslands
7% Cultivation
7% Plantations
4% Thicket/shrubland
3% Urban areas
2% Wetlands
2% Woodland
3% Other

INTERVENTION AREA

~76 000 ha Traditional councils

~124 000 ha Private land

2. BIOPHYSICAL MONITORING IN THE UPPER TSITSA CATCHMENT (SCHLEGEL *ET AL.*, 2019)

The Tsitsa Project strives to restore functional landscapes to the benefits of local and downstream users. It prioritises its limited resources for the maintenance of functioning, but threatened, ecological infrastructure over severely degraded systems. The Tsitsa Project is currently doing restoration work in Quaternary Catchment T35 A-E. This targets the upper Tsitsa River catchment and is the current focus area for the biophysical monitoring. The aim is to better understand the physical processes at play under different land use scenarios currently existing in the landscape and those introduced by restoration and management efforts in order to guide effective restoration.

2.1. Management objectives

The Tsitsa Project vision is:

"To support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services."

As such the broad management objectives for the Tsitsa Project are:

- Minimise land degradation and erosion risk.
- Maintain or/and increase land productivity.
- Maximise forage production for livestock.
- Improve water quality and quantity.
- Maintain or improve ecosystem services and ecological infrastructure.

2.2. Monitoring objectives

Monitoring is used to evaluate the current state of ecological infrastructure as well as the effects of management on the condition of ecological infrastructure. The following monitoring objectives have been preliminary chosen for the Tsitsa Project (Schlegel *et al.*, 2019):

- Compare baseline conditions of areas that are using different management approaches e.g. grazing and fire.
- Monitor how different management systems affect the condition of ecological infrastructure over time.
- Monitor changes in the landscape as a whole because of natural biophysical conditions (e.g. climate, pests, disasters etc.)

2.3. Indicators and measured variables

The Tsitsa Project Biophysical Monitoring Group's selection of the catchment indicators began with a review (Schlegel *et al.,* 2019) of existing monitoring plans and programs from around the world (e.g. Northern Colorado Plateau Inventory and Monitoring Network; Vital Signs Monitoring Plan; U.S National Park Service; Action Against Desertification; FAO United Nations etc.). This review provided a list of catchment biophysical indicators that are used in similar situations elsewhere. The review resulted in relevant indicators that could be summarized along the following themes (Figure 2):

- Climate (Rainfall);
- Land/Terrestrial systems: Terrestrial ecosystems, land cover and land use, which included indicators of changing land use/land cover, fire dynamics, and important ecosystems such as grasslands, forests, riparian vegetation and wetlands, as well as alien vegetation; and
- Water systems, which included indicators of hydrology, water quality and aquatic ecology.

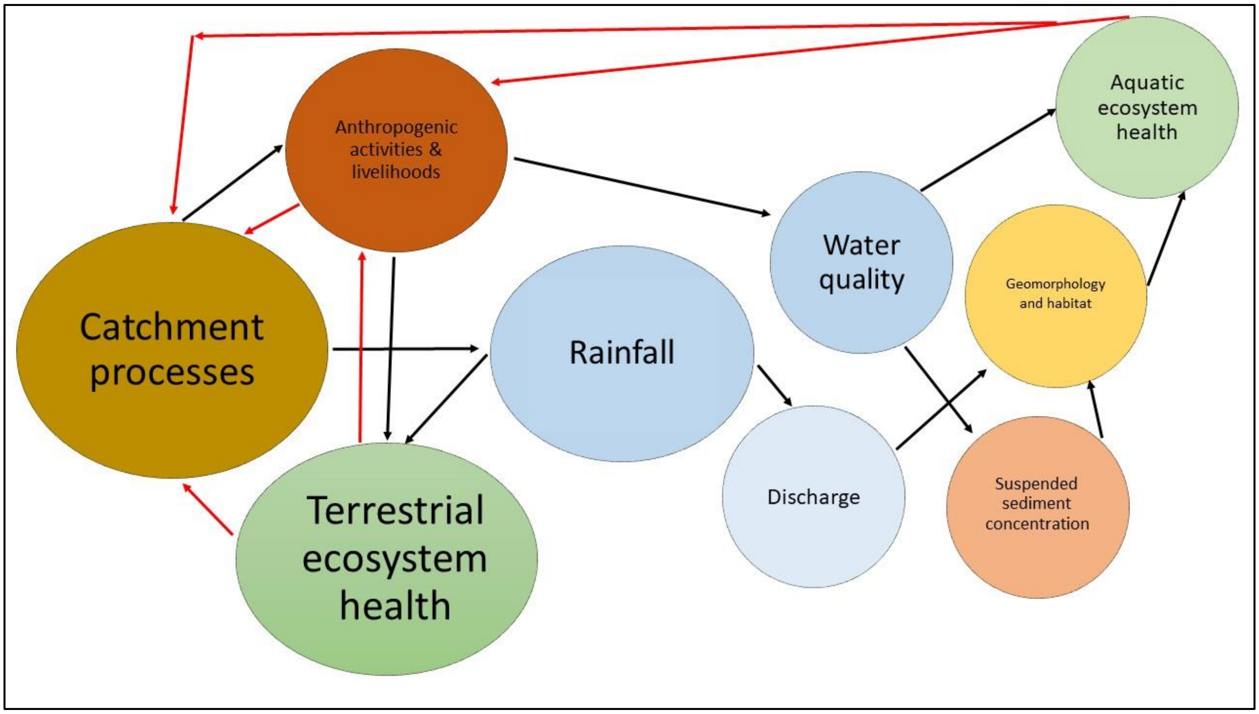


FIGURE 2: MONITORING FRAMEWORK SHOWING THE LINKS BETWEEN CATCHMENT PROCESSES

Table 1 shows indicators and measured variables under different domains and themes that have been adopted for the current biophysical monitoring in the Tsitsa Catchment.

Variables are measured at different time scales (Table 2). Monitoring of in-depth variables occur on a seasonal basis whereas catchment wide mapping of ecosystems occurs at longer time scales.

This is discussed in more detail in the chapters below.

TABLE 1: TABLE SHOWING INDICATORS AND MEASURED VARIABLES UNDER DIFFERENT DOMAINS AND THEMES

Theme	Domain	Indicators	Measured variables
Climate	Regional rainfall	Rainfall trend over time	Rainfall (mm)
Land	Geomorphology	Hillslope features and processes	Connectivity (m/ha) Erosion (m^3) Gully expansion (%)
	Terrestrial ecosystems	Fire dynamics	Fire frequency, location, intensity, extent, severity (% or ha)
		Grasslands	Condition, species composition, grazing value
		Forests	Extent (% or ha)
		Riparian zones	Extent, composition, condition (% or ha) VEGRAI assessment
		Wetlands	Size, type, location, condition, dominant species (% or ha)
		Alien vegetation	Extent, composition, density, age (% or ha)
Water	River ecosystems	Hydrology	Base flow monitoring ($m^3.s^{-1}$) Flood peaks ($m^3.s^{-1}$)
		Water quality	pH; Electrical conductivity; Temperature; Dissolved Oxygen; Nitrates; Phosphates; Turbidity; Clarity; Suspended Sediment Concentration (mg/l^{-1})
		Aquatic macroinvertebrates	SASSv5 assessment
		River channel characteristics	Classification of river channel

Table 2: Breakdown of monitoring strategy

	Rainfall	Terrestrial Ecosystems							River Ecosystems		
	Tip-bucket rain gauges	Hillslope features and processes	Fire Dynamics	Grassland condition	Forests	Riparian zones	Wetlands	Alien vegetation	Hydrology	Water Quality	Channel classification
Dry season monitoring			■							■	■
Wet season monitoring				■		■	■			■	
Continuous data collection	■								■	■	
≥ 5 Yearly mapping		■	■		■	■	■	■			■

3. OVERALL MONITORING LOCATIONS

Current monitoring sites are indicated in (Figure 3) and coordinates are given in Table 3 . GIS shapefiles and Google Earth .kml layers can be made available on request.

Sites were adapted from previous studies (e.g. Huchzermeyer, 2017; Bannatyne, 2018; Nyamela, 2018) where the data already collected is invaluable for the biophysical monitoring. In addition new sites were chosen (veld monitoring and wetlands monitoring). Sites are discussed in more detail in the sections below.

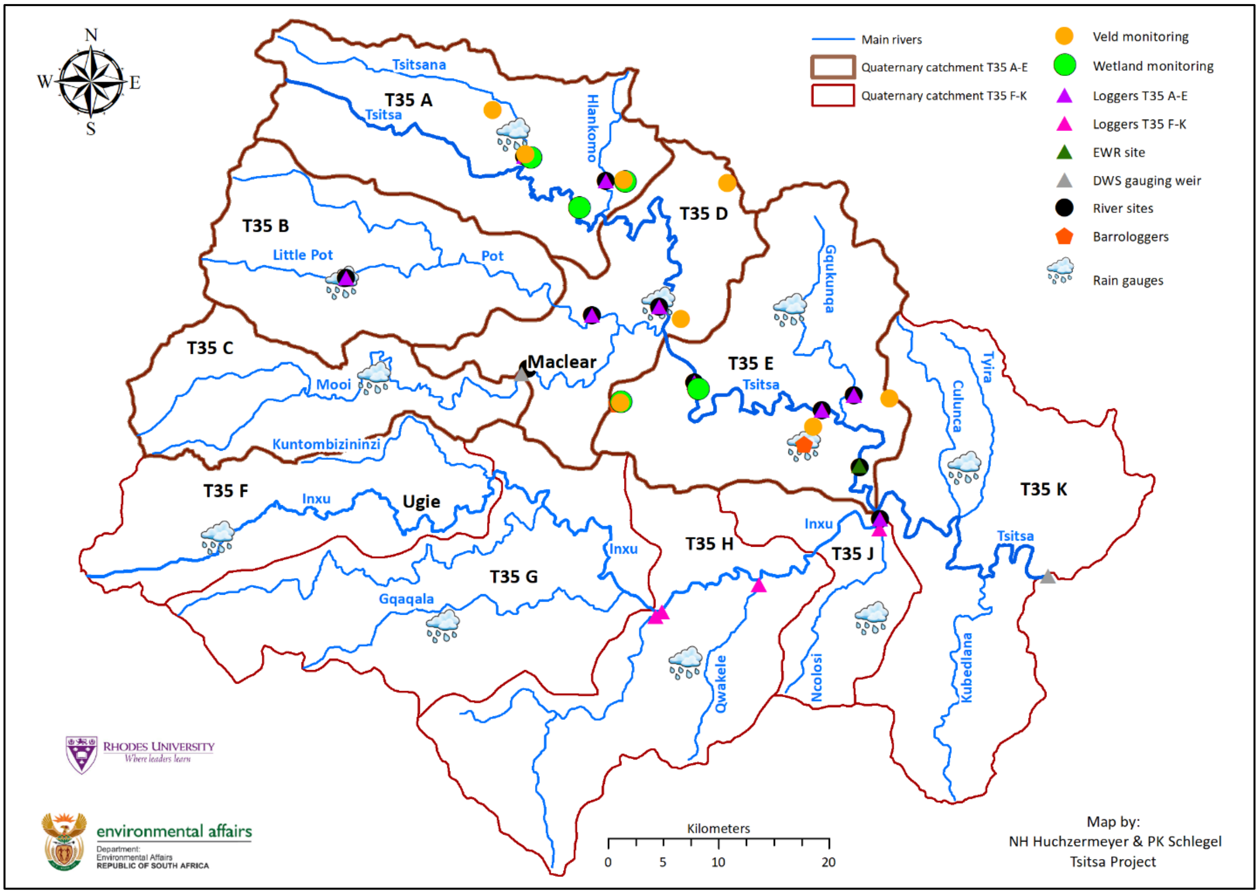


FIGURE 3: CURRENT MONITORING LOCATIONS IN THE TSITSA RIVER CATCHMENT.

TABLE 3: TABLES SHOWING SITE COORDINATES FOR BIOPHYSICAL MONITORING

	Raingauges	
Quaternary Catchment	**Site name**	**Coordinates**
T35 A	Tsitsana	30°52'35,637"S 28°20'49,83"E
T35 B	Woodcliffe	30°59'46,764"S 28°11'2,851"E
T35 C	Mooi/PG Bison	31°4'28,345"S 28°12'49,763"E
T35 D	Tsitsa Falls	30°52'35,637"S 28°20'49,83"E
T35 E	Sinxaku	31°7'49,957"S 28°37'14,8"E
T35 E	Gqunqunka	31°1'14,822"S 28°36'29,546"E
T35 F	Morvan	31°8'58,61"S 28°46'23,176"E
T35 G	Montgomery	31°8'58,61"S 28°46'23,176"E
T35 H	Mposa/Mphele	31°18'29,535"S 28°30'27,211"E
T35 J	Ntsiqo/Nosandise	31°16'21,1"S 28°41'4,781"E
T35 K	Tyirha/Nkosana	31°8'58,61"S 28°46'23,176"E

River Sites					
Quaternary Catchment		**Site name**	**Coordinates**	**Current biomonitoring site**	**Depth logger present**
Catchment T35 A-E	T35 A	Tsitsana (Ta)	30°53'39,079"S 28°21'27,655"E	Yes	Yes
	T35 A	Hlankomo (H)	30°54'53,554"S 28°26'5,285"E	Yes	Yes
	T35 B	Little Pot (LP)	30°59'33,426"S 28°11'16,404"E	Yes	Yes
	T35 C	Mooi Gauging Weir (T3H009)	31°4'17,951"S 28°21'12,944"E	No	Yes
	T35 D	Pot (P)	31°1'27,413"S 28°25'14,975"E	Yes	Yes
	T35 D	Mooi (M)	31°4'56,623"S 28°22'31,692"E	Yes	No
	T35 D	Tsitsa 4 (T4)	31°1'3,516"S 28°29'3,691"E	Yes	Yes
	T35 E	Tsitsa (T3)	31°4'46,461"S 28°31'3,371"E	Yes	Yes
	T35 E	Gqunqunka (G)	31°5'25,075"S 28°40'7,227"E	Yes	Yes
	T35 E	Tsitsa 2 (T2)	31°6'9,711"S 28°38'17,933"E	Yes	Yes

	T35 E	Tsitsa EWR (N3)	31°8'51,776"S 28°40'24,946"E	Yes	Yes
Catchment T35 F-K	T35 J	Inxu	31°11'28,447"S 28°41'35,739"E	Yes	Yes
	T35 J	T35 F-K_1	31°11'59,542"S 28°41'32,688"E	No	Yes
	T35 H	T35 F-K_2	31°14'40,635"S 28°34'40,968"E	No	Yes
	T35 H	T35 F-K_3	31°15'59,122"S 28°29'9,101"E	No	No
	T35 H	T35 F-K_4	31°16'12,964"S 28°28'46,475"E	No	Yes
	T35 K	Tsitsa Gauging Weir (TN2/T3H006)	31°14'17,033"S 28°51'7,962"E	No	Yes

Veld monitoring site

Quaternary Catchment	**Site name**	**Coordinates**
T35 E	Veld 1	31°6'57,087"S 28°37'48,203"E
T35 E	Veld 2	31°5'35,652"S 28°42'8,88"E
T35 E	Veld 3	31°5'45,254"S 28°26'50,222"E
T35 A	Veld 4	30°51'23,031"S 28°19'39,928"E
T35 A	Veld 5	30°53'33,566"S 28°21'31,205"E
T35 A	Veld 6	30°54'49,959"S 28°27'4,896"E
T35 D	Veld 7	30°54'49,959"S 28°27'4,896"E
T35 D	Veld 8	30°54'49,959"S 28°27'4,896"E

Wetland monitoring site

Quaternary Catchment	**Site name**	**Coordinates**
T35 E	Wetland 1	31°5'6,438"S 28°31'15,131"E
T35 E	Wetland 2	31°5'40,528"S 28°26'52,817"E
T35 A	Wetland 3	30°53'40,266"S 28°21'47,154"E
T35 A	Wetland 4	30°56'18,568"S 28°24'26,736"E
T35 A	Wetland 5	30°54'56,264"S 28°27'20,945"E
T35 D	Wetland 6	30°54'43,458"S 28°33'5,555"E
T35 B	Wetland 7	30°59'57,904"S 28°13'23,335"E

Barologgers

Quaternary Catchment	**Site name**	**Coordinates**
T35 E	Green village	31°7'49,742"S 28°37'17,42"E
T35 D	Bob's Place	31°5'47,628"S 28°26'38,861"E

4. RAINFALL MONITORING

Rainfall is an important driver of catchment processes. A total of 11 self-logging tipping rain gauges are currently managed by the biophysical monitoring team (Figure 4). Of these 6 tipping rain gauges are in Catchment T35 A-E. These were set up in 2015 by Bannatyne (2018). A further 5 rain gauges are in Catchment T35 F-K which were set up in 2016 by Nyamela (2018). The later rain gauges fall out of the current target area for the biophysical monitoring however these are easy to maintain and the data is seen as important to have for when the biomonitoring is expanded to Catchment T35 F-K.

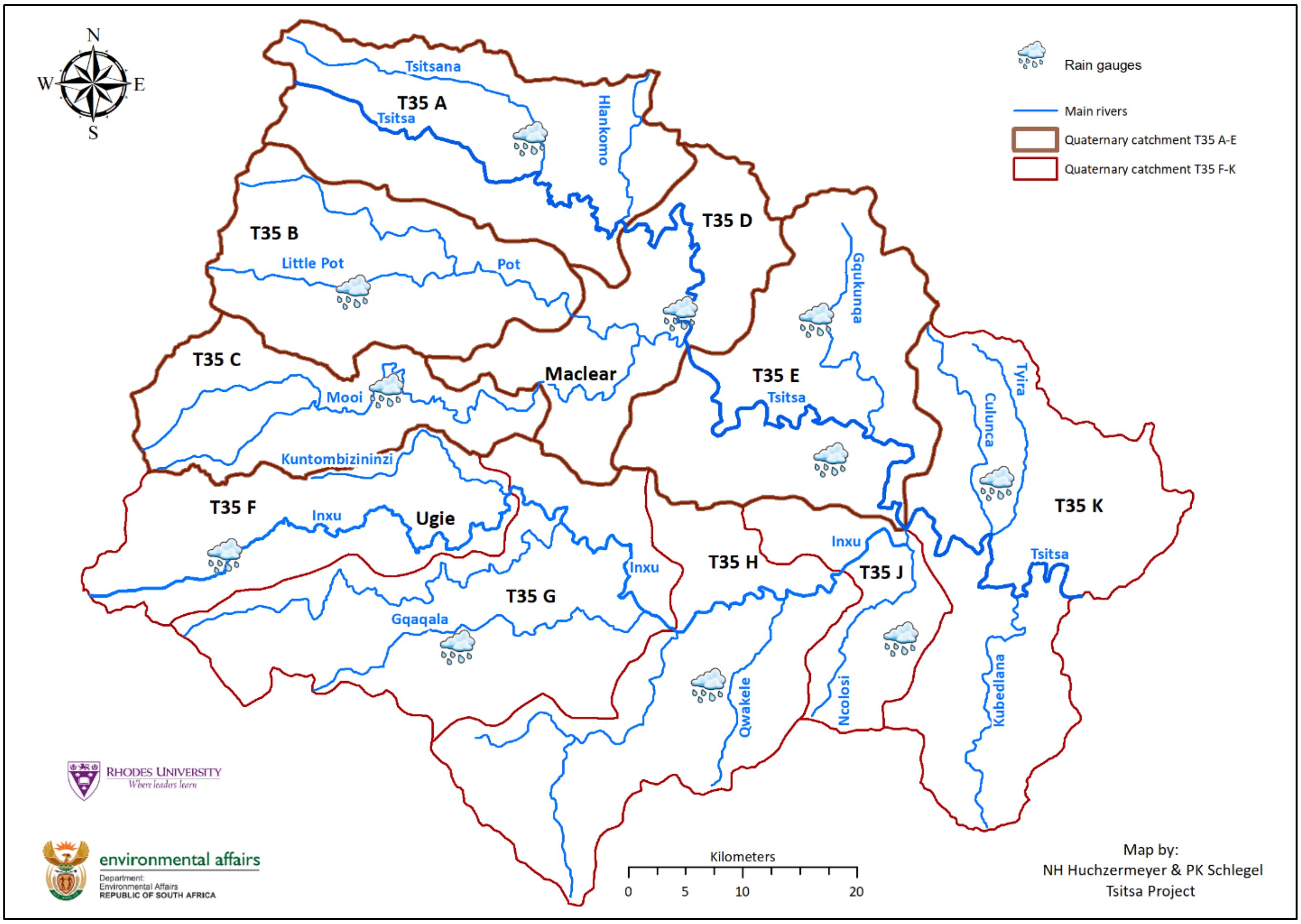


FIGURE 4: LOCATION OF TIPPING BUCKETS COLLECTING RAINFALL DATA IN CATCHMENT T35 A-E AND F-K

The rainfall data is downloaded bi-annually (once before and once after the rainy season). Maintenance of the rain gauges is important to try minimise unforeseen calamities (Table 4). During the bi-annual visit the rain gauges are cleaned and downloaded, batteries are replaced and the data consistency is checked.

TABLE 4: RAIN GAUGE HITCHES 2015-2019

	Rain gauge blocked (date cleaned)	Rain gauge partially blocked (date cleaned)	Stopped logging (month/year)	No issues
T35 A: Tsitsana				
T35 B: Woodcliff	25/01/2017 16/01/2018			
T35 C: Mooi		16/01/2018		
T35 D: Tsitsa Falls	26/01/2017 16/01/2018	23/08/2018		
T35 E: Sinxaku	18/01/2018	21/08/2018	01/2018-08/2018	
T35 E: Gqukunqa				Installed 18/01/2018
T35 F: Morven				
T35 G: Montgomery	25/01/2017 23/08/2018	19/01/2018		
T35 H: Nolutando/Mpele			04/2018-04/2019	
T35 J: Nosandise			12/2017-02/2019	
T35 K: Nkosana			06/2016-12/2016	

The raw data is analysed and set out into a time-series database (available on request) showing the following rainfall data:

- 5 minute,
- 30 minute,
- Hourly,
- Daily,
- Monthly and
- Yearly.

Monthly average rainfall is shown in Figure 5 and Figure 6. Rainfall events in the catchment have increased from 2015.

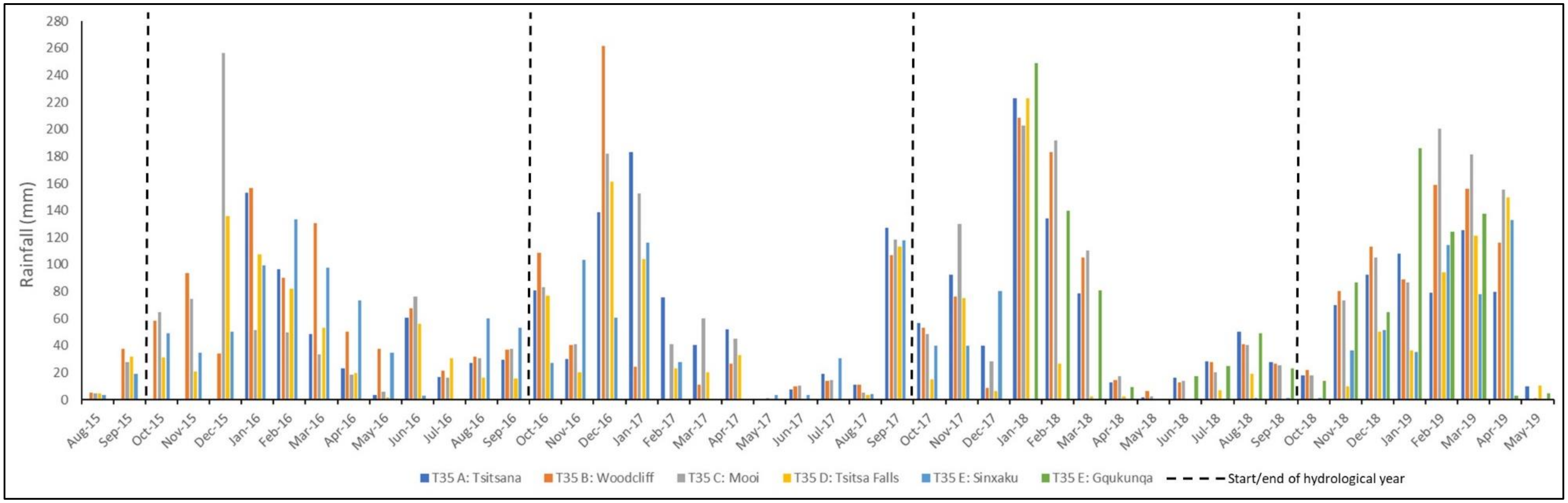


Figure 5: Monthly average rainfall at monitoring sites in Catchment T35 A-E from 2015-2019

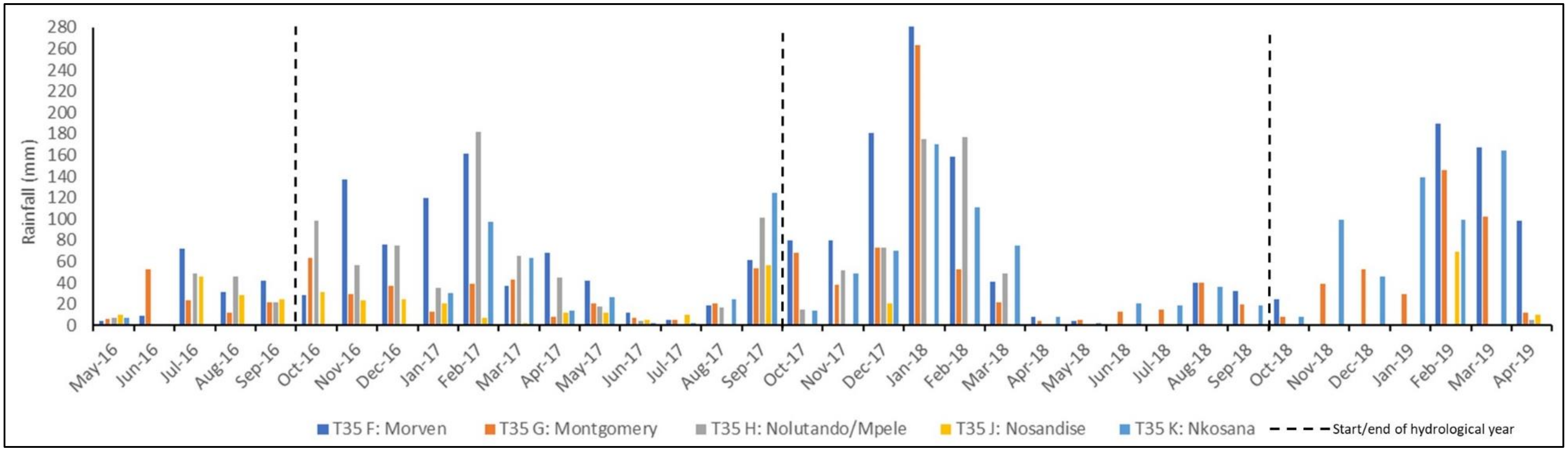


Figure 6: Monthly average rainfall at monitoring sites in Catchment T35 F-K from 2016-2019

The location, magnitude, duration and extent of rainfall plays an important role in the effects of different catchment processes. Therefore, the rainfall data can be used to help aid the interpretation of catchment processes and can be linked to spikes in hydrology, increased sediment yields etc. (Figure 7).

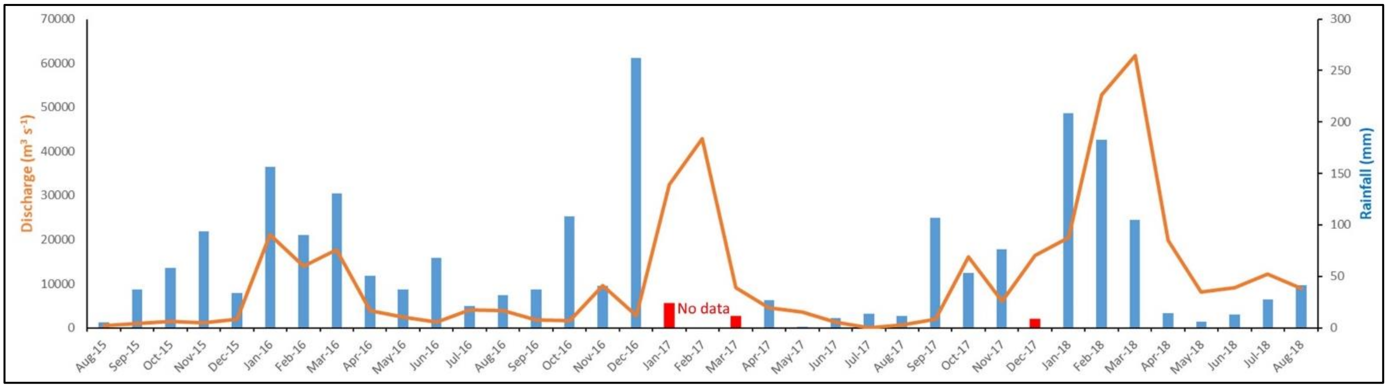


FIGURE 7: TOTAL MONTHLY RAINFALL PLOTTED WITH TOTAL MONTHLY DISCHARGES FOR THE LITTLE POT MONITORING SITES

Table 5 summarises the rainfall trends from 2015-2019. Generally the trend shows higher average rainfall at higher altitudes particularly closer to the Drakensberg escarpment. Rainfall intensity is highest in the North-westerly part of the catchment (Figure 8). Rainfall trends per hydrological year can be found in Appendix 4.

TABLE 5: RAINFALL TRENDS FROM 2015-2019, EXCLUDING DATA WITH ERRORS

	Average total yearly rainfall (mm)	Max monthly rainfall (mm)	Max daily rainfall	Max hourly rainfall	Max 5 minute rainfall
T35 A: Tsitsana	642	223	52	29	14.2
T35 B: Woodcliff	773	262	53	34	13.4
T35 C: Mooi	781	203	48	28	10.8
T35 D: Tsitsa Falls	522	223	47	34	14.6
T35 E: Sinxaku	559	134	52	21	12.0
T35 E: Gqukunqa	609	249	49	29	11.0
T35 F: Morven	772	281	58	29	7.8
T35 G: Montgomery	508	264	50	21	10.8
T35 H: Nolutando/Mpele	620	182	32	27	8
T35 J: Nosandise-	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
T35 K: Nkosana	574	164	64	18	6.2

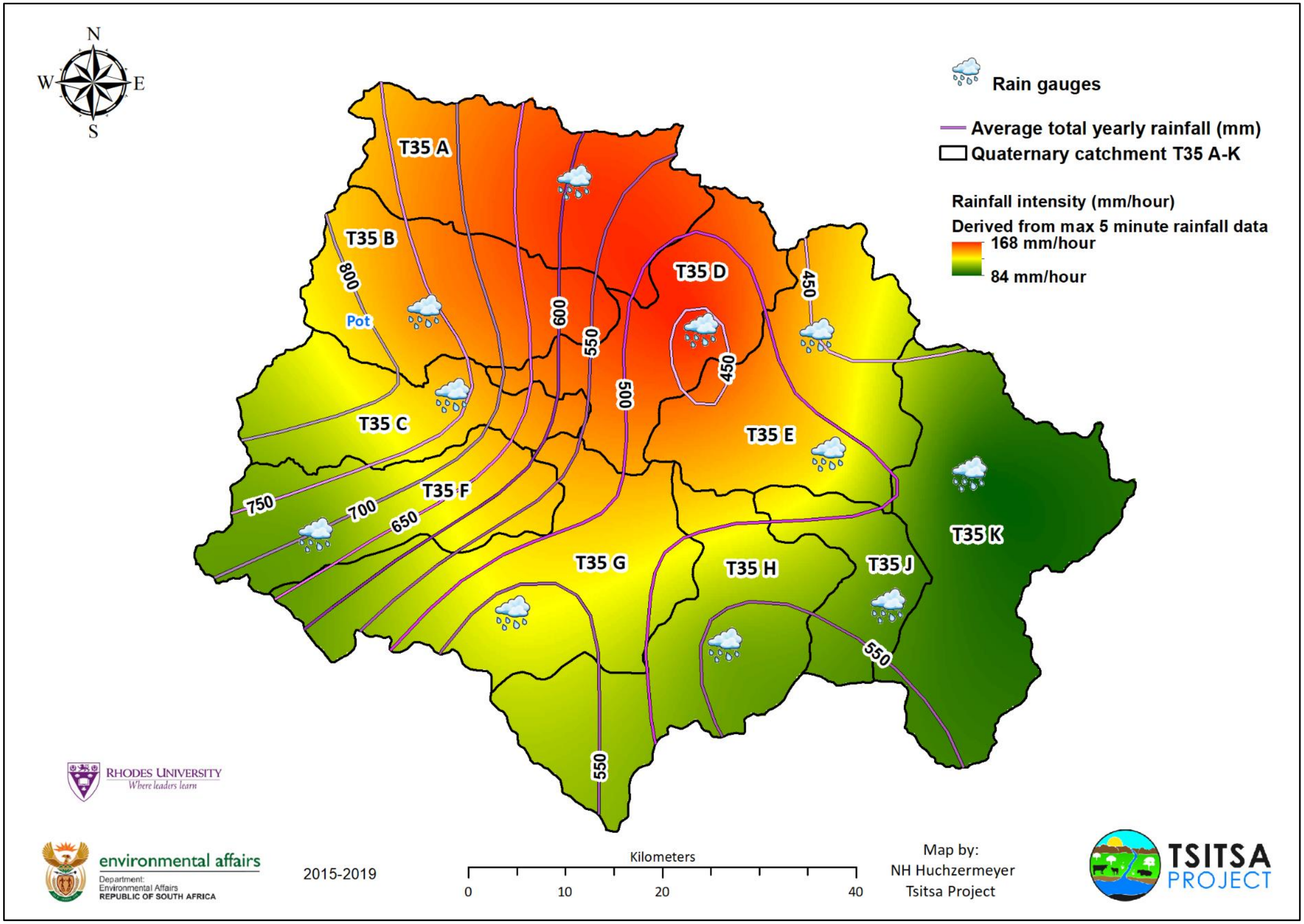


Figure 8: Rainfall intensity and average total yearly rainfall for Catchment T35 A-F for 2015-2019

5. HYDROLOGY AND RIVER MONITORING

The health of rivers is an important indicator of catchment processes. There are currently 11 river monitoring sites in Catchment T35 A-E (Figure 9). Hydrology, water quality and the geomorphic condition (habitat conditions) of the channel are being monitored at these points and are discussed in this chapter.

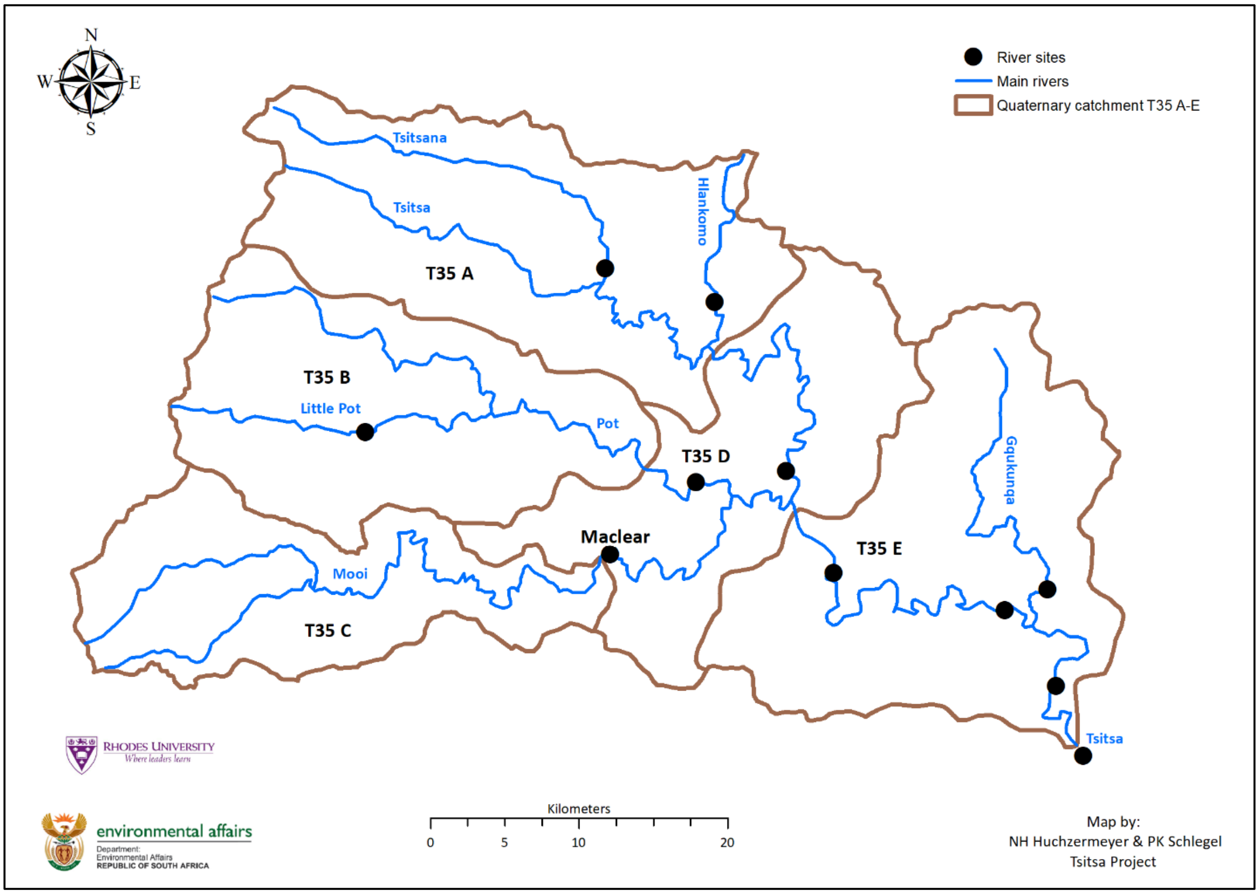


FIGURE 9: RIVER MONITORING SITES IN CATCHMENT T35 A-E

The Tsitsa River originates in the Drakensberg Mountains, in the Great Escarpment geomorphic province, and flows through the South-eastern Coastal Hinterland geomorphic province (Partridge *et al.*, 2010) to its confluence with the Umzimvubu River. Elevations in the area range from ~2 700 m in the Drakensberg in the north-east, to ~600 m towards the confluence with the Umzimvubu (Le Roux et al., 2015). The topography of the study area is steep around the escarpment in the headwaters and middle catchment. The remainder of the landscape is hilly to rolling with v-shaped valleys and limited sediment accommodation space.

Longitudinal profiles give an indication of what hydrological and sediment depositional processes might come into effect at different river reaches (Figure 10 and Figure 11).

The Tsitsa River transitions between a bedrock and mixed bedrock alluvial river. The river long profile is strongly influenced by rock type, where steeper sections form on more resistant bedrock (such as basalt, dolerite) and gentler sections form on sandstones, mudstones and mudrocks (Figure 10).

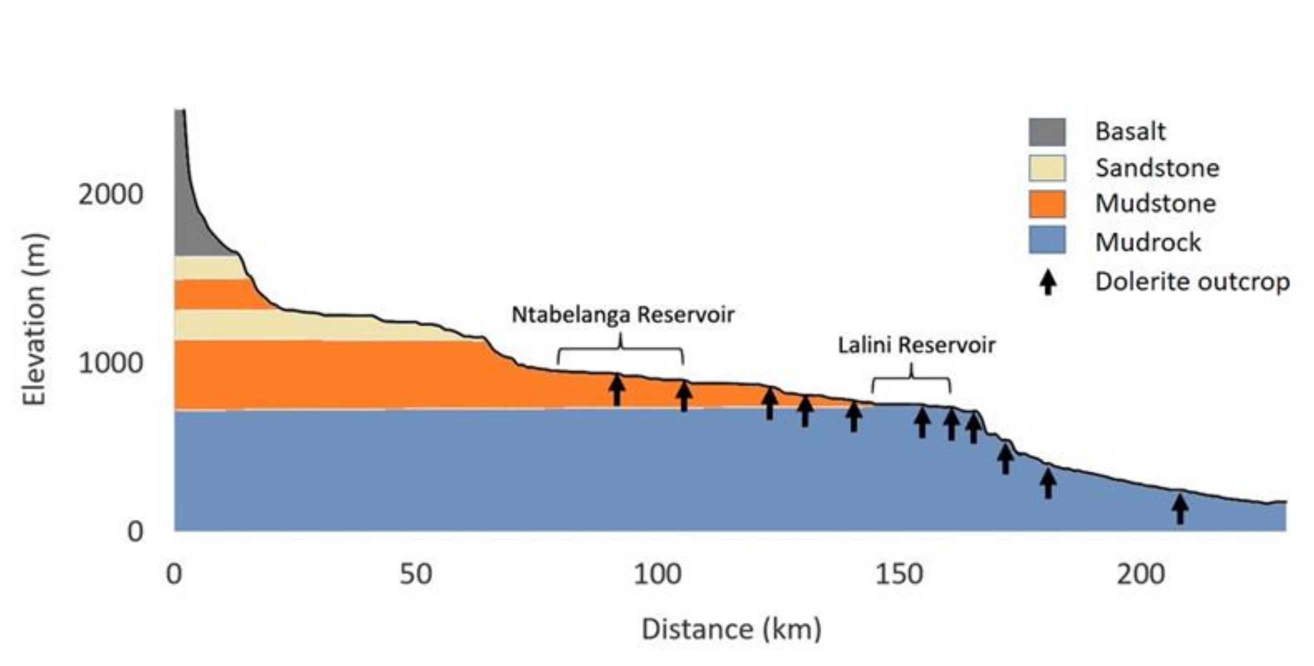


FIGURE 10: LONGITUDINAL PROFILE OF THE GREATER TSITSA RIVER SHOWING GENERALISED ROCK TYPES

Along the steeper escarpment zones (upper reaches of the Tsitsa River and its tributaries) the river beds have steep gradients and are dominated by bedrock with rapids, riffles and waterfalls. The upper reaches commonly have input of coarse material from the surrounding hillslopes. Very little fine sediment is deposited in these high energy areas. Hillslope seep wetlands are common in these areas and feed into the river systems. The mid- reaches are characterised by a reduction in gradient as the rivers reach the foot slopes of the escarpment. The lower gradient results in reduced flow velocities. These gentler sections of the river profile are dominated by a mixed alluvial/bedrock river, typically with a sandy bed except where dolerite dykes or sills are evident. Instream vegetation is generally absent, with riparian vegetation dominated by alien invader tree species. In many places, channels are deeply to very deeply incised in the alluvial plains, and may be locally characterised by flood benches, meanders and ox-bow lakes. In the mid-reaches there is an area of rejuvenation where many of the rivers pass over a waterfall and into a steep gorge. Below the Tsitsa waterfall, the Tsitsa River passes through a deep and largely inaccessible gorge as it crosses the middle escarpment. The Mooi River, having been joined by the Pot River, converges with the Tsitsa River within this gorge. Sediment is mobilised in these areas as the gradient becomes steeper and flow velocities faster. Bedrock and cobble riffles and rapids are common in this part of the river reaches. After the gorge in the lower reaches of the rivers the gradient becomes very low. Additional sediment input from tributaries increases the amount of accumulated deposited sediment and reduces habitat health.

Appendix 5 shows the river specific long profiles and the relation of monitoring sites to the river reaches described above.

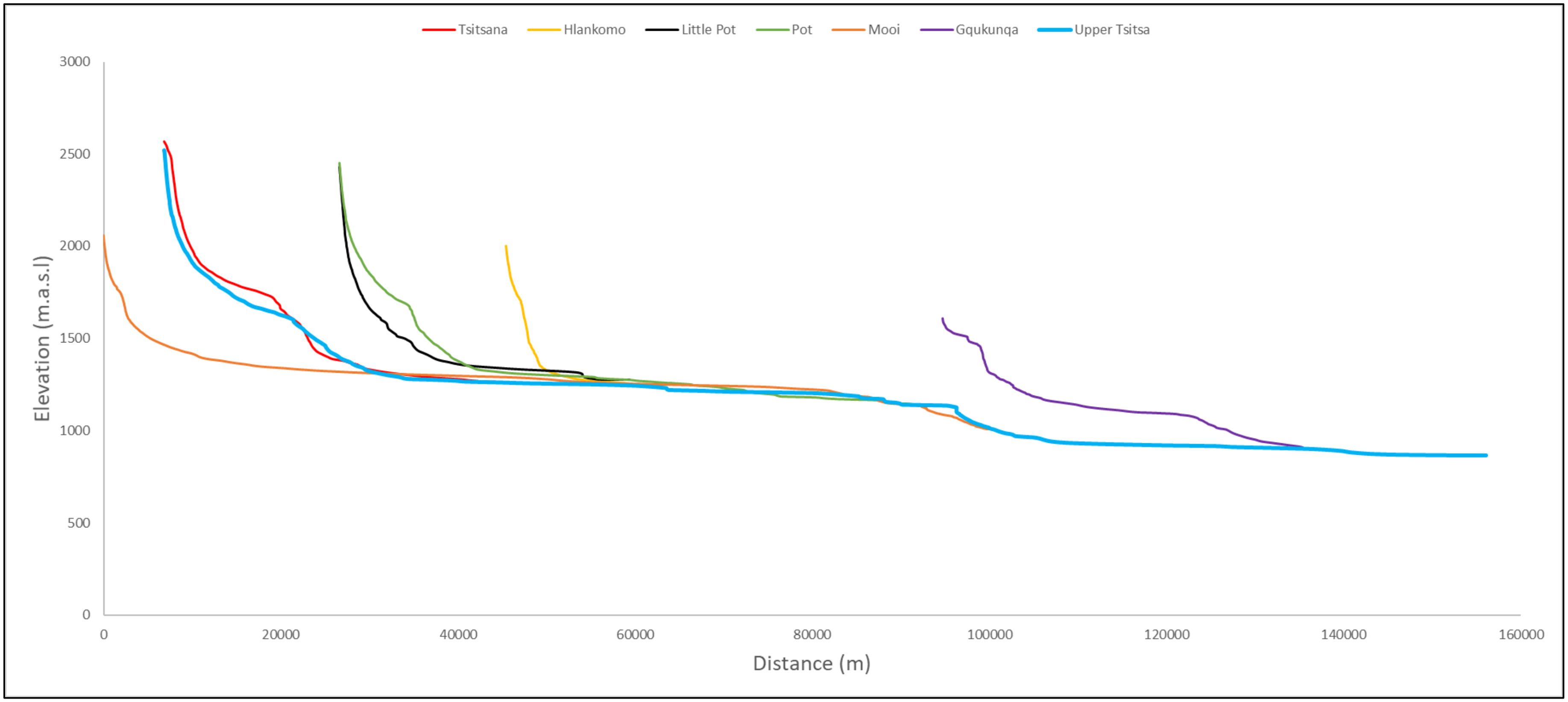


FIGURE 11: LONGITUDINAL PROFILES OF THE MAIN RIVERS IN CATCHMENT T35 A-E

5.1. Hydrology

Hydrographs can be separated into two main components (Gordon *et al*., 2004). The first component is *baseflow* which can be defined as the volume of water representing the groundwater contribution. The second component is *direct runoff* and is defined as the volume of water produced from rainfall and snowmelt events (discharge). By monitoring the hydrology at specific monitoring point's, trends in baseflow and direct runoff can be picked up over time. These are important indicators of catchment processes above each monitoring point.

Baseflow modelling

Solinst level loggers installed at each site are used to collect continuous data on variations in depth (water pressure above the logger) and temperature (Figure 12). Currently 9 depth loggers are situated in Catchment T35 A-E. A further 4 depth loggers are maintained in Catchment T35 F-K.

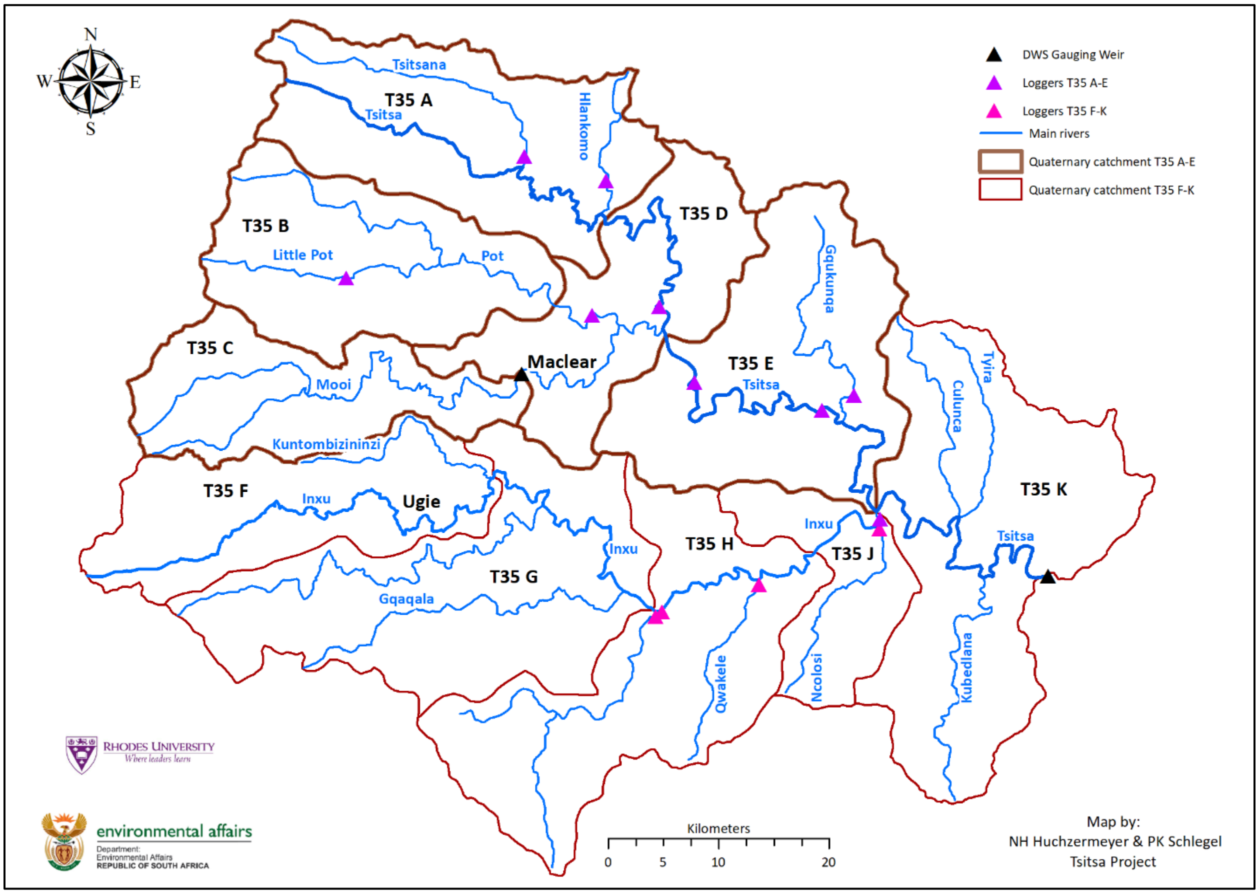


FIGURE 12: LOCATION OF DEPTH LOGGERS AND NATIONAL GAUGING WEIRS ON THE MAIN RIVERS IN CATCHMENT T35 A-K

Within Catchment T35 A-E two barologgers are measuring air pressure at different elevation ranges (Figure 13). These are used to compensate for atmospheric pressure fluctuations when measuring water level with the depth loggers. Two barollogers are installed in the catchment each within a 30 km radius and 300 meter change in elevation from a levellogger.

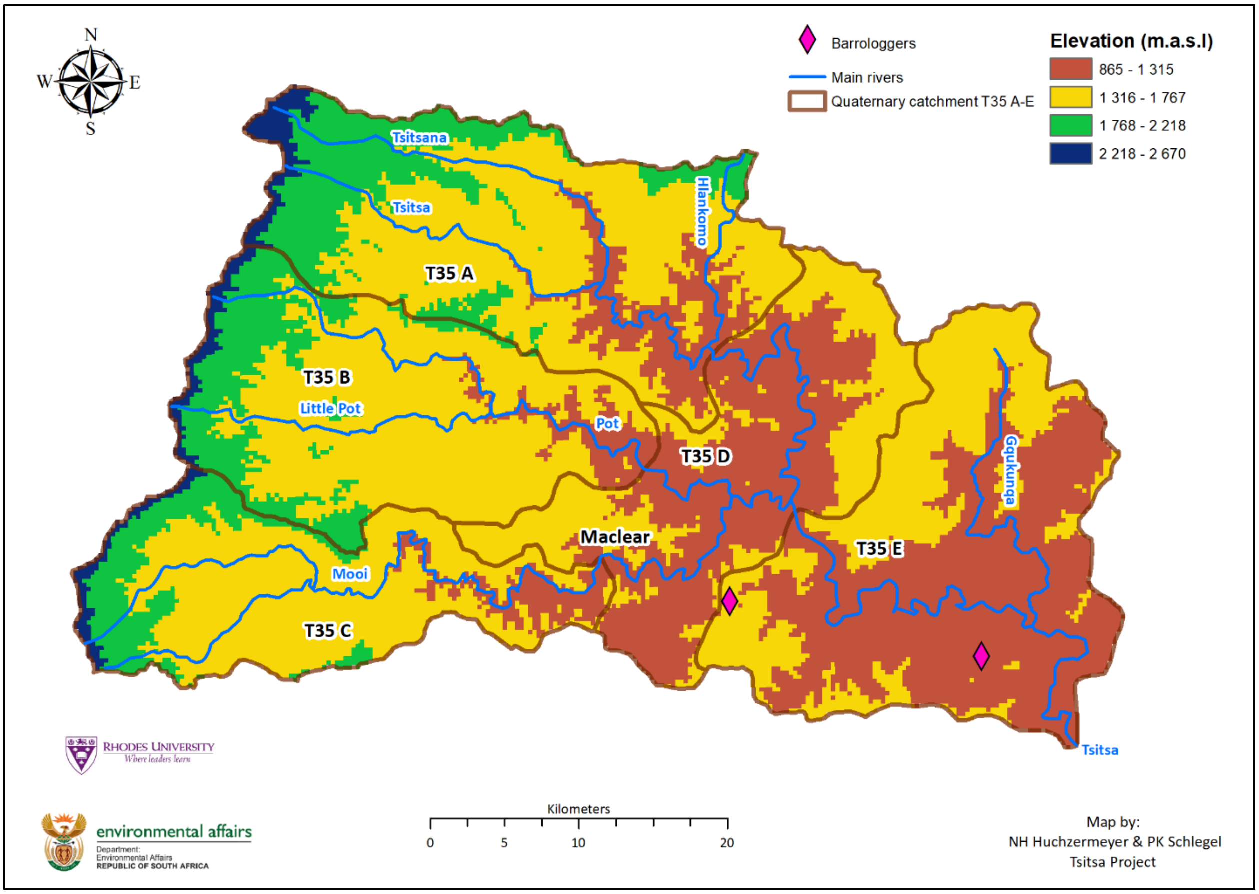
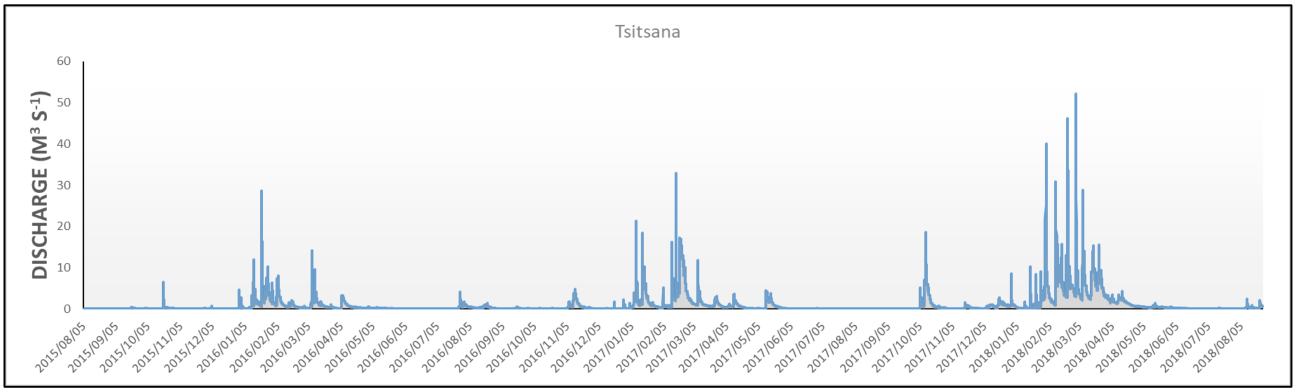


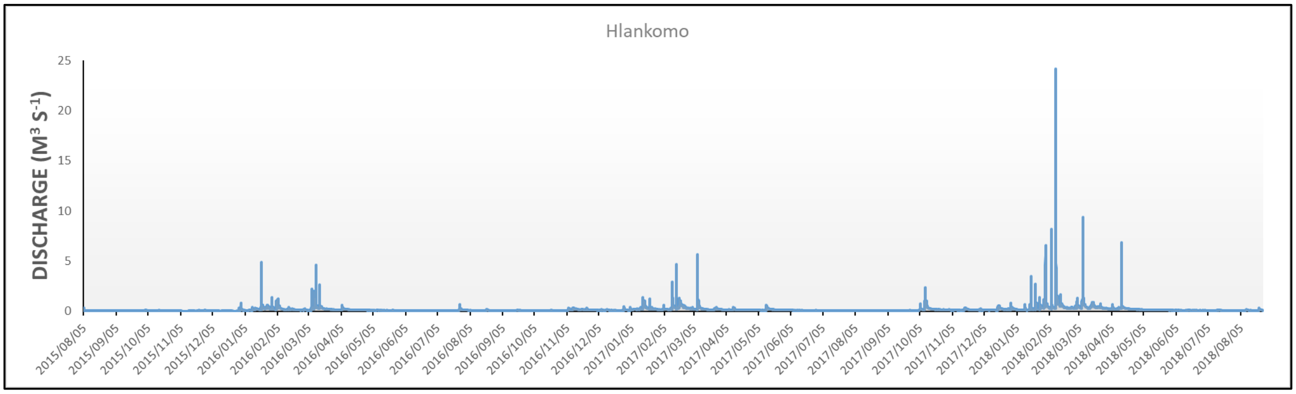
FIGURE 13: LOCATION OF BAROMETRIC LOGGERS IN CATCHMENT T35 A-E

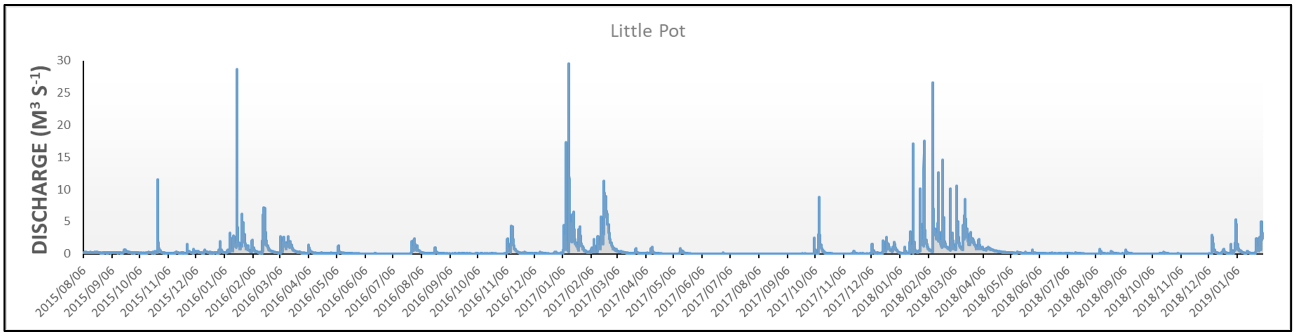
Seasonally measured discharges and known depths to the level loggers on the bed of the river were used to create rating curves for each monitoring site. These rating curves are continuously being updated as new depths and discharges are measured in the field. These can be made available .xlsx (Microsoft Excel) format on request. Very high discharges are estimated using the Manning's equation and cross-sectional profiles over the loggers. It is important to note that the rating curves will be updated once higher discharges have been measured in the field.

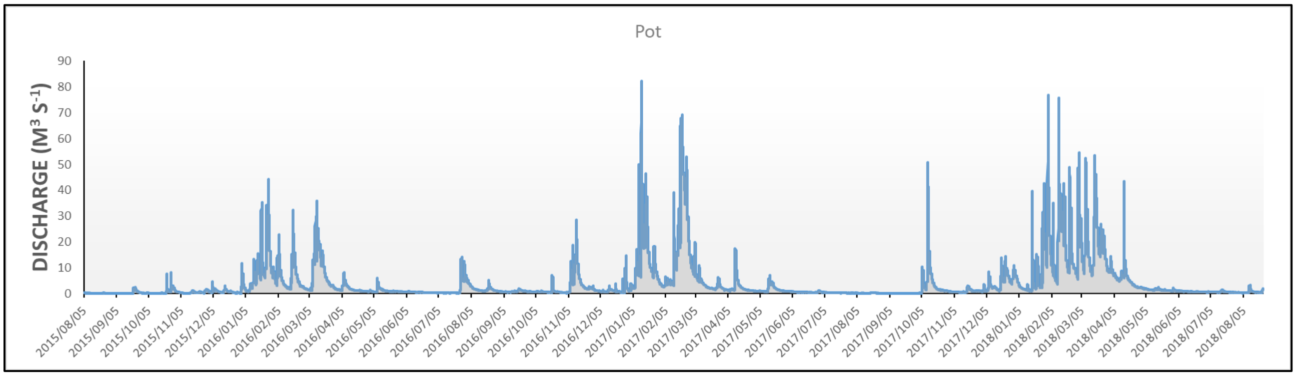
The rating curves are used to extrapolate level logger readings to instantaneous discharge which are plotted to show seasonal fluctuations in flow properties as well as peak discharges. Twenty minute discharges for each site can be found in Figure 14 and Figure 15.

Discharge and flow velocities play an important role in sediment mobility and the stability of beds. The discharges and flow velocities are highest at the sites with larger catchment areas above the site. All the sites show similar trends in discharge fluctuations with discharge increasing further down the catchment. Months with little or no rainfall generally have low discharge values. Discharge peaked during summer months due to heavy rains in the catchment. Local rainfall events can increase the discharge significantly, particularly at the start of the rainy seasons. Snowmelts (e.g. August 2016) can also cause spikes in discharge during the winter months. Peak discharges at the start of the monitoring period (2016) were well below average but have been rising with increased rainfall in the catchment in subsequent summer months.


Tsitsana
DISCHARGE (M³ S⁻¹)
0
10
20
30
40
50
60


Hlankomo
DISCHARGE (M³ S⁻¹)
0
5
10
15
20
25


Little Pot
DISCHARGE (M³ S⁻¹)
0
5
10
15
20
25
30


Pot
DISCHARGE (M³ S⁻¹)
0
10
20
30
40
50
60
70
80
90

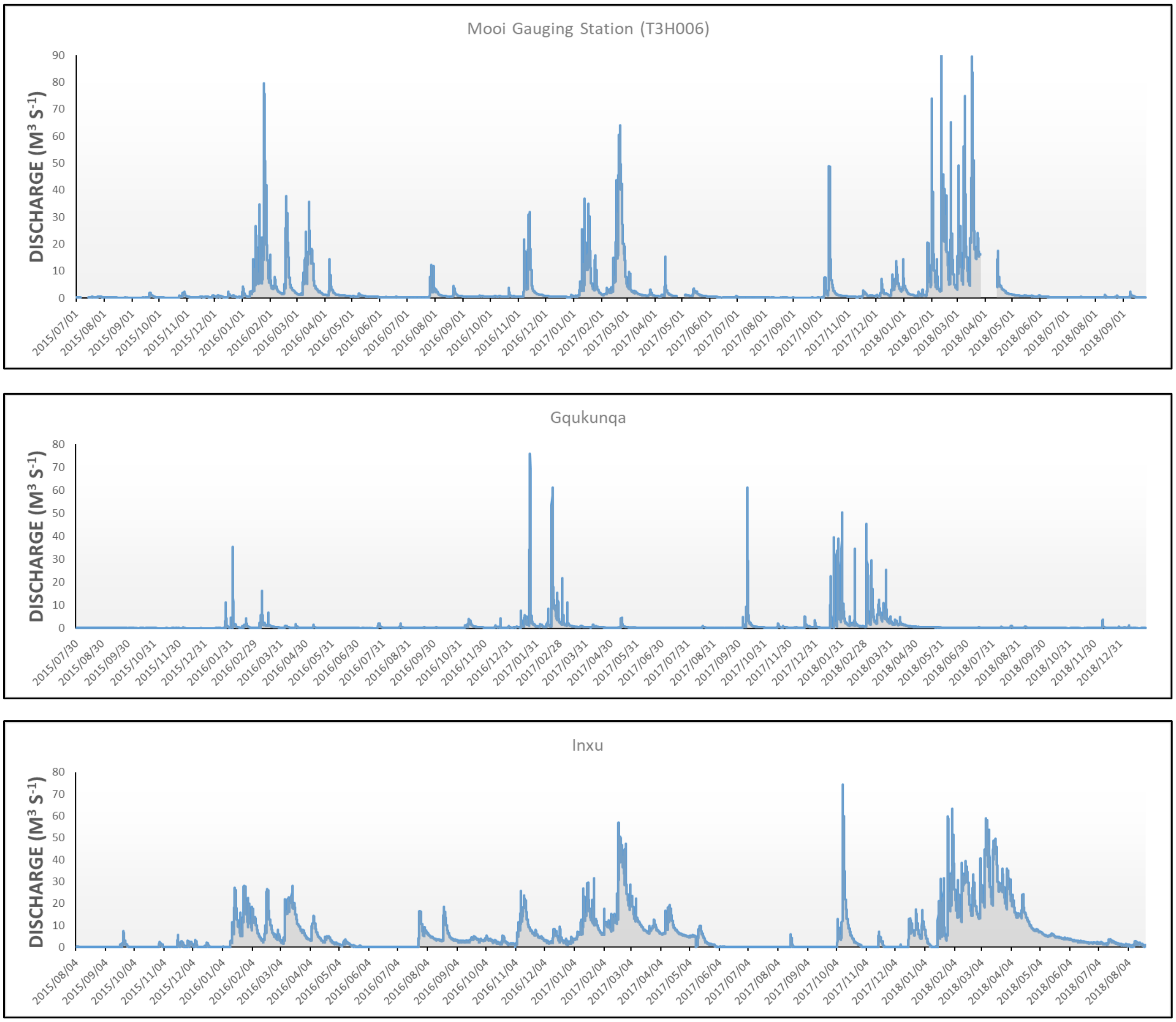


Figure 14: Twenty minute discharges for the tributaries of the upper Tsitsa River.

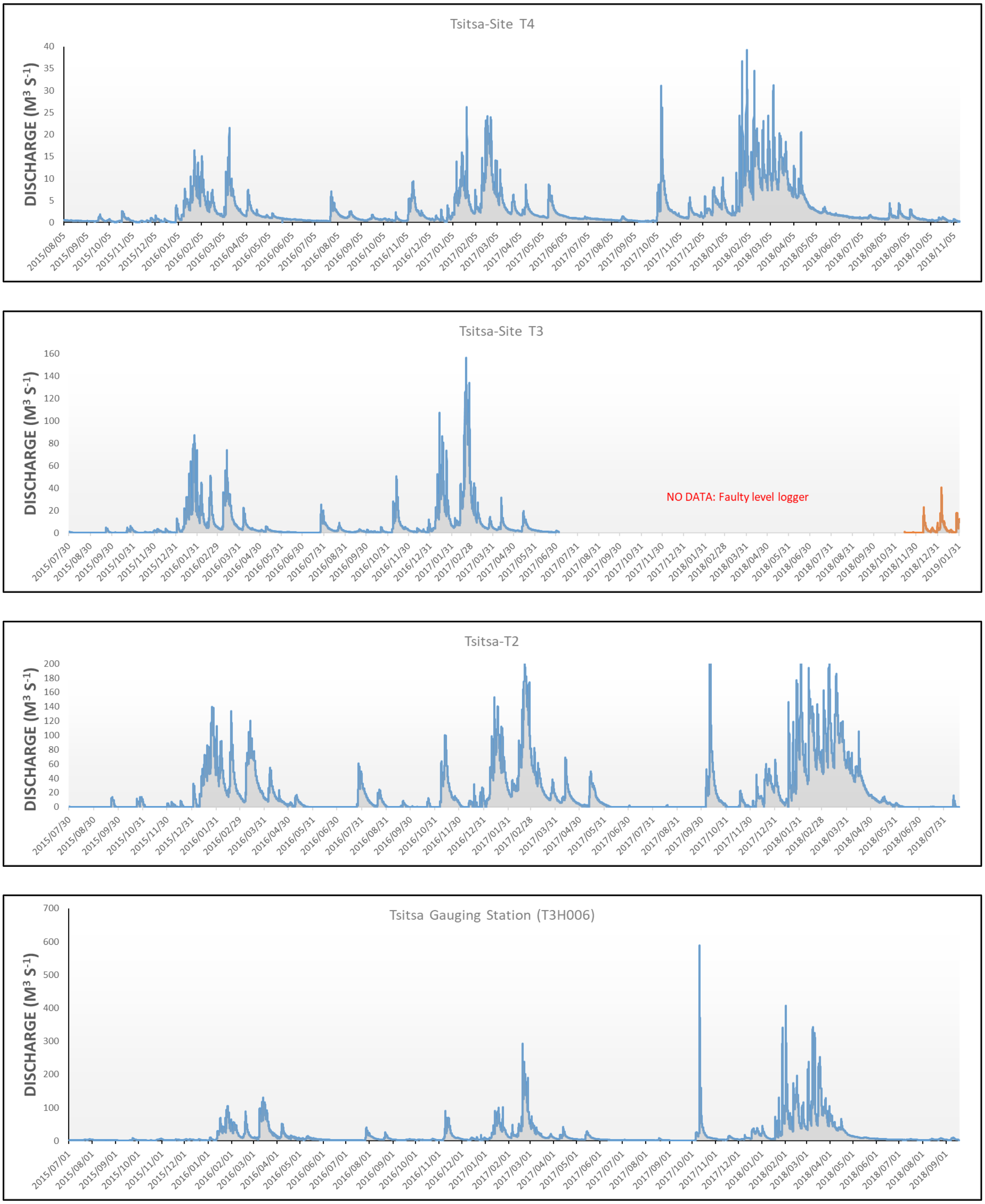


Figure 15: Twenty minute discharges for the Tsitsa River from upstream to downstream.

Flood peak modelling

Discharge is an important variable that determines channel response over time with high discharges having the ability to entrain sediment and transport it downstream (Rowntree & Wadeson, 1999).

Long-term flow data was sourced from gauging stations T3H006 (Tsitsa River at Xonkonxa; catchment area 4 285 km^2) and T3H009 (Mooi River at Maclear, catchment area 307 km^2).

The Tsitsa River, above gauging station T3H006, has a high peak discharge at the 10 year flood recurrence interval and the 10 year flood will occur when peak discharges are equal to or exceed 935 m^3.s^{-1} (data sourced from the Department of Water and Sanitation). Floods with very large peak discharges fell outside of the rating curves and were not included in the analysis.

Figure 16 illustrates that a larger catchment area, such as that of the Tsitsa River (4 285 km^2), will result in a bigger mean annual flood and therefore peak discharges (in the 10 year flood interval) compared to the Mooi River (which has a smaller catchment area of 307 km^2). However, it is important to note that high discharges are not accurate as each gauging station has a limit above which large floods are estimated.

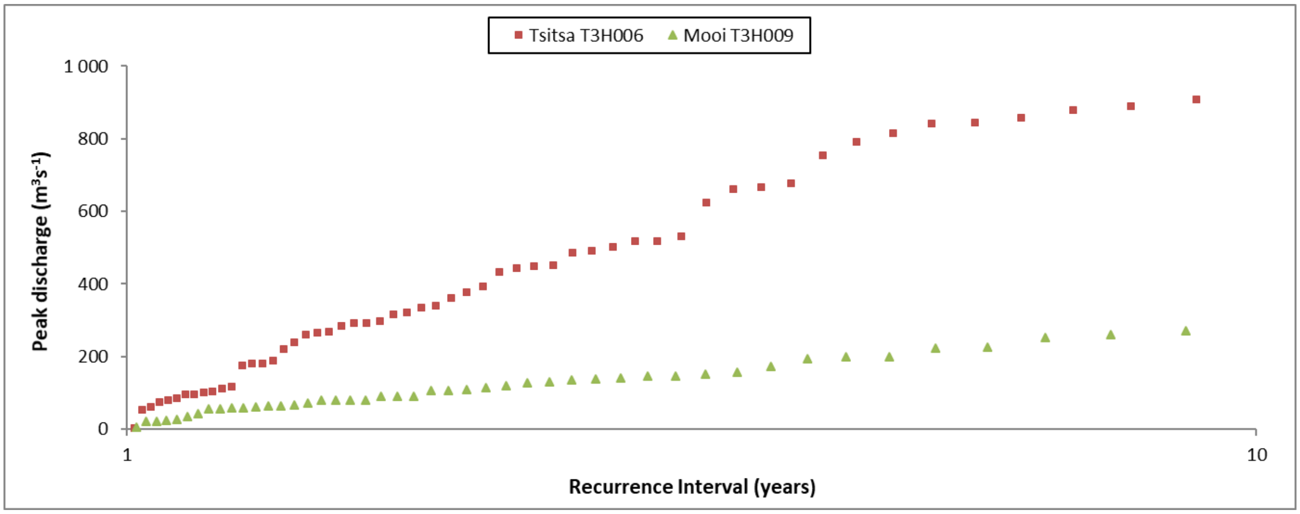


FIGURE 16: FLOOD FREQUENCY CURVES FOR TWO RIVERS WITH GAUGING STATIONS IN THE TSITSA CATCHMENT (DATA SOURCED FROM THE DEPARTMENT OF WATER AND SANITATION).

Figure 17 and Figure 18 show the annual peak discharges from 2000-2019 for the Tsitsa River (at gauging station T3H006) and the Mooi River (at gauging station T3H009) respectively. Flood peaks occur throughout the wet season with years ranging below and above the average flood peaks.

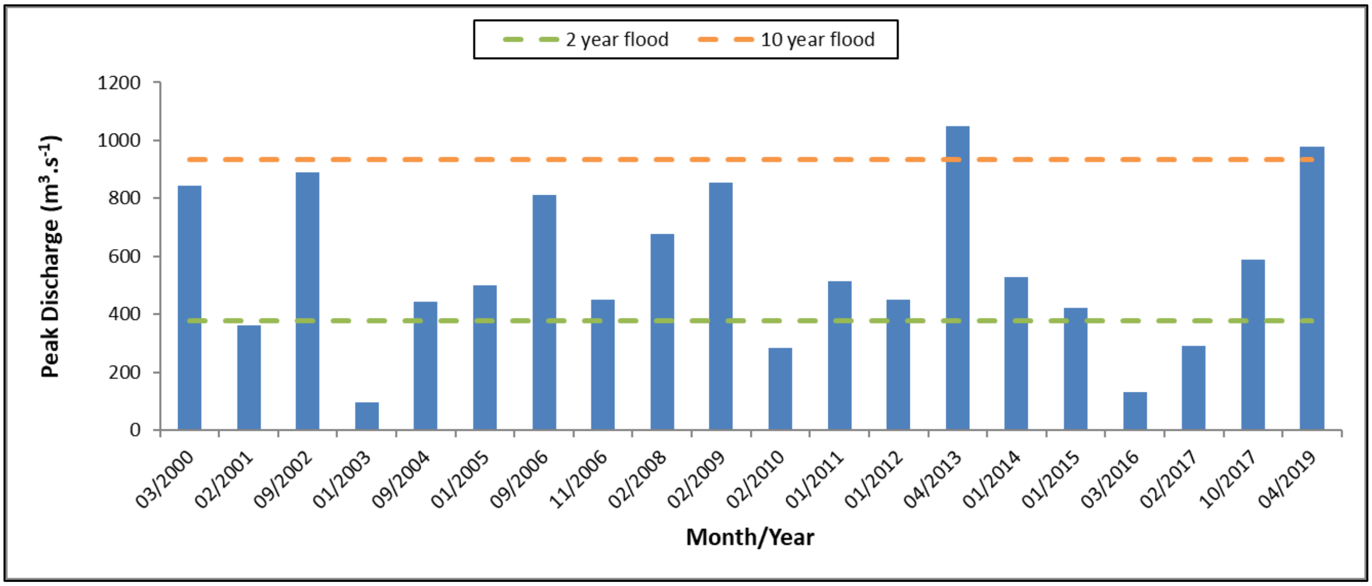


Figure 17: Annual peak discharges, plotted against the two year and ten year floods, from the Tsitsa River gauging station T3H006 (data obtained from the Department of Water and Sanitation). Data may be skewed as outliers such as 2013 have not been audited.

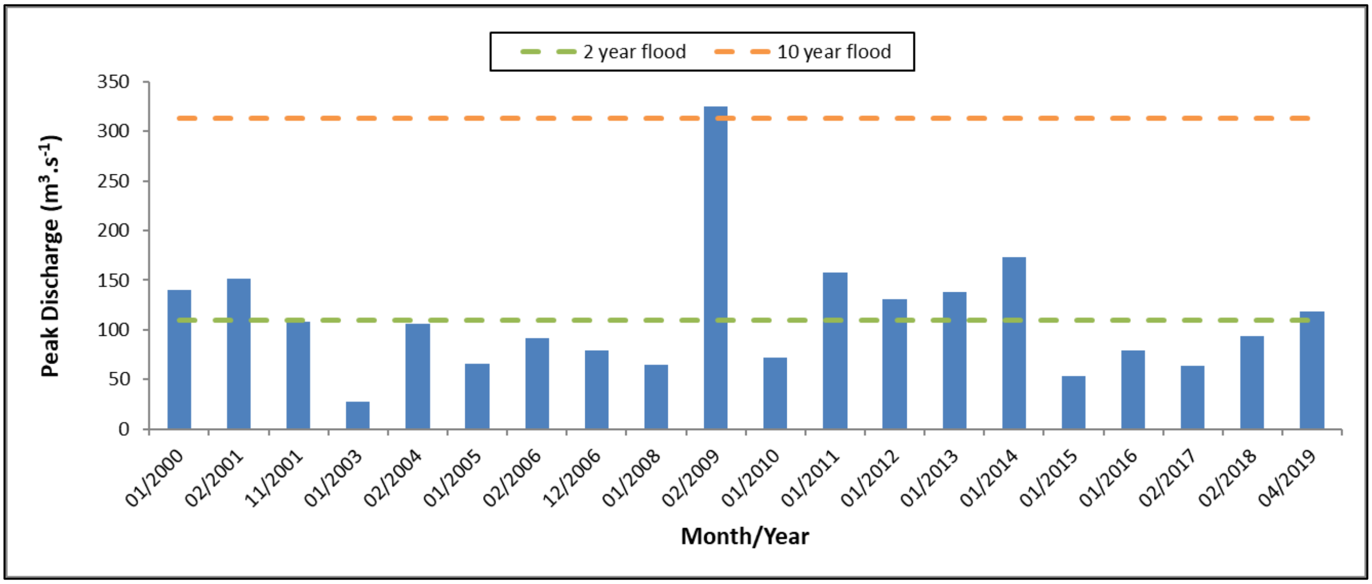


Figure 18: Annual peak discharges, plotted against the two year and ten year floods, from the Mooi River gauging station T3H009 (data obtained from the Department of Water and Sanitation). Data may be skewed as outliers such as 2009 have not been audited.

5.2. Water quality

Monitoring water quality variables gives an indication of the health of aquatic habitats. Five variables (Pennack, 1971; Díaz *et al.,* 2008) were identified for a short-term habitat assessment, namely dissolved nitrogen and phosphate concentrations, pH, electrical conductivity, dissolved oxygen content and water temperature. In rivers where the water is well mixed rapid assessments of water quality can be undertaken by taking a single representative sample at each site (Gordon et al., 2004). Samples are taken in the middle of each site (Figure 9), prior to any other field measurement activities to avoid disturbance or contamination of the sample site. Measurements are taken in the field to avoid contamination of the samples. In addition, turbidity and clarity are measured, habitat diversity assessed and a rapid assessment of water quality is conducted by looking at the macroinvertebrates present. In addition turbidity and suspended sediment concentrations are continuously measured (Bannatyne, 2018). A comparison of trends over time and under different flow conditions can point to either an improved or degraded aquatic ecosystem.

Measured values of water quality variables for each site for April 2019 are presented in Table 6. The water quality at each site is affected by external factors such as the underlying geology, point sources of pollutants and sediment inputs into the channel. Discharge also has an important effect on the water quality at each site. It is important to note that not all the sites were visited under the same discharges or on the same day.

pH is a measure of a rivers acidity (Behar, 1997). pH is measured at a scale between 1-14 with 1 being extremely acid, 7 neutral and 14 extremely basic. Freshwater aquatic life thrive in a pH range between 6.5-8.0. Measured pH at most of the sites in April 2019 ranged from 7.3-8.0. Site T4 on the Tsitsa River exhibited a higher pH value of 9.6. Overall the pH values indicated a balanced system.

Electrical conductivity (EC) is a measure of the capability of water in a river to pass an electrical current (Behar, 1997). Significant increases in EC can indicate an increase in pollutants in a river system. EC values should not exceed 500 µS/cm in order to support a diversity of aquatic life. EC ranged from 20-60 µS/cm for April 2019.

Water temperature is affected by air temperature, time of day, runoff, turbidity and the exposure of the channel to sunlight (Behar, 1997). Different aquatic organisms thrive under varying optimal temperatures. Water temperature in April 2019 ranged from 13-17.3 °C. It is difficult to establish whether the water temperatures impact negatively on aquatic biota, due to the spatial differences in the times of temperature measurements and the differences in temperature tolerances of biota.

Dissolved Oxygen (DO) is the amount of oxygen gas molecules present in the water (Behar, 1997). Oxygen enters rivers from surrounding air and as a product of photosynthesis from aquatic plants. Water temperature, time of day, season, water depth, altitude and rate of flow can all affect DO levels. Water at high temperatures and altitudes will have less DO. DO levels peak during the day. DO in streams can be anthropogenically affected by the addition of oxygen consuming organic wastes and nutrients as well as altering flow and water temperature. Sufficient DO concentrations of >80% are critical for the survival of aquatic organisms. DO levels below 50% are defined as sub-lethal to aquatic organisms (DWAF,1996). DO levels ranged between 98-114%. Concentrations of DO were not expected to have any significant impacts on biotic health in April 2019.

Nitrate enter river systems from natural sources such decomposing plants and animal waste but it can be elevated by human induced sources such as sewage and fertilisers (Baher, 1997). Natural levels of nitrates are generally <1mg/l. Concentrations of >10 mg/l are seen as detrimental to aquatic life and human consumption. Most of the sites exhibit Nitrate levels of >1 mg/l in April 2019 with the exception of Site T2 on the Tsitsa River which was 1.6 mg/l. This is however still very low and not seen as being detrimental to the health of the river at the site.

Phosphates are sourced from animal waste, sewage, detergents and fertilizers. An increase in phosphate levels in rivers may result in an increase in plant growth in the river which can be detrimental to DO levels when the plants die off. Phosphates only pose a risk to humans at very high levels. Phosphates can have an impact on a river at prolonged concentration of >1 mg/l. Phosphate levels for April 2019 ranged from 0-0.6 across all the sites. The highest levels were measured during a flooding event and levels of phosphate dropped with the reseeding flood. Runoff from the catchment was the most likely source of this increase as levels of phosphates did not seem to stay elevated for prolonged periods. An increase in phosphate concentrations was likely to occur due to leaching of sewage from pit latrines or runoff from cultivated lands during periods of rainfall in the catchment. The levels of phosphate are not high enough to have a noticeable impact on aquatic health.

The clarity and turbidity of the water can be linked to rainfall events in the catchment resulting in an increased runoff and turbidity within the river which decreases clarity. Turbidity peaked during high discharges when runoff from rainfall in the catchment increased the amount of sediment entering the river system.

Overall the water quality was found to indicated a balanced system with the exception of increased phosphate levels and turbidity and the reduction in clarity due to flood waters. Rivers with healthy amounts of marginal and aquatic vegetation take up phosphates, regulating spikes in phosphate levels experienced during floods (DWAF, 1996). Concentrations of phosphates need to be considerably higher than those found in the rivers to have a significant impact on biotic health (Dallas & Day, 2004). None of the DO concentrations fell below 50%, which is defined as sub-lethal to aquatic organisms (DWAF, 1996). Therefore, concentrations of DO were not expected to have any significant impacts on biotic health in the rivers. A well buffered South African river will be expected to have a pH ranging between 6 and 8, but fluctuations occur due to a changes in temperature, photosynthetic activity or biotic respiration and decomposition of organic matter (DWAF, 1996; Dallas & Day, 2004). According to Dallas & Day (2004) very little information is available on the tolerance of aquatic organisms to increased conductivity. The rate of change rather than the absolute change is important in assessing the effects on organisms. Turbidity increased and clarity decreased progressively with higher discharge and down the river system which can be linked to an increase in the erosion potential of the surrounding catchment.

Table 6: Water quality measurements for April 2019

	Tsitsana	Hlankomo	Little Pot	Pot	Mooi	T4/Falls	T3/Gorge	T2/Bridge	NH3/IWR	Gqukunqa	Inxu
pH	No data	No data	No data	7.7	No data	**9.6**	7.7	7.3	7.5	7.5	8.0
Electrical conductivity (µS/cm)	60	20	21	33	44	39	31	27	32	27	39
Temperature (°C)	13	16.5	13.1	16.8	15	14.5	14.4	16.3	17.3	17	16.9
Dissolved Oxygen (%)	106	114	102	109	114	99	108	99	103	98	103
Nitrate (mg/l)	0.2	0.3	0.4	0.4	0.2	0.2	0.2	**1.6**	0.3	0.6	0.1
Phosphate (mg/l)	0.3	0.3	0.3	0.2	0	0.2	0.6	0.3	0.3	0.3	0.3
Turbidity (FTU)	10	12	2	6	4	48	88	438	114	580	142
Clarity (cm)	26	41	86	27	41	16	8	4	7	4	5
Date	01.05.2019	02.05.2019	30.04.2019	28.04.2019	03.05.2019	28.04.2019	26.05.2019	25.04.2019	27.04.2019	25.04.2019	27.04.2019
Time	11h19	11h00	11h20	13h20	08h32	10h31	09h45	16h15	15h30	13h50	13h50
Comment	Slightly turbid	Milky	Clear	Receding flood	Milky	Receding flood	Turbid & flooding	Turbid & flooding	Turbid & flooding	Turbid & flooding	Turbid & flooding

5.3. South African Scoring System (SASSv5)

Macroinvertebrates provide barometers of river health as they are the first to register ill effects of negative impacts on a river system. River health, in terms of water quality, can be rapidly assessed by looking at the taxa richness of macroinvertebrate species sensitive to water quality (Dickens & Graham, 2002). A score derived using the South African Scoring System (SASS) (Dickens & Graham, 2002), a widely used technique in South African Rivers, was calculated for each site to look at a rapid assessment of water quality. This gave a measure of river health at the site scale. The average score per taxa (ASPT) is the total sensitivity score for all the classes/families found, divided by the number of classes/families found.

Changes in habitat result in changes in types of organisms and give a clear indication of the current condition of a river channel. Habitat quantity, quality and diversity must be taken into consideration when interpreting the SASSv5 scores (Graham *et al*., 2004). Habitat diversity can be linked to the diversity of biota present. This will be evident when looking at the SASS score. The ASPT score is less affected by the biota present at each site because the biota present may have representative sensitivities to the water quality present at the site. The SASS score may be high due to many taxa being present because of a diversity of habitats. But if these taxa all have low sensitivity scores then the ASPT score will be lower or if the taxa exhibit high sensitivity scores the ASPT will he higher. Therefore, the ASPT is the more reliable measure of the health of good quality rivers (Graham *et al*., 2004). The ASPT score should be interpreted with caution when the SASS score is very low (Dallas, 2007).

Table 7 lists the ecological categories and ranges of sensitivity scores used to interpret the SASSv5 data. The SASS score will be used to interpret habitat and macroinvertebrate diversity at each site and the ASPT will be used to look at the overall quality of the river at each site.

Table 7: Ecological categories and sensitivity scores used to interpret SASSv5 data for this study (Adapted from: Graham *et al*., 2004; Dallas, 2007).

SASS score	Description		Sensitivity score (ASPT)	Description	Ecological category	Ecological category name
>172	Very high habitat diversity		> 8.0	Unmodified, natural	A	Natural
135-171	High habitat diversity		6.9 - 7.9	Largely natural with few modifications	B	Good
105-134	Moderate habitat diversity		6.2 - 6.8	Moderately modified	C	Fair
76-104	Low habitat diversity		5.1 - 6.1	Largely modified	D	Poor
<75	Very low habitat diversity		< 5.0	Seriously modified	E	Very poor

Table 8 lists the SASSv5 data for April/May 2019. The SASSv5 scores are reported for each monitoring sites and give an indication of the ecological condition of the river at the monitoring site and the river upstream of the site. The sites are reported on from the top of the catchment moving downwards.

The SASSv5 survey on the Tsitsana River was undertaken under moderately high flow conditions following a flood event. The Tsitsana River had a SASS score of 107 which shows moderate habitat diversity. The dominant habitat present at the site during the monitoring survey included marginal vegetation, stones and sand. The ASPT score was 6.7 implying that the site is moderately modified. 16 taxa were found with a moderate average abundance. The **Tsitsana River** is classified as being in a **Fair ecological condition**.

The SASSv5 survey on the Hlankomo River was undertaken under moderately high flow conditions following a flood event. The water was noted to be very milky. The Hlankomo River had a SASS score of 95. This points toward a low habitat diversity present at the site. The dominant habitat present during the monitoring survey included bedrock, stones, marginal vegetation and sand. The ASPT was 5 implying a seriously modified river. 18 taxa were found with a low average abundance. The **Hlankomo River** is classified as being in a **Very Poor ecological condition**.

The SASSv5 survey on the Little Pot River was undertaken under moderate flow conditions following a flood event. The water was clear. The Little Pot River had a SASS score of 192 implying very high habitat diversity. All biotopes, except aquatic vegetation, were found at the site. The ASPT was 7.1 implying a largely natural river. 27 taxa were found with a moderate average abundance. The **Little Pot River** is classified as being in a **Good ecological condition**.

The SASSv5 survey on the Pot River was undertaken under high flow conditions during a receding flood. The Pot River had a SASS score of 160 implying a high habitat diversity. All biotopes with the exception of aquatic vegetation were sampled. The ASPT was 6.7 implying a moderately modified system. 24 taxa were found with low average abundance. The **Pot River** is classified as being in a **Fair ecological condition.**

The SASSv5 survey on the Mooi River was undertaken under moderately high flow conditions following a flood event. The Mooi River had a SASS score of 137 implying high habitat diversity. All biotopes with the exception of aquatic vegetation were sampled. The ASPT was 6 implying a largely modified system. A total of 22 taxa were found with moderate average abundance. The **Mooi River** is classified as being in a **Poor ecological condition.**

The SASSv5 survey on the Tsitsa River at site T4 was undertaken under high flow conditions during a receding flood. The water was turbid. The Tsitsa River had a SASS score of 64 implying very low habitat diversity. The dominant habitats present at the time of surveying were marginal vegetation, bedrock, gravel, sand and mud. The ASPT was 4.9 implying a seriously modified system. A total of 13 taxa were found with moderate average abundance. The **Tsitsa River at site T4** is classified as being in a **Very Poor ecological condition.**

The SASSv5 survey on the Tsitsa River at site T3 was undertaken under very high flow conditions during a flood. Water was turbid. The Tsitsa River had a SASS score of 144 implying a high habitat diversity. The dominant vegetation habitats sampled included marginal vegetation, gravel, sand and mud. The channel was too deep to sample stones and bedrock. This may result in a reduced ASPT score. The ASPT was 7.2 implying a largely natural system with few modifications. A total of 19 taxa were found with a low average abundance. The **Tsitsa River at site T3** is classified as being in a **Good ecological condition.** The change in ecological condition between site T4 which is upstream of site T3 could be explained by the location of each site. Site T3 is situated at the bottom of a gorge with fast flowing water. This could result in less imbrication of substrate allowing for more habitat diversity for taxa.

The SASSv5 survey on the Tsitsa River at site T2 was undertaken under very high flow conditions during a flood. Water was very turbid. The Tsitsa River had a SASS score of 60 implying very low habitat diversity. The dominant vegetation habitats sampled were limited to marginal vegetation, sand, mud and gravel. The channel was too deep to access any other biotopes. The ASPT was 7.5 implying a largely natural system with few modifications. A total of only 8 taxa were found with a low average abundance. This is likely due to the flooding and lack of access to the full biotopes present at the site. The **Tsitsa River at site T2** is classified as being in a **Good ecological condition.**

The SASSv5 survey on the Tsitsa River at site NH3/EWR was undertaken under very high flow conditions during a flood. Water was very turbid. The Tsitsa River had a SASS score of 65 implying very low habitat diversity. The dominant vegetation habitats sampled were limited to marginal vegetation, sand and mud. The channel was too deep to access any other biotopes. The ASPT was 7.2 implying a largely natural system with few modifications. A total of only 9 taxa were found with a low average abundance. This is likely due to the flooding and lack of access to the full biotopes present at the site. The **Tsitsa River at site NH3/EWR** is classified as being in a **Good ecological condition.**

The SASSv5 survey on the Gqukunqa River was undertaken under high flow conditions during a flood. The water was turbid. The Gqukunqa River had a SASS score of 52 implying very low habitat diversity. All the biotopes with the exception of aquatic vegetation and bedrock were samples. The ASPT was 5.8 implying a largely modified system. A total of only 9 taxa were found with a low average abundance. The **Gqukunqa River** is classified as being in a **Poor ecological condition.**

The SASSv5 survey on the Inxu River was undertaken under high flow conditions during a flood. The water was turbid. The Inxu River had a SASS score of 42 implying very low habitat diversity. The Inxu River has very little habitat present and the only biotopes present are marginal vegetation, sand, mud and fine gravel. The ASPT was 6 implying a largely modified system. A total of only 7 taxa were found with a low average abundance. The **Inxu River** is classified as being in a **Poor ecological condition.**

Within the range of parameters monitored in April 2019, water quality could be discounted for having any noticeable effects in altering the types of macroinvertebrates that would naturally occur in the river. This corresponds to the findings of Madikizela & Day (2003) in the Mzimvubu River and its tributaries including the Tsitsa River and Huchzermeyer (2017) on the Tsitsa River. Madikizela & Day (2003) established that macroinvertebrate families in the Mzimvubu River and its tributaries were not found in abundance however, species sensitive to poor water quality were present. Madikizela & Dye (2003) identified that the secondary effects of sedimentation and reduction in habitat played an important role in the ecological health of a river and might cause a reduction in the abundance of certain macroinvertebrate families. Huchzermeyer (2017) monitored the Tsitsa River over a time (2015-2016) characterised by a combination of low discharges (Figure 17) causing an increase in bed sediment storage and the lack of influence from water quality variables on macroinvertebrate community structure. This made conditions ideal for researching the effect that bed sediment was having on macroinvertebrates. A review of the common macroinvertebrate families of the upper Tsitsa River Catchment and their associated habitats with an emphasis on fine sediment accumulation can be found in Appendix 6 (following on work from Huchzermeyer, 2017).

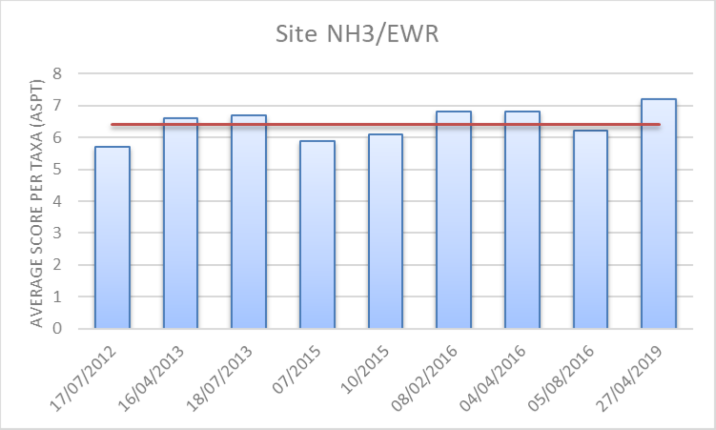
TABLE 8: SASSV5 DATA FOR APRIL/MAY 2019

	Tsitsana	Hlankomo	Little Pot	Pot	Mooi	T4/Falls	T3/Gorge	T2/Bridge	NH3/EWR	Gqukunqa	Inxu
SASS score	107	95	192	160	131	64	137	60	65	52	42
No. of taxa	16	18	27	24	22	13	19	8	9	9	7
ASPT	6.7	5	7.1	6.7	6	4.9	7.2	7.5	7.2	5.8	6
Average dominant estimated abundance per taxon (A:1-10 low; B:10-100 moderate; C:100-1000 high; D:>1000 very high)	B	A	B	A	B	B	A	A	A	A	A
Ecological condition	Fair	Very Poor	Good	Fair	Poor	Very Poor	Good	Good	Good	Poor	Poor

Site NH3/EWR has been used as a site for determining environmental flows for the Mzimvubu Catchment Partnership Programme as well as by Huchzermeyer (2017). Therefore, there is SASS data available from 2012 (Table 9).

TABLE 9: SUMMARY TABLE OF SASSV5 DATA FOR NH3/EWR ON THE TSITSA RIVER

Date	SASS Score	No. of Taxa	ASPT
17/07/2012	80	14	5,7
16/04/2013	126	19	6,6
18/07/2013	147	22	6,7
07/2015	-	-	5,9
10/2015	-	-	6,1
08/02/2016	102	15	6,8
04/04/2016	156	23	6,8
05/08/2016	167	27	6,2
27/04/2019	65	9	7,2



5.4. Channel classifications: Fluvial geomorphology/Geo-habitats (Huchzermeyer, 2017)

Cross-sectional profiles show the current morphology of the river channel. This is shaped by the current flow hydraulics and sediment inputs (Brandt, 2000; Apitz, 2012). Cross-sectional profiles provide a comprehensive depiction of the current physical structure of river sites (Figure 19). Geo-habitats are habitat features that are directly linked to the physical structure of the channel (Rowntree, 2013).

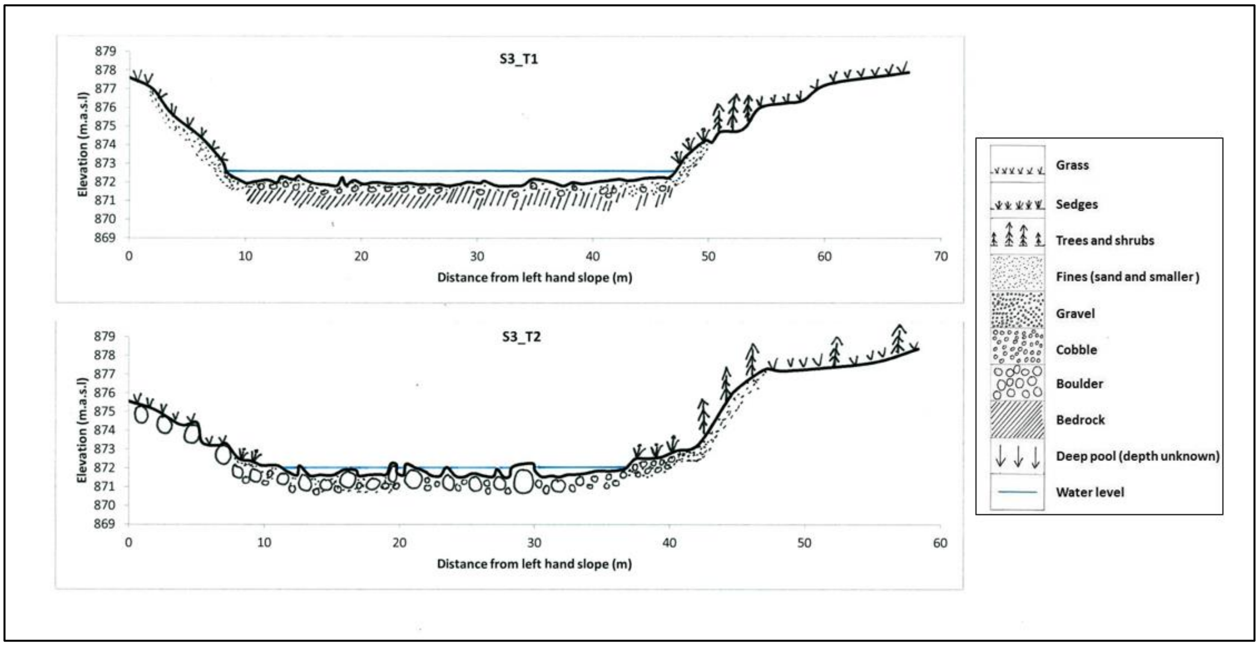


FIGURE 19: CROSS-SECTIONAL TRANSECTS, INCLUDING DISTRIBUTION OF SUBSTRATES, GEO-HABITATS AND JULY 2015 WATER LEVELS, FOR SITE NH3 (HUCHZERMEYER, 2017)

Information on the bed conditions in terms of coarse substrates in each site can be mapped out at a coarse scale using aerial images, cross-sectional profiles and notes at each site. For example, Huchzermeyer (2017) described Site NH3 in 2015-2016. Site NH3 varied from bedrock at the top through a boulder and cobble rapid into a low gradient pool with deposits of fine sediments (Figure 20). The dominant coarse substrates across the site were large gravels, commonly from surrounding alluvial fans (hillslope inputs), as well as small cobbles. The bed conditions along the transects were highly variable and ranged from fines to small boulders. Transect 1 ranged across a pool with low embeddedness values in the middle of the channel and high embeddedness values along the right bank where fines were deposited in an area of reduced flow velocity. Transect 2 and 3 were situated across the rapid with closely packed and highly imbricated boulders forming a stable bed along Transect 2, and Transect 3 being dominated by cobbles with low embeddedness values implying very little deposition of fines in the rapids. Transect 4 was highly embedded due to the deposition of fines in areas of reduced flow velocity making up the pool. Embeddedness values along Transect 5 were reduced as flow velocity increased due to channel confinement by an impinging alluvial fan.

This can be repeated for all the monitoring sites in the Tsitsa Catchment to set up a baseline of the geomorphology and habitats at each site.

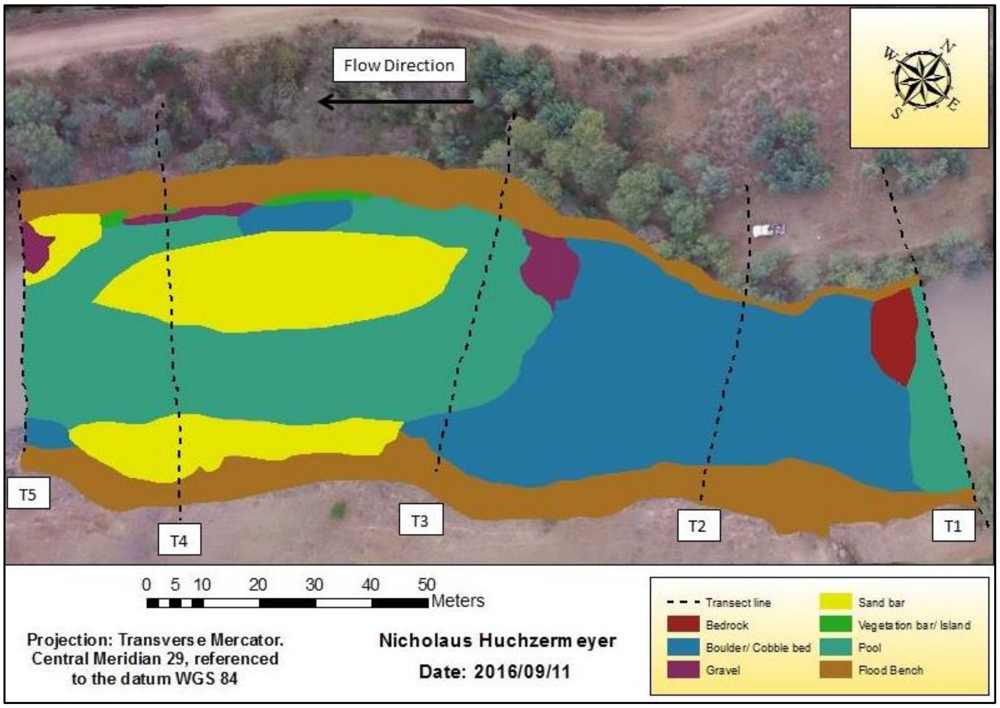


FIGURE 20: CHANNEL FEATURES AT A LARGE SCALE FOR SITE NH3/EWR. POOL IS DOMINATED BY FINE SEDIMENTS (FROM HUCHZERMEYER, 2017)

6. TERRESTRIAL BIOPHYSICAL MONITORING

6.1. Ecosystems

Land cover/use, landscape connectivity and ecosystems have been mapped using a combination of medium-resolution satellite imagery, higher-resolution aerial imagery and field verification (Huchzermeyer *et al*., 2018a; Huchzermeyer, *et al*., 2018b & Schlegel *et al*., 2018). A base-line classified map of the catchment was generated (Figure 21). Mapping of these ecosystem components will be mapped on a ≥ 5 yearly interval.

These datasets are used by catchment managers for integrated planning and prioritisation.

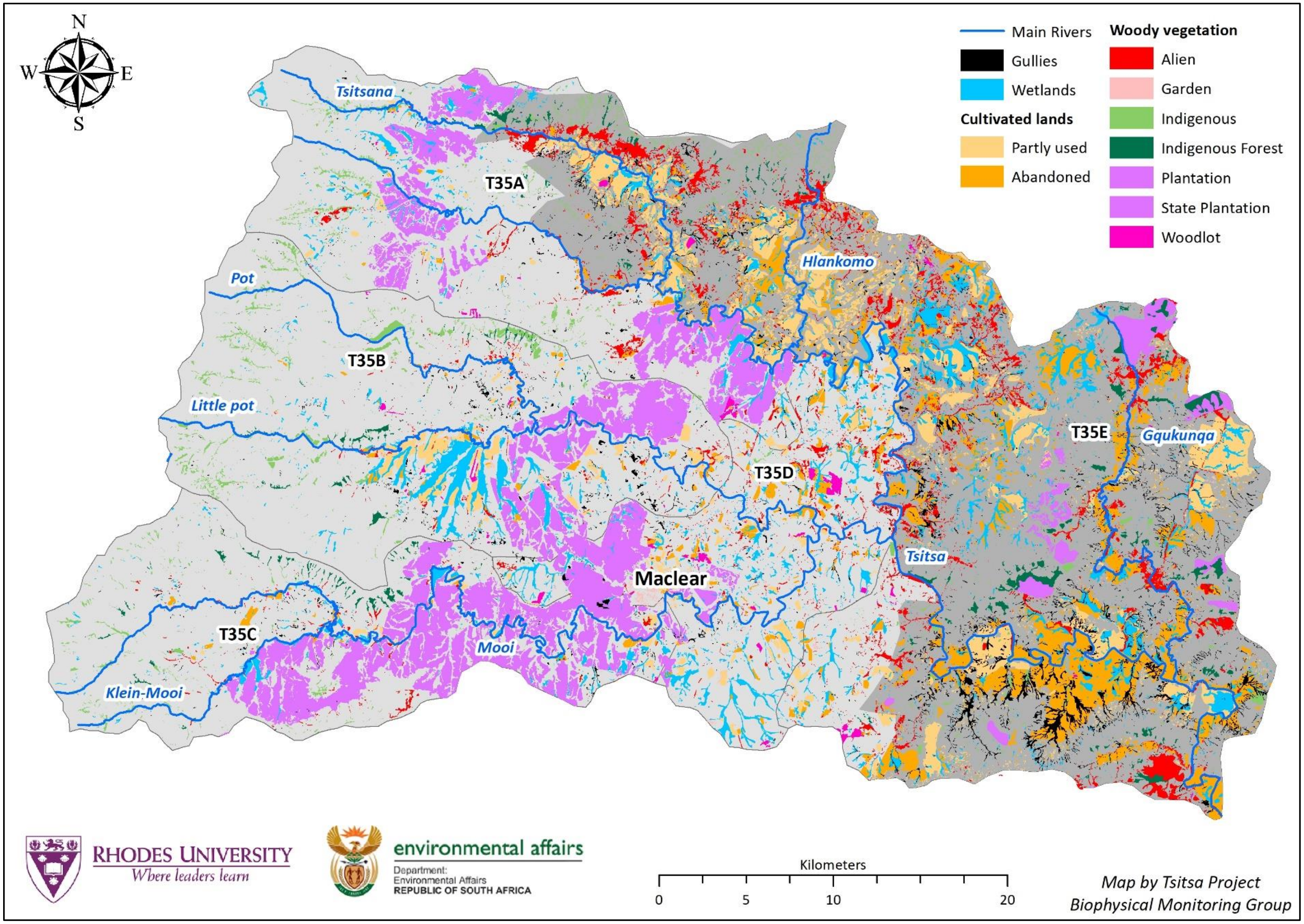


FIGURE 21: IN-DEPTH MAPPING OF CATCHMENT CHARACTERISTICS IN CATCHMENT T35 A-E. (GULLIES MAPPED BY LE ROUX, 2012)

6.1.1. Hillslope features and process

Sediment pathways and landscape connectivity

Landscape connectivity over the past 100 years has been enhanced by the formation of gullies, livestock tracks and roads (Van der Waal & Rowntree, 2017). An increase in both downslope connectivity and across slope connectivity leads to highly increased hillslope to river channel coupling, making water and sediment routing very efficient (Van der Waal & Rowntree, 2017). A high increase in sediment routing and export results as areas that were formerly functioning as water and sediment buffers and sinks are turned into conduits of both water and sediment (Van der Waal, 2015).

The downslope and across slope connectivity is monitored by mapping connectivity features such as gullies, livestock paths, and roads and calculating a percentage increase or decrease in connectivity (Figure 22). This will indicate the level of hillslope to river channel coupling.

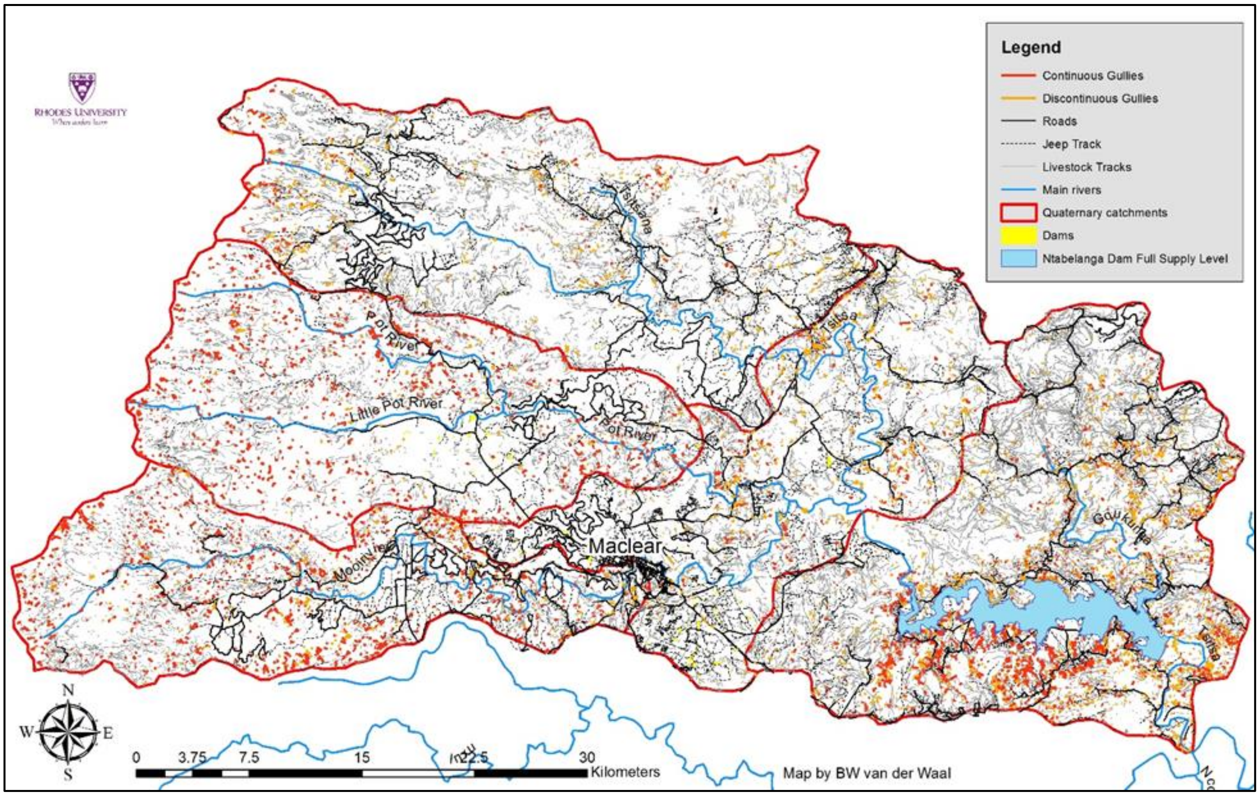


FIGURE 22: CONNECTIVITY FEATURES FOUND IN CATCHMENT T35 A-E

Landscape connectivity is greatly enhanced through anthropogenic related features in Catchment T35 A-E with livestock tracks being one of the most prominent features present (Figure 23). This increases both down slope and cross slope drainage and routing of water and sediment. Densities were highest near human settlements. These areas are disturbed frequently (e.g. through ploughing and building), have surfaces that are often hardened (e.g. through trampling, vehicles, etc.) and impervious (e.g. roofs and pavements). This means that more water and sediment are routed at greater efficiency away from places that produce extra runoff and sediment. Water infiltration and sediment deposition will be reduced through the increased connectivity, leading to greater energy of runoff and flashier system responses. Greater energy will enhance transport power of the water, allowing larger and more particles to move during overland flow.

Further development in the catchment, without consideration to runoff and hillslope processes, will exacerbate this trend, leading to increased water and sediment export from the catchment.

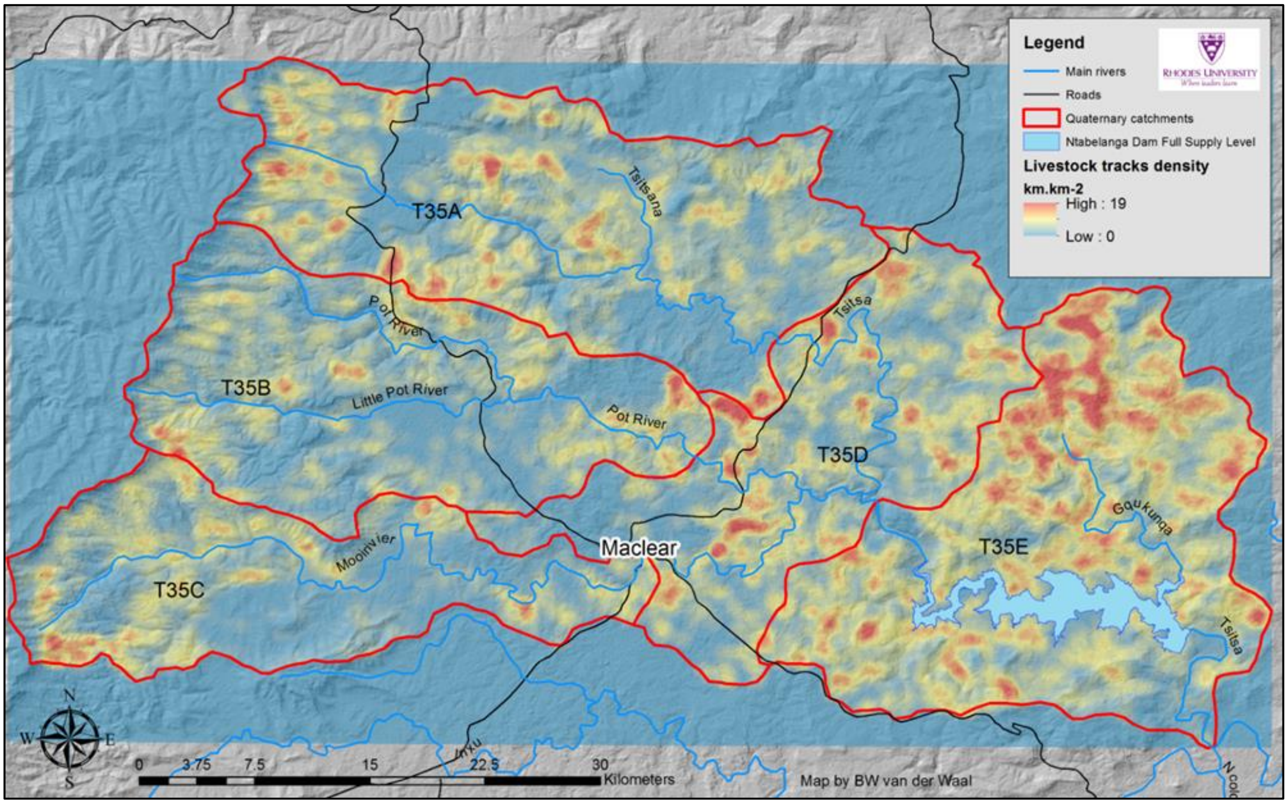


FIGURE 23: LIVESTOCK TRACK DENSITY FOR CATCHMENT T35 A-E

Cross-slope or horizontal drainage features such as roads, jeep tracks and livestock tracks drain, trap, route and concentrate overland flow. This takes place on most slopes, reducing infiltration and sediment storage on the slopes. Livestock tracks were by far the most dense and extensive, whereas main roads were high in urban centres, but limited in spatial extent.

Down-slope connecters, such as gullies are not as widespread throughout the catchment, but are very effective at draining areas that can store sediment (low angled slopes) and routing sediment to the larger channels.

Sediment source tracing (discontinued)

Trollope (2016) made use of the sediment collected in the time integrated samplers (Figure 24) that collected suspended sediment over the wet season of 2015/16. Trollope (2016) concluded the following:

- Sediment tracing presents advantages such as not having any temporal limitations yet a drawback could be that the particles physical and geochemical variability can complicate differentiation of sediments and the source of such sediment.

- Mapping the land uses, understanding the vegetation and geological context of the area are the key aspects that are investigated. In some cases, using the two indexes, colour and magnetics, sediments could be traced back to their sources as well as identify the areas that may need rehabilitation.
- The use of colour and magnetics showed that the Mooi River contributed a significant amount of sediment to the Tsitsa River and may be a main contributor to the proposed dam. The Hlankomo contributed a significantly larger percentage than the Tsitsana and there is evidence of activities such as digging and grazing that are propagating loose sediment on the banks and bed of the river. Gully erosion is seen to contribute to almost a quarter of the sediment to the Tsitsa Bridge (T2).
- Considering the relatively small areas that gullies are affecting in the catchment, they are worth mitigating especially for the sake of the proposed dams.

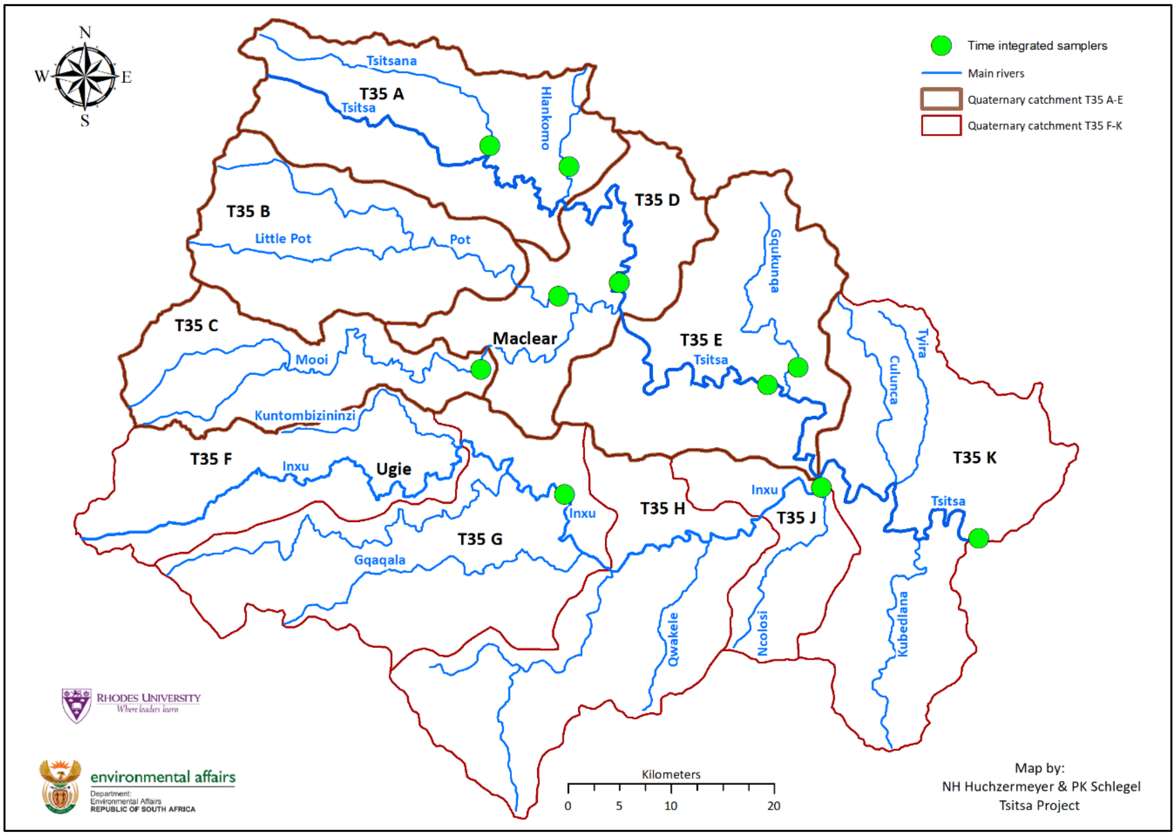


FIGURE 24: LOCATION OF TIME INTEGRATED SAMPLERS IN THE GREATER TSITSA CATCHMENT. THESE NEED TO BE REFURBISHED FOR CONTINUED RESEARCH

6.1.2. Fire dynamics (student project: Snyman, 2019)

Snyman (2019) is using LANDSAT imagery to extract burn scars in Catchment T35 A-E. A time-series analysis is being used to calculate fire frequency and MODIS/VIIRS point data is used to monitor the timing and intensity of fires. This data can then be used to help interpret catchment processes and aid management interventions.

Snyman (2019) is still in the process of finalizing his analysis, but a preliminary fire frequency and fire scar size map is presented in Figure 25.

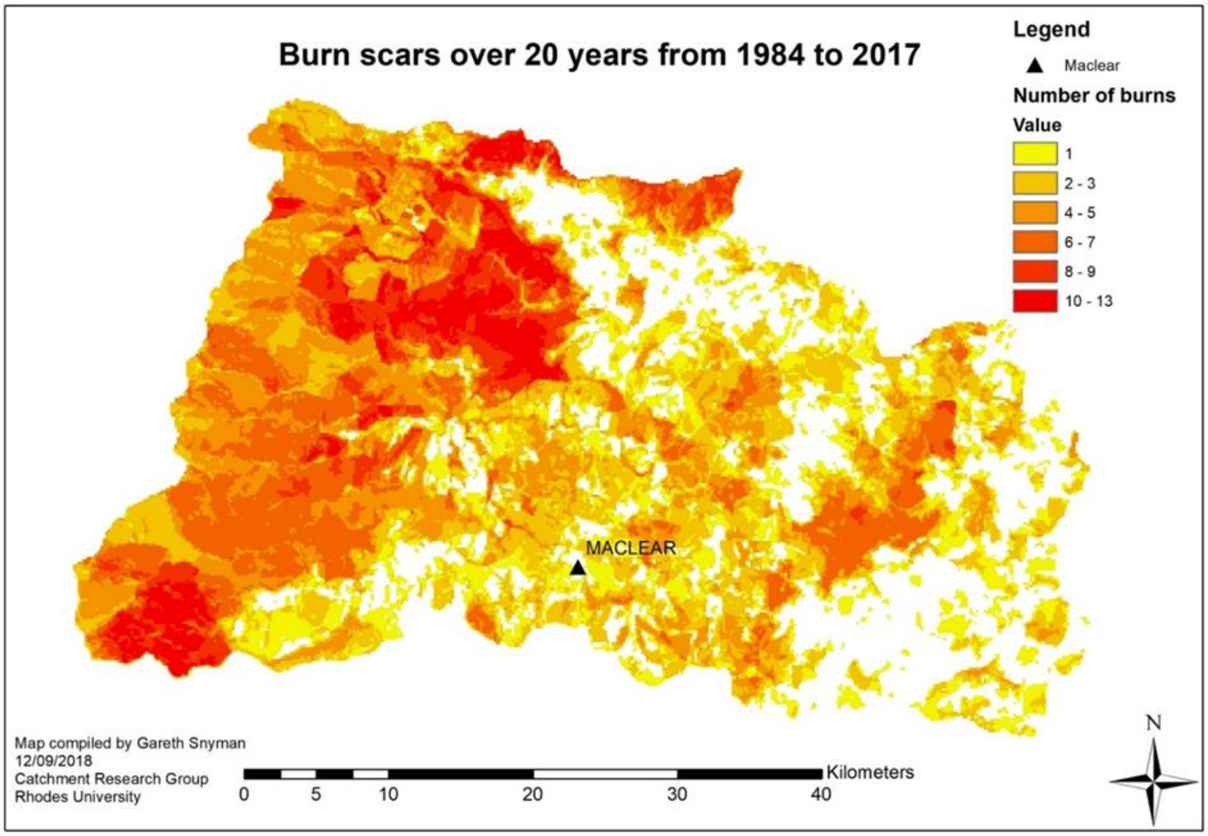


FIGURE 25: MAP OF FIRE FREQUENCY AND BURN SCAR SIZE FROM 1984-2017 IN CATCHMENT T35 A-E (SYYMAN, 2019)

Preliminary findings show that:

- there is a decrease in the area of fire scars,
- fire scars are larger in the upper catchment and smaller in the middle and lower catchment, especially in the traditional council areas,
- fire frequency is highest in the upper catchment,
- fire intensity is highest on the commercial land.

7. VELD CONDITION ASESSMENT IN CATCHMENT T35 A-E: PHASE 1

FIGURE 26: LIVESTOCK GRAZING IN THE TSITSA CATCHMENT

The Tsitsa river catchment vegetation is dominated by grassland (Mucina & Rutherford, 2006). Grasslands are an important resource for the people living within the catchment. However, grasslands in the Tsitsa Catchment are characterised by many symptoms of veld degradation with the most prominent being large-scale and severe erosion and the encroachment of alien vegetation.

One of the driving forces behind this degradation is the lack of grazing and fire management systems. To assess the current veld condition, veld monitoring sites were chosen that represent different land-use areas, geology, elevations and vegetation types. Phase 1 of the veld condition assessment is focused in the traditional council areas.

7.1. Veld monitoring sites

The sites occur in a range of geology and vegetation types (Figure 27 and Figure 28). Table 10 summaries the characteristics for each veld monitoring site.

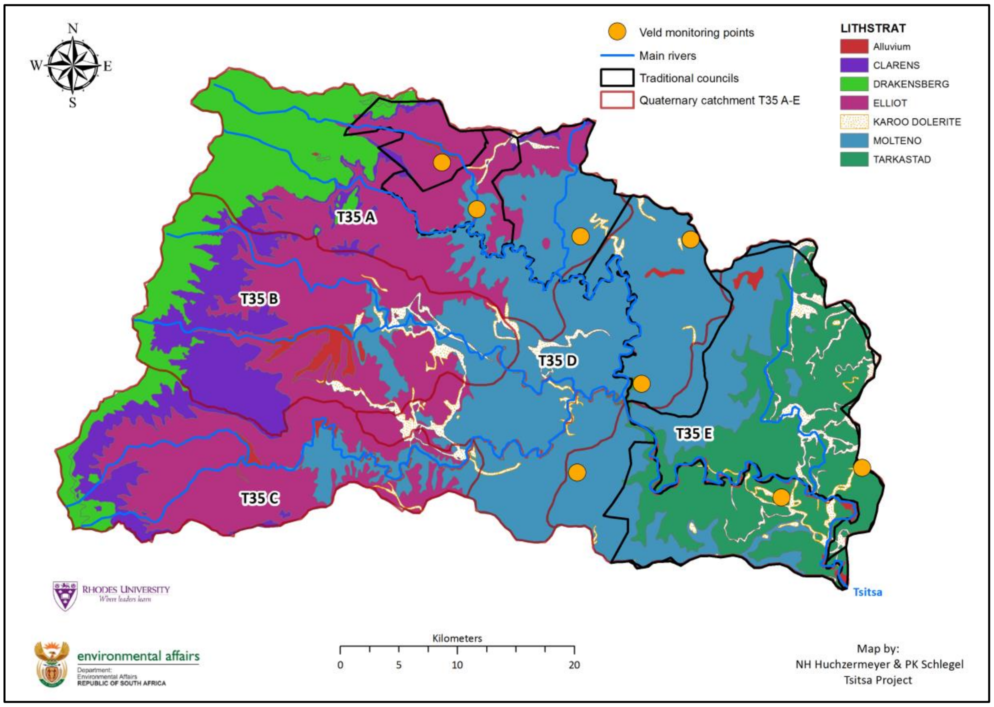


FIGURE 27: VELD MONITORING POINTS IN RELATION TO GEOLOGY

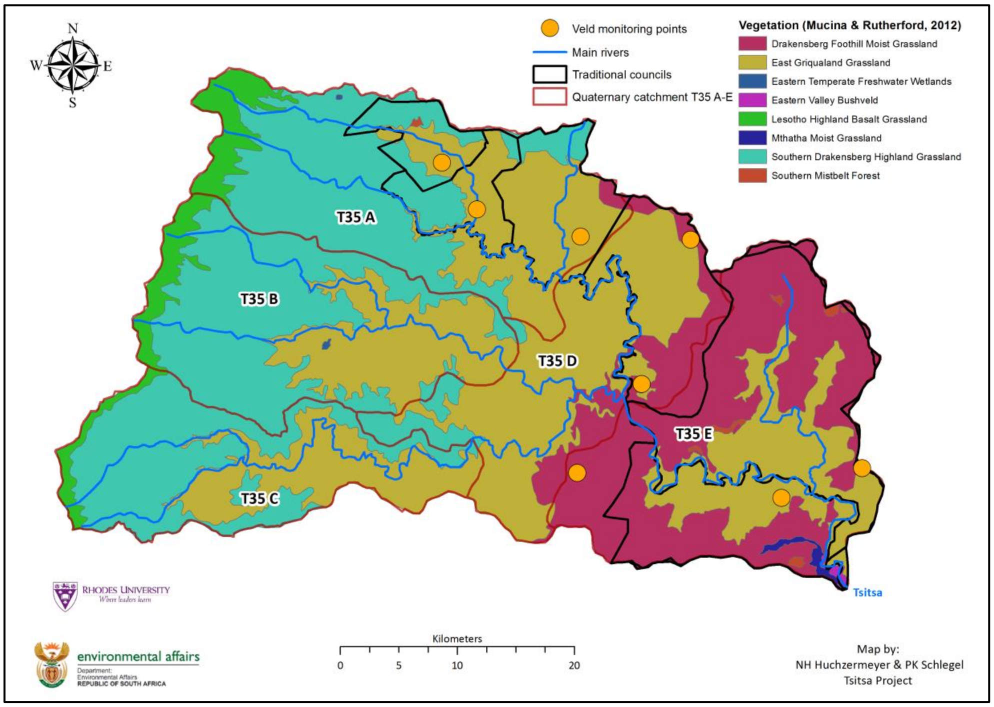


FIGURE 28: VELD MONITORING POINTS IN RELATION TO VEGETATION TYPES

TABLE 10: SUMMARY OF VELD MANAGEMENT DATA COLLECTION POINTS

Vegetation type	Elevation range	Geology	Number of sites
Drakensberg Foothill Moist Grassland	1000-1520	Molteno; Karoo dolerite	2
East Griqualand Grassland	900-1300	Motleno; Tarkastad; Alluvial	6
			8

Veld monitoring point	Location (Quaternary Catchment)	Mean NDVI value (March 2018)	Priority catchment number	Geology	Vegetation	Elevation (masl)	Aspect	Comment
1	Ngecele Traditional Council (T35 E)	0.35	209	Tarkastad	East Griqualand Grassland	948	North	Abandoned cultivated land
2	Northern Pondomise Traditional Counil (T35 E)	0.52	204	Tarkastad	East Griqualand Grassland	1 202	East	Mid-slope
3	Bob's Place Commercial farm (T35 E)	0.68	202	Molteno	Drakensberg Foothill Moist Grassland	1 365	East	Private farm
4	Upper Tsitsana Traditional Council (T35 A)	0.45	18	Elliot	East Griqualand Grassland	1 359	North	Abandoned cultivated land
5	Lower Tsitsana Traditional Council (T35 A)	0.57	34	Alluvial deposit on Molteno	East Griqualand Grassland	1 272	North-West	Valley bottom on floodplain & abandoned cultivated land
6	Batlokoa Traditional Council (T35 A)	0.53	48	Molteno	East Griqualand Grassland	1 333	East	Communal grazing land
7	Basuto Traditional Council (T35 D)	0.68	68	Molteno	Drakensberg Foothill Moist Grassland	1 467	North-West	Valley bottom & moist
8	Basuto Traditional Council (T35 D)	0.48	115	Molteno	East Griqualand Grassland	1 197	North-West	Abandoned cultivated land

Sites locations were confirmed in the field and if necessary locations were moved to ensure easier access for repeat monitoring. A total of 8 sites were chosen for monitoring (Figure 29)

Each site was marked with a cairn at the start point of the veld monitoring transect (Figure 30). Cairns consist of 50 centimeters of black irrigation pipe filled with cement that is buried in the ground with only the top 10 centimeters exposed. Additionally, rocks were packed around the cairn. Each cairn was marked with a GPS point for future reference.

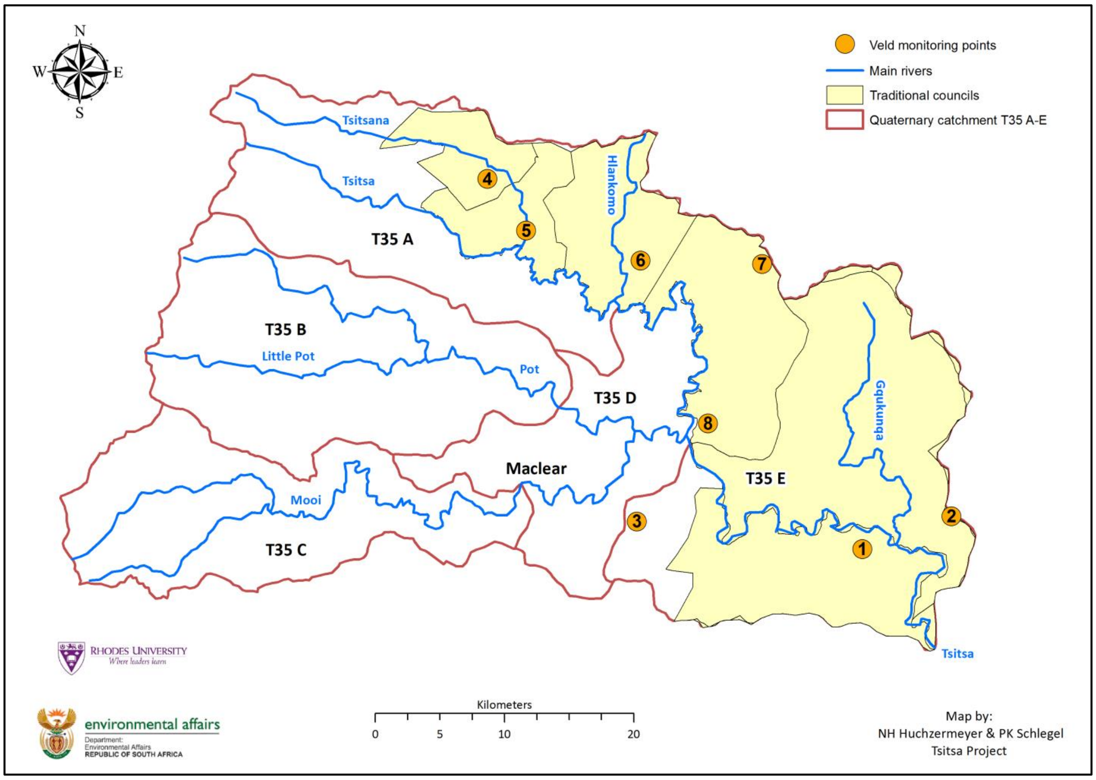


Figure 29: Veld monitoring sites in the Tsitsa Catchment

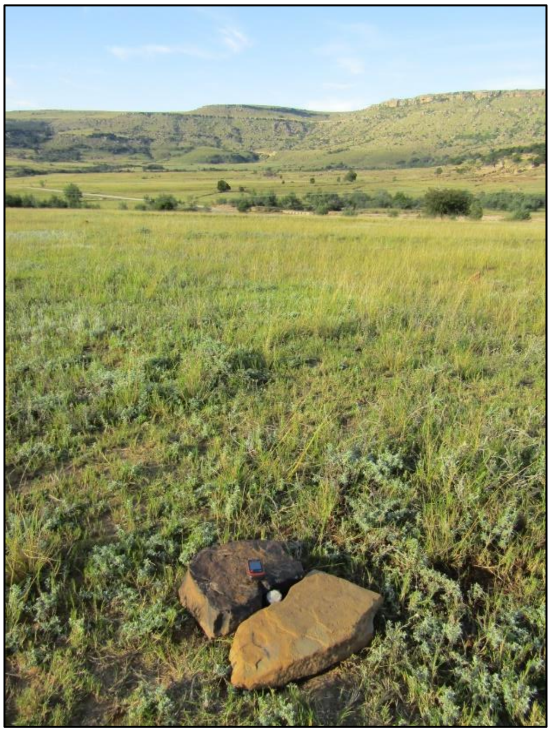


Figure 30: Example of a Cairn marking the starting point of a veld monitoring transect

Table 11 lists the site coordinates for each veld monitoring site and the coordinates correspond to the cairns at each site. The layout of the transects and site descriptions are discussed in Appendix 1.

TABLE 11: COORDINATES FOR VELD MONITORING SITES

Veld monitoring site				
Site name	**Coordinates**		**Site name**	**Coordinates**
Veld 1	31°6'57,087"S 28°37'48,203"E		**Veld 5**	30°53'33,566"S 28°21'31,205"E
Veld 2	31°5'35,652"S 28°42'8,88"E		**Veld 6**	30°54'49,959"S 28°27'4,896"E
Veld 3	31°5'45,254"S 28°26'50,222"E		**Veld 7**	30°54'49,959"S 28°27'4,896"E
Veld 4	30°51'23,031"S 28°19'39,928"E		**Veld 8**	30°54'49,959"S 28°27'4,896"E

Table 12 summarises the veld condition for each site and includes dominant grass species, biomass, veld condition and grazing capacity. The veld condition scores are focused on the grazing potential of each site and not necessarily the diversity of plants present. Forbs, for example, are important for biodiversity and ecology as many are legumes that fix nitrogen which improves the soils and grasses around them.

Sites classified as having a very poor veld condition (Site 4 & 8) occur on abandoned cultivated lands were the soil structure has been previously disturbed and not given enough time to recover. These sites are heavily utilized and have low biomass values (> 960 kg.ha^{-1}) and only poor grazing grass species are present with large areas of bare ground. These sites are also located on the mudstones of the Elliot and Molteno geological formation. These mudstones are highly erodible particularly when the vegetation cover is inhibited.

Sites classified as having a poor veld condition (Site 1, 2, 5 & 6) are heavily grazed with biomass ranging from 1 000-2 000 kg.ha^{-1}. Higher biomass values are present because the sites are located in lower gradient areas where water accumulates stimulating plant growth (e.g. close to wetlands, on alluvial deposits next to rivers or mid-slopes). There is less bare ground visible than in the sites classified as having a very poor veld condition.

Two sites were classified as having a moderate veld condition (Site 3 & 7). Site 3 is located in a managed grazing camp on a private farm and exhibits grasses that provide good grazing despite lower levels of grass biomass than other sites (1 592 kg.ha^{-1}). Site 5 is located on a valley bottom close to a wetland and exhibits the highest biomass of all the sites (2 667 kg.ha^{-1}). Both sites exhibit good grass cover with minimal bare ground and occur at altitudes of greater than 1 350 meters above sea level.

Biomass readings of 4 000 kg.ha-1 or more exhibit high biomass and only then would they benefit from a prescribed burning. Many of the sites are nowhere near this goal for biomass requiring up to 4.5 times the amount of biomass before pre-scribed burning should be considered. Overgrazing is commonly not a function of intensity but rather a function of frequency. Because the catchment is dominated by mudstones that are highly erodible it is important to maintain healthy vegetation cover throughout the catchment. All the sites would benefit by prolonged rest periods to allow for the stabilization of grass and other important plant population through re-growth and full seed production.

TABLE 12: SUMMARY TABLE OF VELD CONDITION, GRASS SPECIES AND GRAZING CAPACITY AT EACH VELD MONITORING SITE

Veld monitoring site	Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score (20=very poor; 80=very good)	Grazing capacity (ha/ large LSU)
1	8	*Sporobolus africanus (50%)*	4.4	1 392	33 Poor	7.9 Poor
2	5	*Sporobolus africanus (32%)*	6.0	1 903	44 Poor	5.9 Poor
3	8	*Themeda triandra (48%)*	5.0	1 592	48 Moderate	5.3 Moderate
4	8	*Sporobolus africanus (76%)*	3.2	958	21 Very Poor	12.6 Poor
5	8	*Digitaria ternata (36%)*	6.6	2 079	38 Poor	6.8 Poor
6	10	*Sporobolus africanus (36%)*	3.6	1 108	30 Poor	8.5 Poor
7	5	*Eragrostis plana (44%)*	8.8	2 667	49 Moderate	5.3 Moderate
8	7	*Sporobolus africanus (46%)*	3.0	881	21 Very poor	12.6 Poor

7.2. Dominant grass species

Table 13 lists the dominant grass species and their characteristics found at monitoring sites in Catchment T35 A-E.

TABLE 13: DOMINANT GRASS SPECIES FOUND ACROSS ALL THE VELD MONITORING SITES (IN ALPHABETICAL ORDER)

Grass Species	Common name (page number: Van Oudtshoorn, 2018)	Plant succession	Grazing value	Grazing status	Perenniality	Notes
Agrostis montevidensis/sp.	Fog Grass		Poor			• Exotic grass
Andropogon eucomus	Snowflake Grass (p.46)	Subclimax	Poor	Increaser 2	Perennial tufted grass (grows for > 5 seasons)	• Unpalatable grass offering little grazing value • Important for stabilising disturbed moist soils • Indicator of poorly drained soils
Aristida adscensionis/sp.	Annual Three-awn (p.108)	Pioneer	Poor	Increaser 2	Annual tufted grass (grows for 1 season)	• Occurs in disturbed areas • Low grazing value due to low leaf production
Bothriochloa insculpta	Pinhole grass (p.217)	Subclimax	Average	Increaser 2	Annual tufted grass (grows for 1 season)	• Useful for soil erosion control in clay soils • Not a preferred grass for grazing due to aromatic smell and taste
Cympopogon nardus	Giant Turpentine Grass (p.55)	Climax	Poor	Increaser 1	Perennial tufted grass (grows for > 5 seasons)	• Contains essential oils • Good thatching grass
Cynodon dactylon	Couch Grass (p.225)	Pioneer	Good	Increaser 2	Creeping grass	• Drought and heavy grazing resistant • Palatable and can be planted as pastures • Excellent soil stabiliser
Digitaria ternata	Black-seed Finger Grass (p.222)	Pioneer	Low	Increaser 2	Annual tufted grass (grows for 1 season)	• Exotic grass • Palatable but has a very low leaf production
Eragrostis chloromelas	Curly Leaf (p.154)	Subclimax to Climax	Average	Increaser 2	Perennial tufted grass (grows for > 5 seasons)	• Palatable early in the season but becomes less palatable due to rolled leaves
Eragrostis curvula	Weeping Love Grass (p.155)	Subclimax to Climax	Average	Increaser 2	Perennial tufted grass (grows for > 5 seasons)	• Good for cultivated pastures for grazing or hay • Low leaf production results in poor palatability in open rangelands
Eragrostis gummiflua	Gum Grass (p.145)	Subclimax	Poor	Increaser 2	Perennial tufted grass (grows for > 5 seasons)	• Tough grass not commonly grazed • Occurs in overgrazed veld • Can be used for broom making

Eragrostis plana	Tough Love Grass (p.138)	Subclimax	Poor	Increaser 2	Perennial tufted grass (grows for > 5 seasons)	• Indicator of overgrazing or veld that is burnt too frequently • Useful for weaving
Hyparrhenia dregeana	Hairy Blue Thatching Grass (p.258)					
Hyparrhenia hirta	Common Thatching Grass (p.52)	Subclimax to climax	Average	Increaser 1	Perennial tufted grass (grows for > 5 seasons)	• Popular thatching grass • Grazed by livestock early in the growing season or after burning • Used for erosion control • Can be used for weaving
Melenis repens	Natal Red-Top (p.156)	Pioneer to subclimax	Poor	Increaser 2	Weak perennial tufted grass (grows for 2-5 seasons)	• Used in stabilising disturbed soil • Has a low leaf yield but is palatable
Miscanthus capensis	Daba Grass (p.198)	Climax	Poor	Increaser 1	Perennial tufted grass (grows for > 5 seasons)	• Prefers moist areas • Grazing and fire resistant
Monocymbium ceresiiforme	Boat Grass (p.60)	Climax	Average	Decreaser	Perennial tufted grass (grows for > 5 seasons)	• Indicator of acidic soils • Most palatable early in the growing season
Paspalum notatum	Bahia Grass (p.241)	Pioneer	Average		Creeping Grass	• Exotic grass • Drought resistant grass • Used in soil stabilisation • Used as a pasture for sheep
Sporobolus africanus	Rat's-Tail Dropseed (p.96)	Subclimax	Poor	Increaser 3	Perennial tufted grass (grows for > 5 seasons)	• Moderate to poor grazing grass due to low and tough leaf yield • Readily grazed in the absence of good grazing grasses • Dominance in veld is an indicator of overgrazing
Themeda triandra	Red Grass (p.48)	Climax	Good	Decreaser	Perennial tufted grass (grows for > 5 seasons)	• Most important grazing grass in open rangelands • Moderate palatability but forms dense stands in healthy rangelands providing good forage for livestock • Resistant to fire and can increase with an increase in fire frequency in the absence of overgrazing • Indicator of veld in a healthy condition
Urochlea mosambicensis	Bushveld Signal Grass (p.246)	Pioneer to Subclimax	Average	Increaser 2	Weak perennial tufted grass (grows for 2-5 seasons)	• Palatable grass with an average leaf production • Indicator of disturbed areas • Can tolerate heavy grazing but reduces with prolonged overgrazing

The chapters in Appendix 1 set out details on each veld monitoring site including species composition and veld condition.

7.3. Analysis of long-term rangeland performance and productivity at five sites in the Catchment T35 A-E and calculation of livestock grazing capacities (Biotrack, 2019)

Trends in rangeland performance and forage production over the past two decades are evaluated at five grassland sites comprising a range of land tenure types, management regimes and condition classes in the T 35 A, B, C, D and E quaternary catchments in the Eastern Cape. Time series of Leaf Area Index (LAI), Normalized Difference Vegetation Index (NDVI), and Net Photosynthetic Activity (PsnNet), analogous to net primary production, derived from surface reflectances retrieved by the MODIS satellite sensor, are analysed using the BFAST package in R. BFAST decomposes the time series data to extract trend and seasonal components and residuals, and detects breakpoints that may reflect vegetation responses to climatic shifts or anthropogenic disturbances. Thematic maps of primary productivity are generated for the entire sub-catchment area, and long-term MODIS estimates of forage availability used to calculate grazing capacities at each of the five study sites.

Of the five study sites, productivity is consistently higher in remote, ostensibly relatively intact grasslands in the upper catchment areas, with lowest production values detected in association with abandoned cultivated lands in communal areas; LAI, NDVI, and PsnNet time series generally demonstrate relatively unique responses in upper and lower catchment sites in terms of both trend directions and the timing of breakpoints, with trends typically more stable and with fewer breakpoints in the former; this may reflect lower levels of human disturbance in these systems, possibly a factor of their remoteness and less palatable grazing characteristic of higher elevations. These differences notwithstanding, across all sites and variables, breakpoints generally coincide in 2003/2004, 2007/2008 and 2010/2011, but show very little agreement between variables after these years; with regards to LAI, breakpoints generally correspond between sites again in 2013/2014, NDVI in 2015/2016, and PsnNet in 2017/2018. Time series at nearly all sites demonstrate gradual declines in productivity overall in the last two decades.

Grazing capacities are calculated to be highest in the lower catchment areas despite lower levels of forage production at these sites (Figure 31), since grasses on alkaline soils in floodplains and valley bottoms are more palatable than 'sour' erect perennial robust grasses in the uplands. Grazing capacities vary from 7.2 – 8.8 hectares per large stock unit (Ha/LSU) in lower catchment sites, to 13.9 – 14 Ha/LSU in the upper catchment sites. Significantly, all grazing capacities calculated in this study are considerably lower than the average long-term grazing norms for the grassland biome provided by DAFF, which are 4 – 6 Ha/LSU.

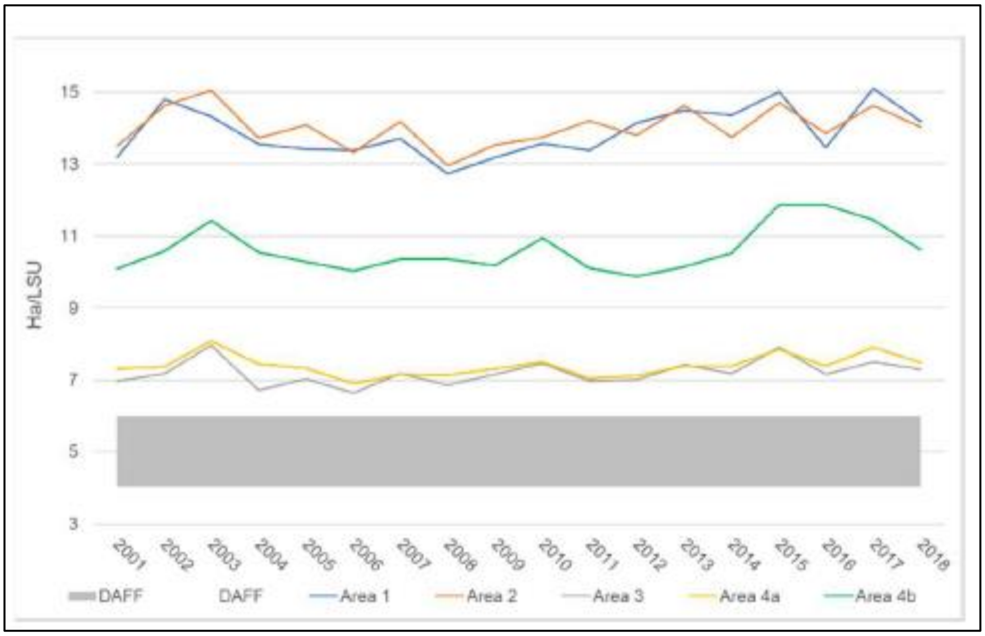


FIGURE 31: ANNUAL GRAZING CAPACITIES CALCULATED FROM 2001-2018 BASED ON FORAGE AVAILABILITY AND VELD TYPES

Three of the Biotrack (2019) sites overlap with the veld monitoring sites described in this report (Figure 32).

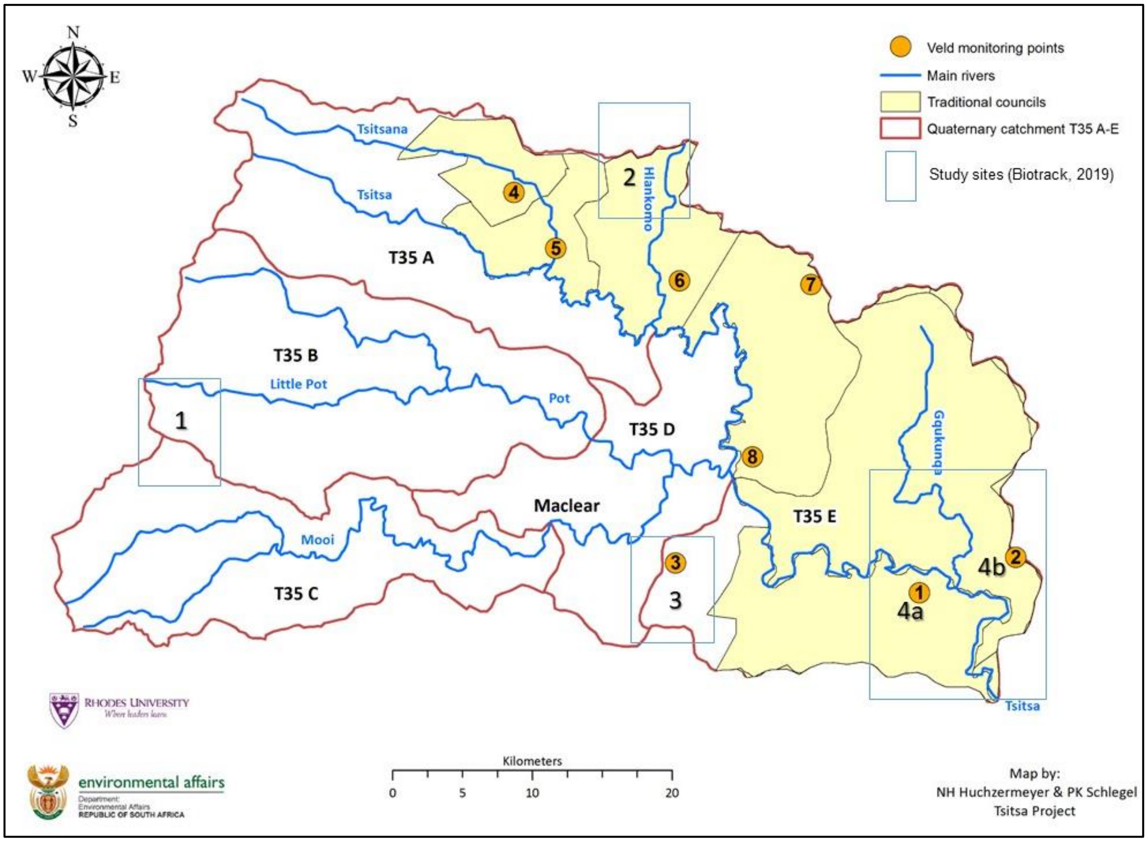


FIGURE 32: BIOTRACK (2019) STUDY SITES IN RELATION TO THE VELD MONITORING SITES

Table 14 lists the differences in estimated grazing capacities for the overlapping sites between Biotrack (2019) and the Tsitsa Project veld monitoring sites. There is a significant difference between the estimated values. It is important to note that the values were estimated at different scales and should be interpreted together with the context of each site and report.

TABLE 14: ESTIMATED GRAZING CAPACITIES FOR OVERLAPPING SITES BETWEEN BIOTRACK (2019) & TSITSA PROJECT VELD MONITORING

Veld monitoring site/Biotrack (2019)	Veld monitoring site (ha/LSU) for 2019	Biotrack (2019) (ha/LSU) for 2018
Site 1/ 4a	7.9	7.4
Site 2/ 4b	5.9	8.8
Site 3/ 3	5.3	7.2

8. WETLAND MONITORING

FIGURE 33: MINIATURE WETLAND IN THE TSITSA CATCHMENT

Over 2800 wetlands were identified covering a total area of over 7 600 ha, ranging from larger valley bottom wetlands to smaller hillslope seep wetlands (Figure 34).

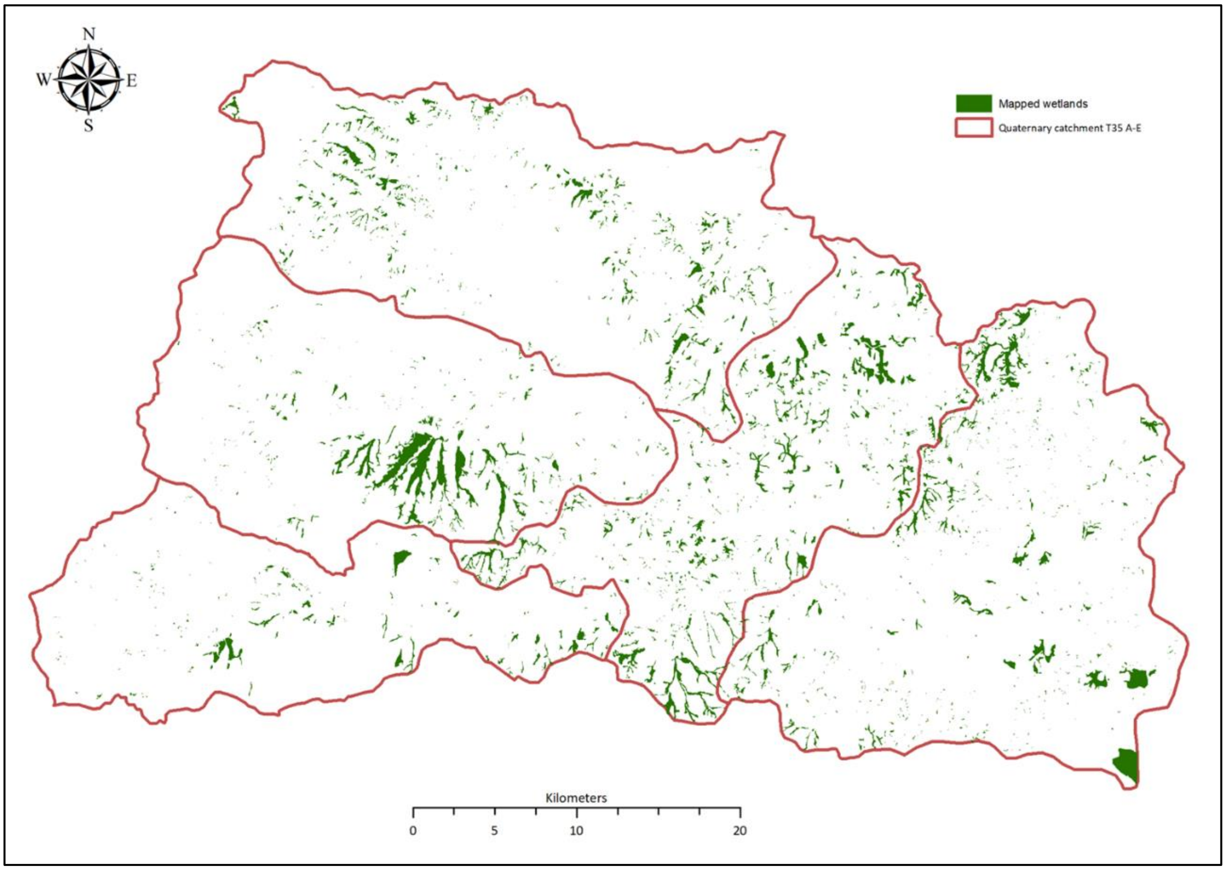


FIGURE 34: MAPPED WETLANDS IN CATCHMENT T35 A-E (SCHLEGEL ET AL., 2018)

A range of wetlands was chosen to investigate their current condition, species composition and look at their effectiveness as sediment buffers in the landscape at a course scale (Figure 35 and Table 15).

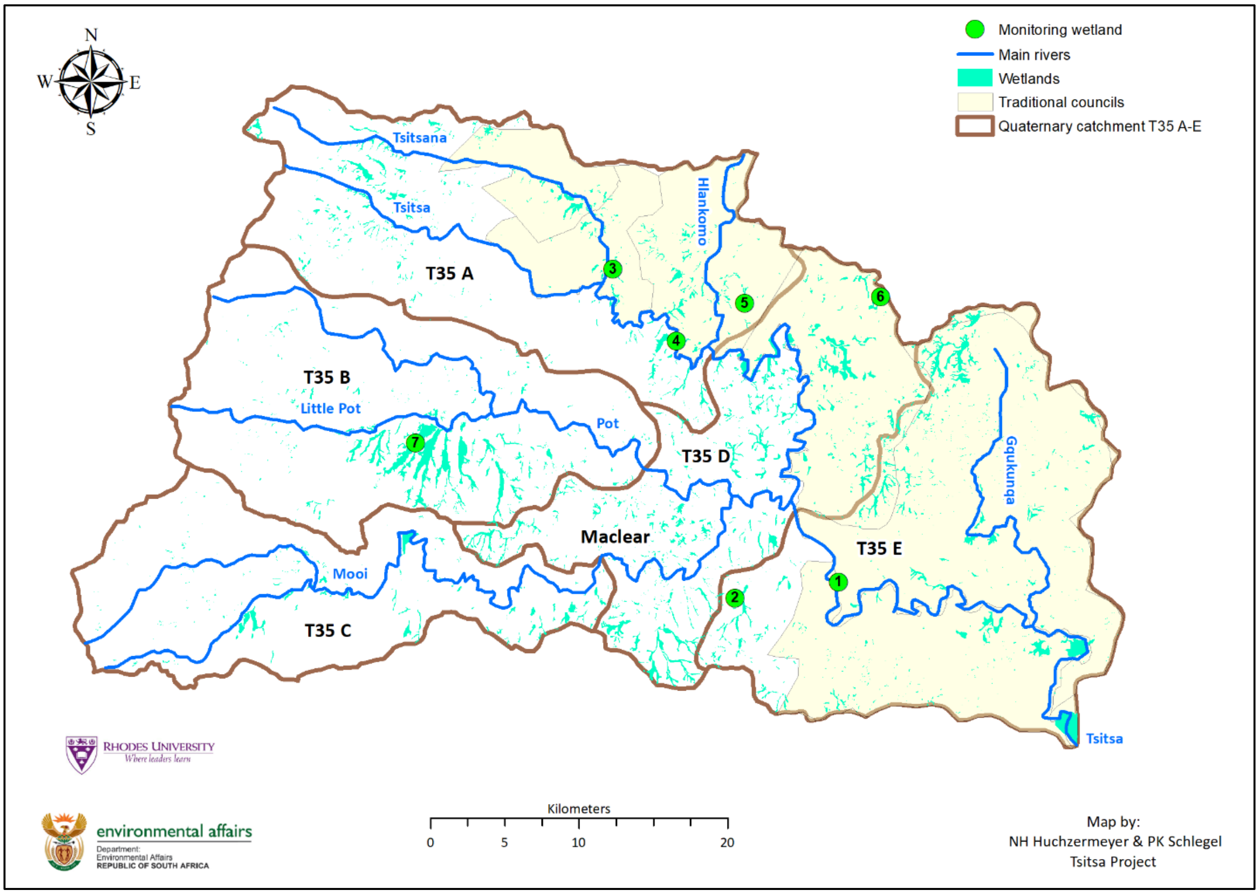


FIGURE 35: WETLAND MONITORING SITES

TABLE 15: SUMMARY OF WETLANDS FOUND IN EACH MONITORING SITE

Wetland no.	Hydro-geomorphic unit type	Wetland area (ha)	Wetland(s) catchment area (ha)	Coordinates	Estimated condition
1	Hillslope seep	0.1	3	31°5'6,438"S 28°31'15,131"E	Good
2	Hillslope seep	0.1	7	31°5'40,528"S 28°26'52,817"E	Fair
3.1	Depression	1.2	304	30°53'40,266"S 28°21'47,154"E	Poor
3.2	Un-channelled valley bottom	10.4			
3.3	Un-channelled valley bottom	6.0			
4.1	Un-channelled valley bottom	15.2	101	30°56'18,568"S 28°24'26,736"E	Fair
4.2	Hillslope seep	4.7			
4.3	Hillslope seep	1.5			
5	Hillslope seep	1.9	11	30°54'56,264"S 28°27'20,945"E	Good
6	Un-channelled valley bottom	42.9	161	30°54'43,458"S 28°33'5,555"E	Fair
7	Floodplain	291.6	2945	30°59'57,904"S 28°13'23,335"E	Good

Most of the investigated wetlands were found to be in a good to fair condition and are acting as important sediment sinks in the landscapes. The biggest risks to the wetlands are alien vegetation, erosion at the toe of the wetlands and potential incision of drainage lines that will cause water sourced at the head of the wetlands to bypass the wetland floodplain and enter the main river channels directly.

Details of each wetland site can be found in Appendix 3.

9. FORESTS

Indigenous vegetation (both forests and other smaller woody species) are important **biodiversity hot spots** that also provide a variety of building materials and are important for cultural (fighting sticks and bark for medicine) and spiritual values (Geldenhuys *et al.,* 2016; Ngwenya, 2016. The indigenous forests occur in fire shadow areas of ravines and steep south facing slopes that are protected by cliffs. Assessments of forests pointed to a healthy population structure, but fire and alien pressures do threaten the outer limits of the forests (Geldenhuys *et al.* 2016).

Restoration and management are needed to improve the quality and sustainability of indigenous forests.

For the level 1 classification indigenous vegetation was split into 2 classes namely, Indigenous Forest and Indigenous. The Indigenous Forest class consists of indigenous forests with larger trees as identified by Geldenhuys *et al.* 2016. This data was augmented and verified during the field work. The Indigenous class consist of other indigenous woody vegetation (small trees, shrubs and bushes) that do not necessarily occur in a forest and have different management implications for example, *Leucosidea sericea* (Ouhout) and *Vachellia karoo*.

There are a total of 4 243 patches dominated by indigenous plants, with a total area of 3 985 ha (this excludes patches of vegetation that have indigenous plants but are dominated by alien vegetation). Of this 466 (1 575 ha) were identified as Indigenous Forest patches and 3 777 (2 410 ha) patches were identified as other indigenous vegetation (small trees, shrubs and bushes).

Fire and alien management are the main drivers to the degradation of the forest fringes and should be targeted in the restoration and protection efforts. Many of the indigenous species such as Ouhout are pioneer species and may contribute to bush encroachment followed by a reduction in grazing potential in the catchment. This is particularly relevant in disturbed areas. However, indigenous vegetation is an important aspect of the natural environment and contributes to the overall biodiversity of the catchment.

FIGURE 36: POCKETS OF INDIGENOUS FOREST IN WHICH, AMONG MANY SPECIES, LARGE YELLOWWOOD (PODOCARPUS SPECIES) TREES ARE FOUND

FIGURE 37: *LEUCOSIDEA SERICEA* (OUHOUT) ON A HILLSLOPE. THIS IS A PIONEER SPECIES AND CAN CONTRIBUTE TO BUSH ENCROACHMENT IN DISTURBED AREAS. HOWEVER, INDIGENOUS VEGETATION ALSO CREATES NATURAL REFUGE FOR OTHER SPECIES SUCH AS THE COMMON DUIKER

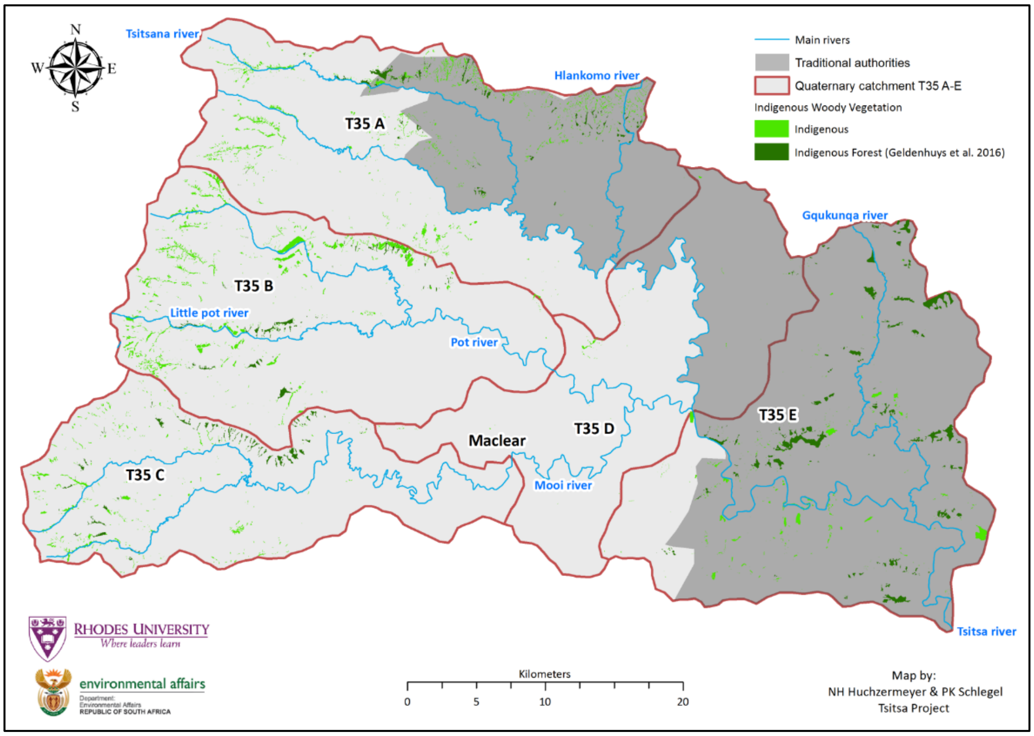


FIGURE 38: LOCATION OF INDIGENOUS FORESTS AND OTHER INDIGENOUS VEGETATION IN CATCHMENT T35 A-E

10. ALIEN INVASIVE PLANTS (AIPS)

Alien plant species are those species that are considered non-indigenous to an ecosystem. South Africa has a long history of problems with Invasive Alien Plants (IAPs) and corresponding research and management of biological invasions. Van Wilgen & Wilson (2018) report that the monetary value of impacts generated by invasive species in South Africa result in economic losses of up to R6 500 million per year. This is mostly due to loss of water runoff, livestock production from invaded rangelands and income from biodiversity-related goods and services (van Wilgen & Wilson, 2018). Many IAPs are products of unwise and unintentional plant introductions (typically with an economic or aesthetic incentive).

According to South Africa's Alien and Invasive Species Regulations there are a total of 556 alien taxa listed as invasive and many more taxa that are also invasive species but not listed (van Wilgen & Wilson, 2018). The NEMBA (Act 10 of 2004) requires [section 75 (4)] the Minister of Environmental Affairs to ensure the coordination and implementation of programmes for the prevention, control or eradication of invasive species.

The Tsitsa Catchment (T35) falls within the grassland terrestrial biome. The grassland biome covers a large area and includes some of the most important water source areas in the country (van Wilgen *et al.* 2008). SANBI (2013) state that grassland ecosystems provide many essential ecosystem services which are underpinned by a rich biodiversity. However, the integrity of the grassland biome is threatened by disturbances such as unsustainable land use and the encroachment of alien vegetation. Poor grassland management, particularly over-grazing and the incorrect application or exclusion of fire, leads to infestation by woody invasive alien species (such as Australian wattle spp., *Acacia* species), as well as shrubs (such as bramble, *Rubus* species). As the ecosystem becomes negatively affected by poor management, the natural resilience to infestation by invasive alien species is reduced and this can ultimately lead to a complete modification of the grassland into a stand of woody invasive alien plants. Ideally, there should be no invasive alien species (or only very few) in a healthy grassland.

The following is taken from Huchzermeyer *et al.* (2018a). A total of 37 dominant alien woody species were identified in Catchment T35 A-E of which 7 species (silver wattle, black wattle, green wattle, poplar, eucalyptus, pine and Mauritius thorn) are invading hillslopes, riparian zones and indigenous vegetation on a large scale. Approximately 51% of the area covered by alien woody vegetation occurs on hillslopes, 43% in the riparian zones and the remaining 6% are spreading from drainage lines, plantations, gardens and woodlots. 56% of the alien vegetation category was verified in the field. From the alien vegetation category verified in the field only 3% was noted to be actively used and harvested to such an extent that it was no longer spreading. This is particularly evident within close walking distance of villages.

The main alien species in Catchment T35 A-E can be detailed as follows:

- **Silver wattle:** A total of 6 955 patches (uncondensed area of 5 502 ha). Of those 3 671 (3 326 ha) of the patches consist of 50 percent and above Silver wattle.
- **Black wattle:** A total of 280 patches (uncondensed area of 262 ha). Of those, 246 (239 ha) of the patches consist of 50 percent and above Black wattle.
- **Green wattle:** A total of 441 patches (uncondensed area of 222 ha). Of those, 243 (97 ha) of the patches consist of 50 percent and above Green wattle.
- **Black and Green wattle co-existing:** A total of 6 675 patches (uncondensed area of 5 398 ha).
- **Mauritius thorn:** A total of 60 patches (uncondensed area of 3.8 ha). However, there might be a higher abundance as they are difficult to identify off aerial photographs and commonly occur in drainage lines and gullies where remote sensing techniques are limited.
- **Eucalyptus species:** A total of 1 028 patches (uncondensed area of 1 293 ha) occur outside of the plantation areas. Of those, 331 (343 ha) of the patches consist of 50 percent and above Eucalyptus species.
- **Pine species:** There are a total of 228 patches (uncondensed area of 137 ha) occur outside of the plantation areas. Of those, 39 (21 ha) of the patches consist of 50 percent and above Pine species.
- **Poplar species:** A total of 917 patches (uncondensed area of 1 099 ha). Of those 190 (160 ha) of the patches consist of 50 percent and above of Poplar species.

In the grasslands of Catchment T35 IAPs pose a threat to rangeland functioning and extent (van Wilgen & Wilson, 2018). Large areas of degraded hillslopes and riverine habitat have been invaded by woody IAPs, for example, *Acacia mearnsii* (Black wattle), *Acacia decurrens* (Green wattle), *Acacia dealbata* (Silver wattle) *and Pinus patula* (Patula pine) (Clark, 2018; Huchzermeyer *et al.*, 2018a).

Clark (2018) conducted a future forecasting for IAPs in the Tsitsa Catchment. A simple horizon detection was undertaken to determine which IAPs are currently present and which additional IAPs may invade the Tsitsa Catchment in the future. The following key points can be taken from Clark (2018) for the management of present and future IAPs in the Tsitsa Catchment:

- In terms of ecological impact and spatial extent, the most extensive species are most likely to be **Australian Acacias (*A. dealbata, A. mearnsii*, *A. decurrens*** and possibly ***A. melanoxylon*)**,
- Other woody invaders comprising a significant threat to either water production or riparian functioning (notably *Pinus patula, Populus x canescens, Robinia pseudo-acacia* and *Salix* spp., but also likely

Cotoneaster spp., *Gleditsia triacanthos, Eucalyptus* spp., *Melia azedarach*, *Populus deltoides, Pyracantha* spp., *Rosa rubig*inosa and *Rubus* spp.).

- Commercial timber species like *Pinus patula* are likely to continue invading the landscape.
- The presence and spread of ornamental species is likely to be associated with urban centers such as Maclear. It is important to assess nodes and factors of invasion such as:
    - Suburban gardens in towns (many ornamental species).
    - Main through roads acting as a disturbed corridor for linear spread.
    - Intentional introductions in urban areas, farmsteads, kraals and plantations.
    - An already degraded environment makes it easier for invasions to spread.
- Herbaceous and graminoid (non-woody) invaders **should not** be overlooked because they do not pose as great a risk on water abstraction as woody species. Herbaceous and graminoid species can be hard to identify in the landscape but can have significant effects on the health of rangelands and in turn affect the livelihoods of stakeholders in the catchment.
- The three South American tussock grasses introduced to South Africa – namely *Nassella neesiana* (Chilean Needle Grass), *N. tenuissima* (White Tussock) and *N. trichotoma* (Serrated Tussock) – and the rapidly spreading *Campuloclinium macrocephalum* (Pompom Weed), are considered as top priority for future catchment management.

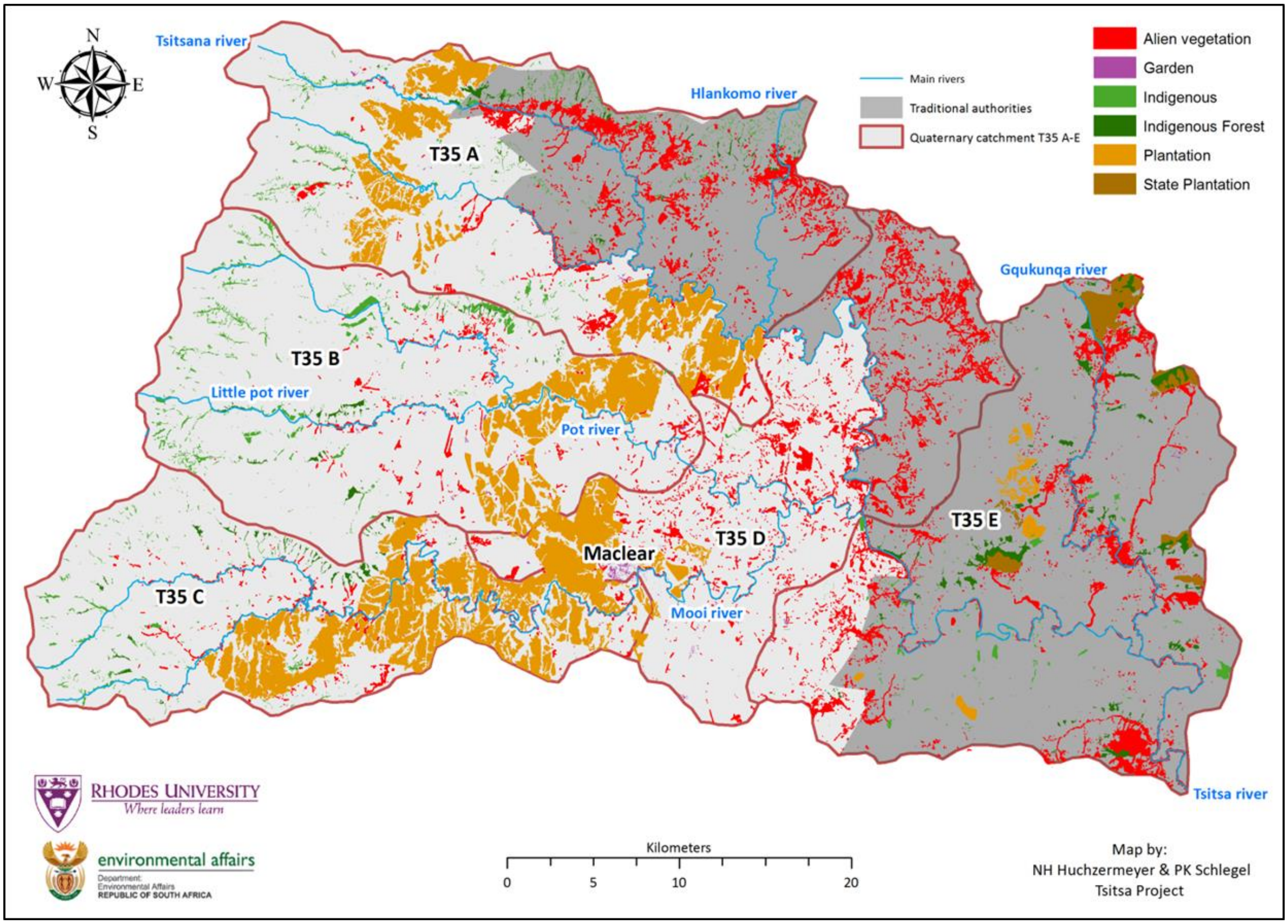


Figure 39: Mapped woody vegetation in Catchment T35 A-E showing alien vegetation extent (Huchzermeyer et al., 2018a)

11. SUMMARY OF THE CONDITION OF TSITSA CATCHMENT

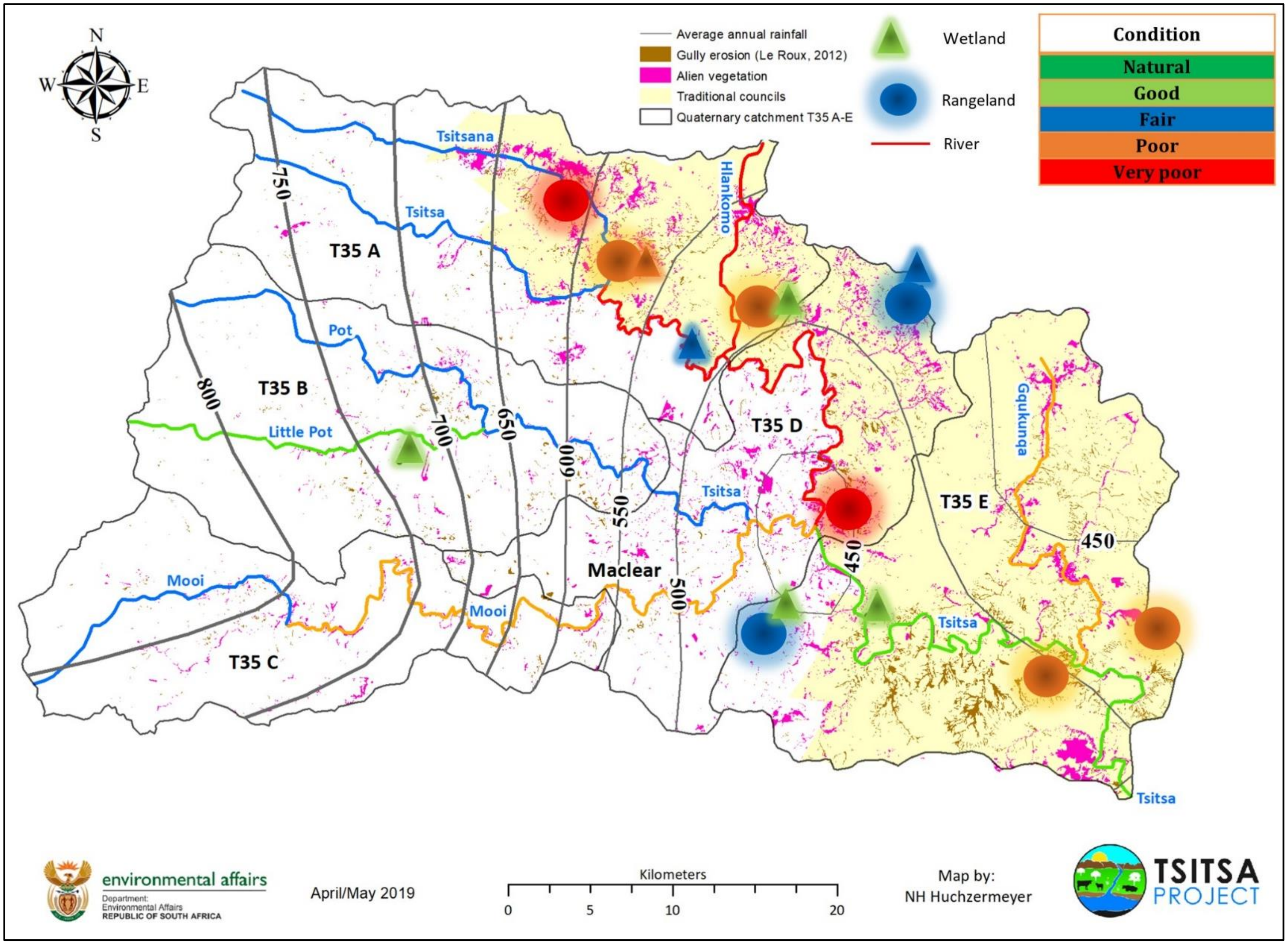


Figure 40: Condition of the Tsitsa Catchment following field surveys in April 2019

12. FURTHER WORK

- State of Riparian areas can be assessed at each river monitoring site using the Riparian Vegetation Response Assessment Index (VEGRAI)
- Link the rainfall spikes in hydrology, increased sediment yields etc.
- Channel classifications for all the river monitoring sites in Catchment T35 A-E
- Landscape Function Analysis (LAF) for veld monitoring
- Camera trap surveys within natural forest pockets to describe relic populations of fauna.

13. STUDENT PROJECTS

Data collected by the biophysical monitoring team can be used to augment data collected for student projects. For example, Herd-Hoare (2018) is investigating the wet season interaction between rainfall intensity, vegetation cover and sediment flux in different areas of Catchment T35. Rainfall and sediment data is being sourced from the Tsitsa Project biophysical monitoring group for this study.

14. DATA MANAGEMENT

The Tsitsa Project Biophysical Monitoring Group is a steward of the data that is a product from our inventory and monitoring work in the Tsitsa River Catchment. While this information is useful and crucial today, it will become even more valuable in the years and decades to come. From planning, to field work, and through to analysis, priorities will be placed on:

- Data Accuracy.

  The quality of the biophysical data we collect is paramount. Analyses to detect trends or patterns require data with minimal error and bias. To ensure data of the highest possible quality, we will use procedures to minimize, identify, and correct errors at every stage of the data life cycle.
- Data Security.

  Data must be protected against loss. Data will be securely stored.
- Data Longevity.

  Data sets need to be cared for. Processing documentation will accompany all data sets.
- Data Accessibility.

  Data will be made available in a variety of formats to any interested and affected stakeholders through the TP knowledge hub.
- Student data collection warrants an embargo period in which a full dataset cannot be shared until the student has published and released their data.

15. REFERENCES

Apitz, S. E. 2012. Conceptualizing the role of sediment in sustaining ecosystem services : Sediment-ecosystem regional assessment (SEcoRA). *Science of the Total Environment,* 415: 9–30.

Bannatyne, L.J. 2018. *Developing a Citizen Technician Based Approach to Suspended Sediment Monitoring in the Tsitsa River Catchment, Eastern Cape, South Africa.* Rhodes University (Unpublished MSc).

Behar, S. 1997. *Testing the Waters: Chemical and Physical Vital Signs of a River*. Montpelier, VT: River Watch Network. ISBN 0787234923.

BioTrack, 2019. *Analysis of long-term rangeland performance and productivity at five sites in the Tsitsa T 35 A, B, C, D and E quaternary catchments, and calculation of livestock and grazing capacities.* BioTrack report for the Tsitsa Project.

Brandt, S. A. 2000. Classification of geomorphological effects downstream of dams. *Catena,* 40: 375–401.

Clark, V.R. 2018. *Notes on a Preliminary Invasive Plant Species Horizon-scanning for the Tsitsa Catchment.* Tsitsa Project Report.

Dallas, H.F. & Day, J.A. 2004. *The Effect of Water Quality Variables on Aquatic Ecosystems : A Review*. WRC Report No. TT 224/04.

Dallas, H.F. 2007. *South African Scoring System (SASS) data intepretation.* River Health Programme, September 2007.

Department of Water Affairs and Forestry (DWAF). 1996. *South African Water Quality Guidelines, Volume 7; Aquatic Ecosystems.* Produced by the CSIR Environmental Services, Pretoria for the Department of Water Affaris and Forestry, Pretoria, South Africa.

Department of Water and Sanitation (DWAS), 2019. Hydrological Services - Surface Water (Data, Dams, Floods and Flows), DWAS, Republic of South Africa. [Online]. Available: www.dwa.gov.za/Hydrology/. [01/09/2019].

Díaz, A.M., Alonso, M.L.S. & Gutiérrez, M.R.V.A. 2008. Biological traits of stream macroinvertebrates from a semi-arid catchment: patterns along complex environmental gradients. *Freshwater Biology,* 53: 1–21.

Dickens, C. W. S. & Graham, P. M. 2002. The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers. *African Journal of Aquatic Sciences,* 27: 1–10.

Geldenhuys, C; Funda, O; Aromaye, T; & Mugure, M., 2016. Evaluation of natural forests in the Ntabelanga quaternary catchments in the Maclear area in relation to resource use management (No. FW-04/16). Forestwood CC, Pretoria, South Africa.

Gordon, N. D., McMahon, T. A., Finlayson, B. L., Gippel, C. J. & Nathan, R. J. 2004. *Stream Hydrology: An Introduction for Ecologists,* Second Edition. Wiley: Chichester, 440 pp. ISBN: 978-0-470-84357-4.

Gerber, A. & Gabriel, M. J. M. 2002. *Aquatic Invertebrates of South African Rivers: Field Guide*, First Edition. Institute for Water Quality Studies. Department of Water Affairs and Forestry.

Graham, P. M., Dickens, C. W. S. & Taylor, R. J. 2004. MiniSASS — A novel technique for community participation in river health monitoring and management. *African Journal of Aquatic Science,* 29(1): 25–35.

Huchzermeyer, N.H. 2017. *A baseline survey of channel geomorphology with particular reference to the effects of sediment characteristics on ecosystem health in the Tsitsa River, Eastern Cape, South Africa.* Rhodes University (Unpublished MSc).

Huchzermeyer, N.H., Schlegel, P.K. & van der Waal, B. 2018a. *Woody vegetation in Catchment T35 A-E: mapping and classifying the extent of woody vegetation with an emphasis on alien invasive species.* Tsitsa Project: Mapping report.

Huchzermeyer, N.H., Sibiya, S., Schlegel, P.K. & van der Waal, B. 2018b. *Cultivated Lands in the Upper Tsitsa River Catchment T35 A-E. Cultivated land mapping: level of degradation and vulnerability to erosion.* Tsitsa Project: Mapping report.

Huchzermeyer, N.H., Schlegel, P.K., van der Waal, B. & Clark, V.R. 2019a. Managing invasive alien plants in the upper Tsitsa River Catchment. Tsitsa Project: Management Plan.

Huchzermeyer, N.H., Schlegel, P.K. & van der Waal, B. 2019b. *Biophysical monitoring methods in the upper Tsitsa River Catchment.* Tsitsa Project: Ecosystem report.

Le Roux, J.J., Barker, C.H., Weepener, H.L., van den Berg, E.C., & Pretorius, S.N. 2015. Sediment yield modelling in the Mzimvubu River Catchment. WRC Report 2243/1/15. Water Research Commission: Pretoria.

Mucina, L., Hoare, D.B., Lotter, M.C., Du Preez, P.J., Rutherford, M.C., Scott-Shaw, C.R., Bredenkamp, G.J., Powrie, L.W., Scott, L., Camp, G.T., Cilliers, S.S., Bezuidenhout, H., Mostert, T.H., Siebert, S.J., Winter, P.J., Burrows, J.E., Dobson, L., Ward, L., Stalmans, M., Oliver, E.G., Siebert, G., Schmidt, E., Kobisi, K. & Kose, L. 2006. Grassland Biome. In: Mucina, L., Rutherford, M.C. (Eds.), *The Vegetation of South Africa, Lesotho and Swaziland*. South African National Biodiversity Institute: Pretoria, pp 349-431.

Ngwenya, M. 2016. Participatory identification of key places and species valued by Shukunxa residents in the Ntabelanga dam catchment. Honours Dissertation. Department of Environmental Science, Rhodes University.

Nyamela, N. 2018. The Suspended Sediment Yield and Provenance of the Inxu River Catchment, Eastern Cape. Rhodes University (Unpublished MSc).

Partridge, T., Dollar, E., Moolman, J. & Dollar, L. 2010. The geomorphic provinces of South Africa, Lesotho and Swaziland: A physiographic subdivision of earth and environmental scientists. *Transactions of the Royal Society of South Africa,* 65: 1–47.

Pennack, R. 1971. Toward a Classification of Lotic Habitats. *Hydrobiologia,* 38: 321–334.

Rowntree, K. M. 2013. Module B: *Geomorphology Driver Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2).* Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No TT 551/13.

Schlegel, P., Huchzermeyer, N. & Van der Waal., B. 2018. *Wetlands in Catchment T35 A-E: Wetland type, current condition and rehabilitation prioritisation.* Ecosystem report, Tsitsa Project, Rhodes University.

Schlegel, P., Huchzermeyer, N. & Van der Waal., B. 2019. *Biophysical Monitoring Plan of the Upper Tsitsa River Catchment (T35 A-E)*. Ecosystem report, Tsitsa Project, Rhodes University.

Snyman, G. 2019. *An investigation into the fire regimes of the Upper Tsitsa River catchment.* Rhodes University. MSc in progress.

Trollope, C. 2016. *Identifying sources of sediments through Sediment Tracing in the Tsitsa River Eastern Cape, South Africa.* Rhodes University: Honours thesis.

Türkmen, G. & Kazanci, N. 2010. Applications of various diversity indices to benthic macroinvertebrate assemblages in streams in a national park in Turkey. *Review of Hydrobiology,* 3(2): 111–125.

Van der Waal, B. 2015. *Sediment Connectivity in the Upper Thina Catchment, Eastern Cape, South Africa*. Rhodes University (Unpublished PhD).

Van der Waal, B. & Rowntree, K.M., 2017. Landscape Connectivity in the Upper Mzimvubu River Catchment: An Assessment of Anthropogenic Influences on Sediment Connectivity. *Land Degradation and Development,* 29: 713–723. https://doi.org/10.1002/ldr.2766

Van Oudtshoorn, F. 2015. Veld Management: Principles and Practices. First Edition. ISBN: 978-1-920217-23-7

Van Oudtshoorn, F. 2018. Guide to Grasses of southern Africa. Third revised edition, third impression. ISBN: 978-1-920217-38-8

16. APPENDIX 1: SITE SPECIFIC VELD CONDITION ASSESSMENT

16.1. Veld monitoring Site 1

Veld monitoring Site 1 is located on an abandoned cultivated land and used by local livestock for grazing (Figure 41). The veld condition is poor due to the dominance of poor grazing grasses and very poor ground cover. Table 16 summarises the condition at Site 1 as well as the current grazing potential.

TABLE 16: SUMMARY OF VELD CONDITION AT SITE 1

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition	Grazing capacity (ha/ large LSU)
8	*Sporobolus africanus (50%)*	4.4	1 391.5	33 Poor	7.9

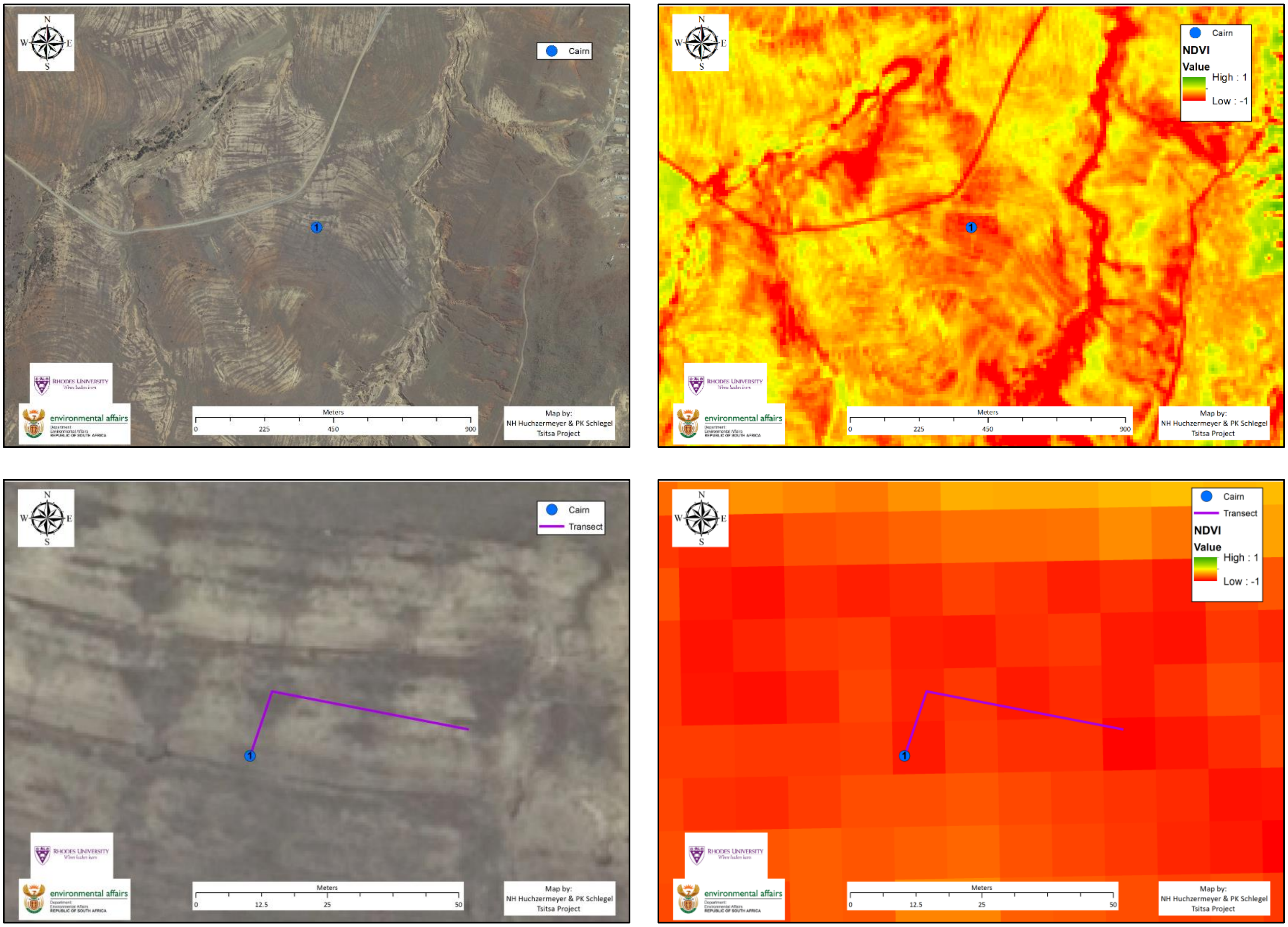


FIGURE 41: LOCATION OF VELD MONITORING SITE 1

16.1.1. Fixed point photography 25.04.2019 10h00

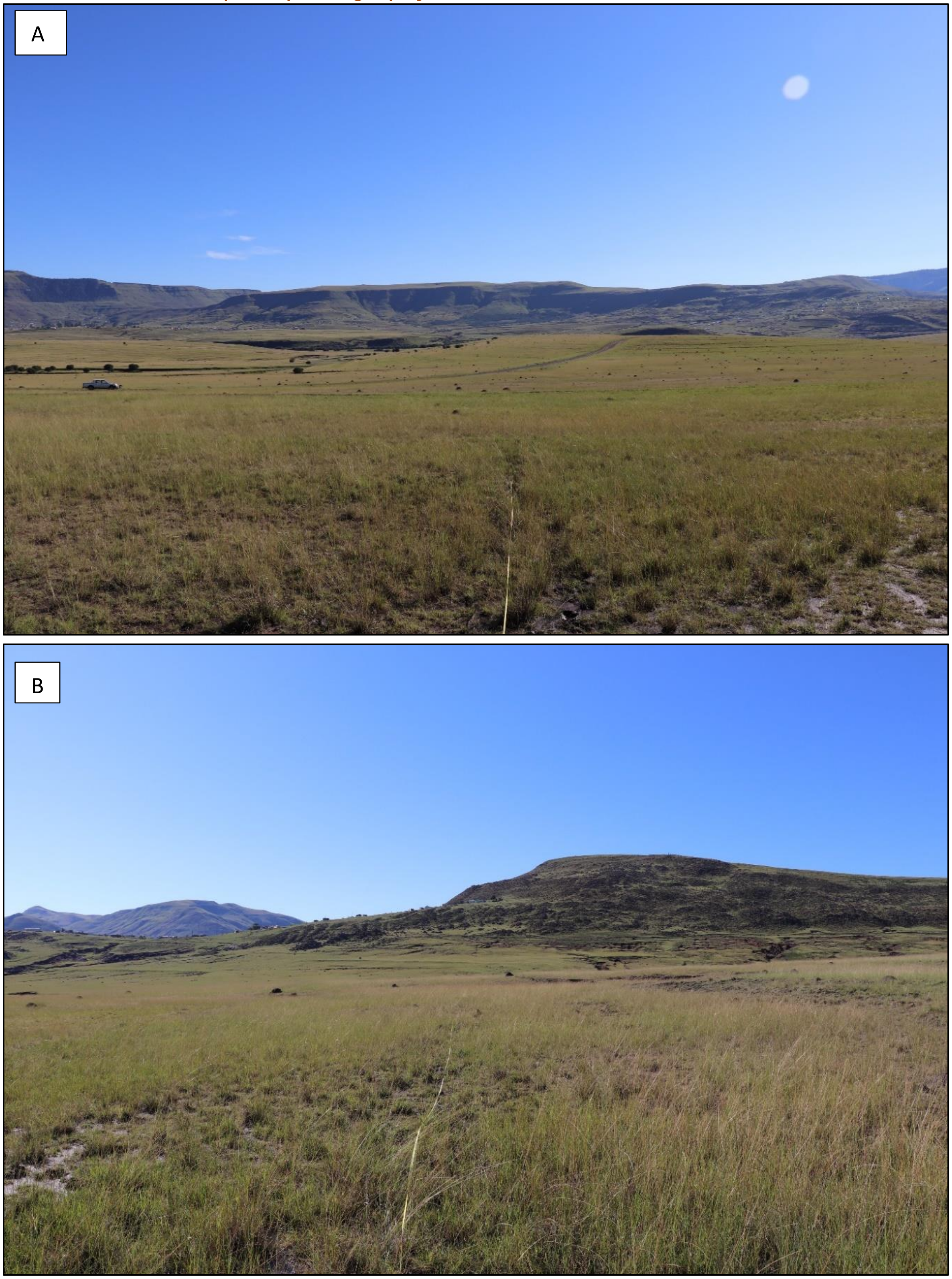


FIGURE 42: LANDSCAPE LAYOUT OF SITE 1. A) 15 M TRANSECT DOWNSLOPE; B) 35 M TRANSECT PERPENDICULAR TO THE SLOPE

Figure 43: Portrait layout of site 1. A) 15 m transect downslope; B) 35 m transect perpendicular to the slope

16.1.2. Species Composition

Grass Species Transect | Site name: Ngecele | Site no.: 1 | GPS: 31°06’57.1”S; 28°37’48.1”

Date: 25/04/2019 | Time: 10h00 | Assessor: N Huchzermeyer & P Schlegel

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total		Total	Total (%)
		Hit on bare ground	Hit on a forb						
1	*Sporobolus africanus*	IIIII IIIII IIIII I		16	IIIII IIII	9		25	50
2	*Aristida sp.*	III		3	I	1		4	8
3	*Eragrostis plana*	IIIII IIII		9	IIII	4		13	26
4	*Bothriochloa insculpta*			0		0		0	0
5	*Aristida adscensionis*	III		3		0		3	6
6	*Cynodon dactylon*	I		1	II	2		3	6
7	*Hyperrhenia hirta*			0	I	1		1	2
8	*Urochlea mosambicensis*	I		1		0		1	2
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
	Total			**33**		**17**		**50**	
	Total (%)			**66**		**34**			**100%**

FIGURE 44: FIELD FORM SHOWING GRASS SPECIES FOUND AT SITE 1

16.1.3. Biomass & grazing capacity

The average disc pasture meter height for site 1 is 4.4 cm with a standard deviation of 2.5 cm. This can be converted to **1 391.5 kg.ha^{-1}**.

16.1.4. Multi-criteria assessment (Van Oudtshoorn, 2015)

Site Description Site 1:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage (%) occurrence	Grazing value
Sporobolus africanus	50	Poor
Eragrostis plana	26	Poor
Aristida sp.	8	Poor
Aristida adscensionis	6	Poor
Cynodon dactylon	6	Good
Hyperrhenia hirta	2	Average
Urochlea mosazmbicensis	2	Average

Common Trees on site:

- *Vachellia karoo*

Percentage hits on Forbs along transect:

0 %

Comments:

Abandoned/discontinued field. Used for livestock grazing (Figure 45). Low grass cover and heavily utilized.

Site 1 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	5
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	
B.	How many good grazing grasses are present? (quality grazing)		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	3
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	
C.	How good is the ground cover?		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	3
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	
D.	How much encroachment by unwanted plants is present?		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	9
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	
E.	How is the soil surface condition/erosion?		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	5
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	Soil Depth			Score F:
		Deep	Shallow	Gravelly	
1	Sandy soil (< 10% clay)	2-4	-3	-5	8
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	
Veld Condition Score = A+B+C+D+E+F					33
Veld Condition					POOR

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average rainfall (see Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity for Site 1 = 7.9 ha/large LSU

FIGURE 45: LIVESTOCK GRAZING AT SITE 1

16.2. Veld monitoring Site 2

Site 2 occurs on a mid-slope and exhibits good ground cover and soils but it is dominated by poor grazing grasses.

TABLE 17: SUMMARY OF VELD CONDITION AT SITE 2

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score	Grazing capacity (ha/ large LSU)
5	*Sporobolus africanus (32%)*	6.0	1 903.4	44 Poor	5.9

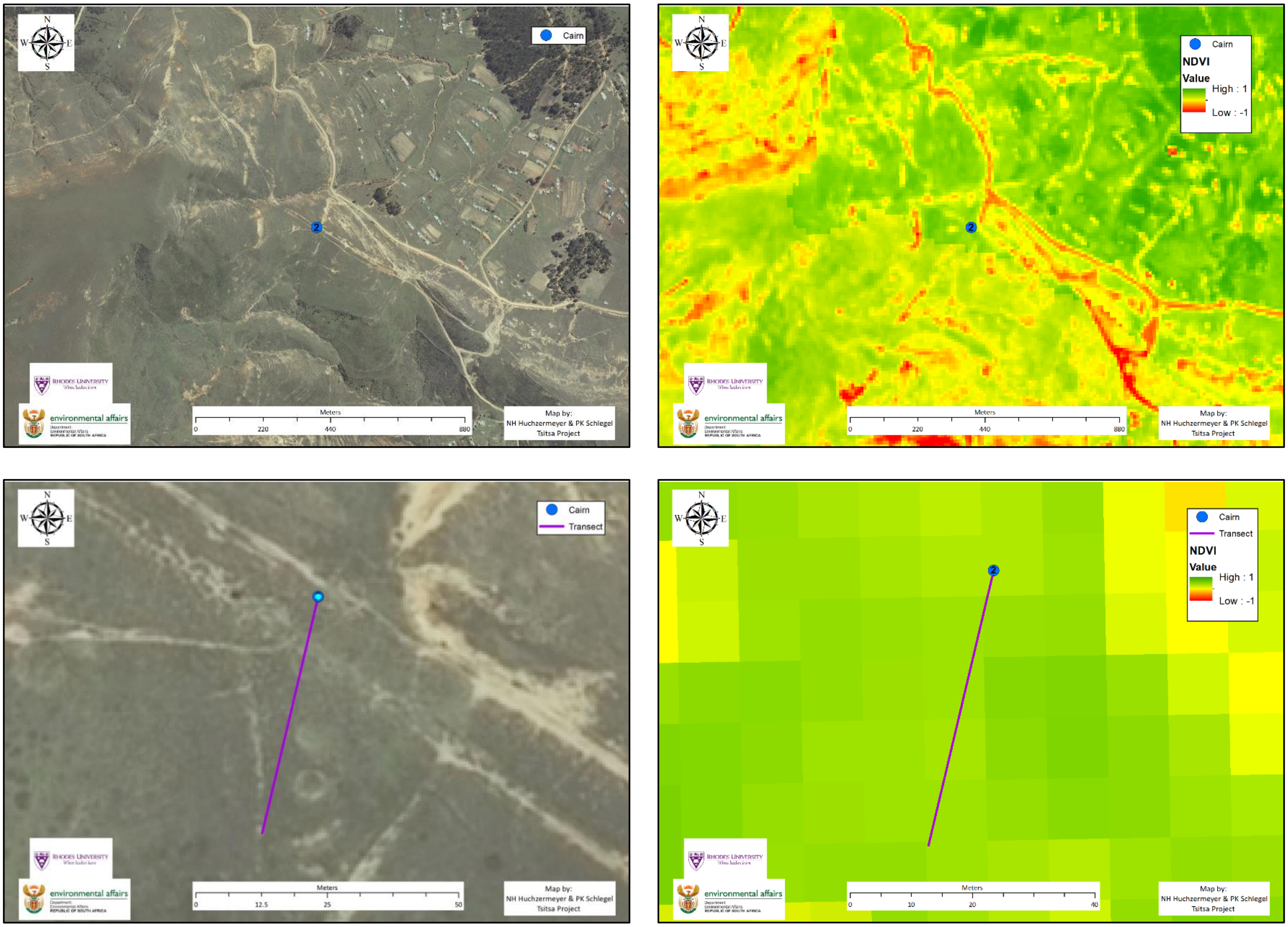


FIGURE 46: LOCATION OF VELD MONITORING SITE 2

16.2.1. Fixed point photograph 25.04.2019 12h30

FIGURE 47: LANDSCAPE LAYOUT OF SITE 2 WITH A 50 M TRANSECT ACROSS THE SLOPE

FIGURE 48: PORTRAIT LAYOUT OF SITE 2 WITH A 50 M TRANSECT ACROSS THE SLOPE

16.2.2. Species Composition

Grass Species Transect **Site name:** Northern Pondomise **Site no. :** 2 **GPS:** 31°05'35.5"S; 28°42'08.9"E

Date: 25/04/2019 **Time:** 13h50 **Assessor:** N Huchzermeyer & P Schlegel

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total	Total	Total (%)
		Hit on bare ground	Hit on a forb					
1	*Cynodon dactylon*	I		1	IIIII III	8	9	18
2	*Sporobolus africanus*	IIIII III		7	IIIII IIII	9	16	32
3	*Eragrostis plana*	IIIII		5	IIIII I	6	11	22
4	*Miscanthus capensis*	II		2	III	3	5	10
5	*Paspalum notatum*	I		1	IIIII III	8	9	18
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Total			**16**		**34**	**50**	
	Total (%)			**32**		**68**		**100%**

Figure 49: Field form showing grass species found at Site 2

16.2.3. Biomass & grazing capacity

The average disc pasture meter height for site 2 is 6.0 cm with a standard deviation of 2.3 cm. This can be converted to **1 903.4 kg.ha^{-1}**.

16.2.4. Multi-criteria assessment (Van Oudtshoorn, 2015)

Site Description Site 2:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage occurrence	Grazing potential
Sporobolus africanus	32	Poor
Eragrostis plana	22	Poor
Cynodon dactylon	18	Good
Paspalum notatum	18	Average
Miscanthus capensis	10	Poor

Common Trees on site:

- *Caesalpinia decapetala* (Mauritius thorn)

Percentage occurrence of Forbs along transect:

- 0% hits
- Present but not abundant

Comments:

Midslope. Moist area possibly hillslope seepage. Signs of grazing present but not overgrazed.

Site 2 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	10
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	
B.	**How many good grazing grasses are present? (quality grazing)**		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	3
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	
C.	**How good is the ground cover?**		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	8
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	
D.	**How much encroachment by unwanted plants is present?**		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	9
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	
E.	**How is the soil surface condition/erosion?**		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	7
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	Soil Depth			Score F:
		Deep	Shallow	Gravelly	
1	Sandy soil (< 10% clay)	2-4	-3	-5	7
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	
	Veld Condition Score = A+B+C+D+E+F				44
	Veld Condition				Poor

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average rainfall (see: Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity = 5.9 ha/large LSU

16.3. Veld monitoring Site 3

Site 3 is situated in a grazing camp on a private farm (Figure 50). Table 18 summarises the veld condition at Site 3. It exhibits a moderate veld condition and a large proportion of the grass present is grass with a good grazing value. However, over utilisation and reduction in ground cover and biomass is reducing the veld condition score.

TABLE 18: SUMMARY OF VELD CONDITION AT SITE 3

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass ($kg.ha^{-1}$)	Veld condition	Grazing capacity (ha/ large LSU)
8	*Themeda triandra (48%)*	5.0	1 591.5	48 Moderate	5.3

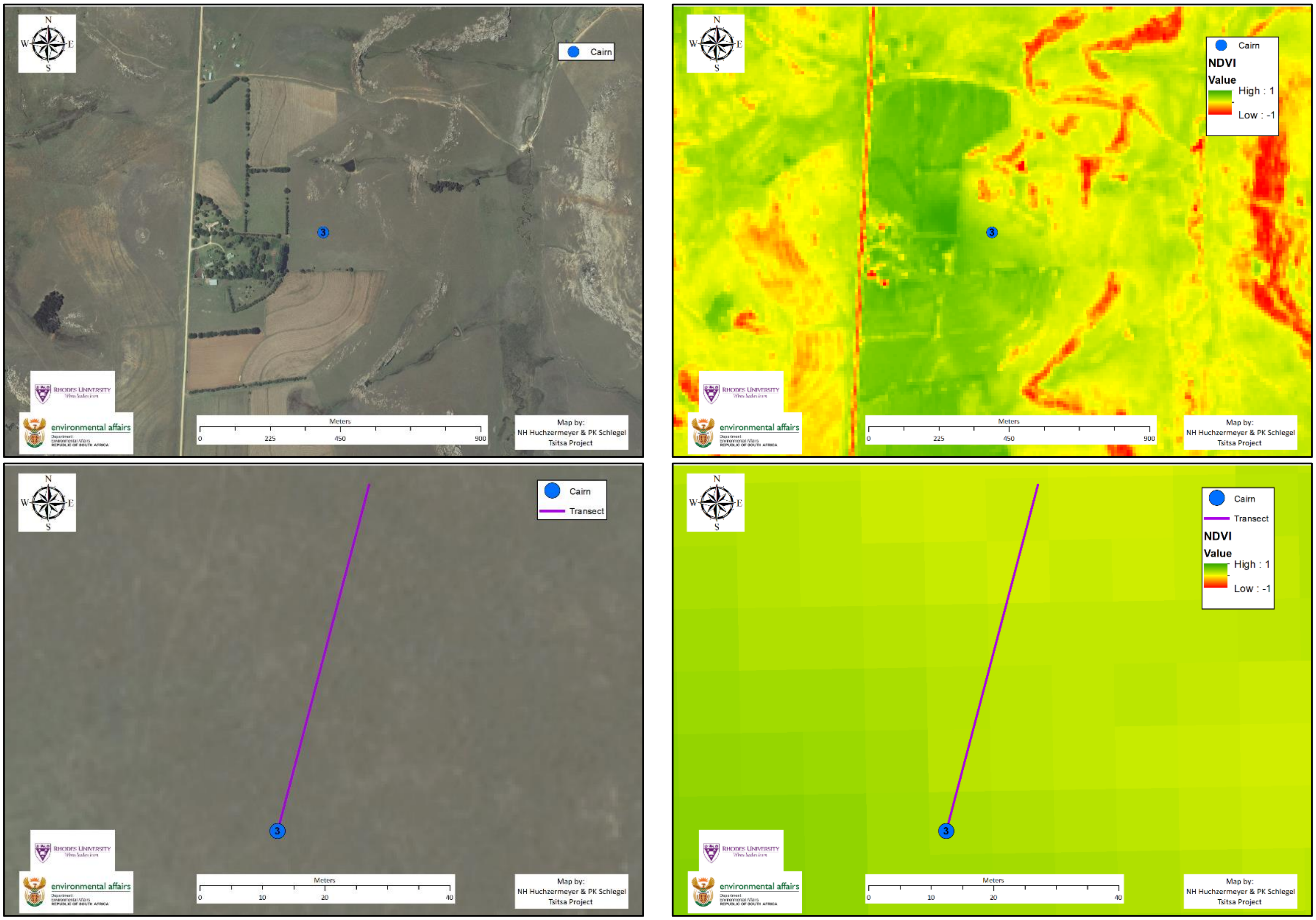


FIGURE 50: LOCATION OF VELD MONITORING SITE 3

16.3.1. Fixed point photography 29.04.2019 13h40

FIGURE 51: LANDSCAPE LAYOUT OF SITE 3 WITH A 50 M TRANSECT DOWN THE SLOPE.

Figure 52: Portrait layout of site 3 with a 50 m transect down the slope.

16.3.2. Species Composition

Grass Species Transect Site name: Bob's Place Site no. : 3 GPS: 31°05'45.1"S; 28°26'50.2"E

Date: 29/04/2019 Time: 15h42 Assessor: N Huchzermeyer

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total		Total	Total (%)
		Hit on bare ground	Hit on a forb						
1	*Sporobolus africanus*	IIIII I		6	IIIII IIIII IIIII	15		21	42
2	*Eragrostis plana*	II		2	II	2		4	8
3	*Themeda triandra*	IIIII IIIII		10	IIIII IIIII IIII	14		24	48
4	*Hyparrhenia hirta*			0		0		0	0
5	*Urochloa mosambicensis*			0	I	1		1	2
6	*Unknown (check press)*			0		0		0	0
7	*Aristida adscensionis*			0		0		0	0
8	*Cynodon dactylon*			0		0		0	0
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
	Total			**18**		**32**		**50**	
	Total (%)			**36**		**64**			**100%**

FIGURE 53: FIELD FORM SHOWING GRASS SPECIES FOUND AT SITE 3

16.3.3. Biomass & grazing capacity

The average disc pasture meter height for site 3 is 5 cm with a standard deviation of 1.6 cm. This can be converted to **1591.5 kg.ha^{-1}**.

16.3.4. Multi-criteria assessment

Site Description Site 3:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage occurrence	Grazing potential
Themeda triandra	48	Good
Sporobolus africanus	42	Poor
Eragrsotis plana	8	Poor
Urochloa mosambicensis	2	Average

Common Trees on site:

- None

Percentage occurrence of Forbs along transect:

- 0 % hits
- Present but not abundant

Comments:

Private grazing land. *Themeda triandra* heavily utilized but present. Veld showing signs of over-utilisation.

Site 3 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	8
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	

B.	How many good grazing grasses are present? (quality grazing)		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	12
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	

C.	How good is the ground cover?		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	6
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	

D.	How much encroachment by unwanted plants is present?		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	8
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	

E.	How is the soil surface condition/erosion?		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	8
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	**Soil Depth**			**Score F:**
		Deep	**Shallow**	**Gravelly**	
1	Sandy soil (< 10% clay)	2-4	-3	-5	6
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	

Veld Condition Score = A+B+C+D+E+F	48
Veld Condition	Moderate

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average see (Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity= 5.3 ha/large LSU

16.4. Veld monitoring Site 4

Site 4 is situated on an abandoned field and is used as grazing lands for cattle (Figure 54). Table 19 summarises the condition of Site 4. It is heavily utilized and shows poor biomass and ground cover and is dominated by grasses with poor grazing potential and an abundance of unpalatable forbs. Site 4 has a very poor veld condition with moderate levels of topsoil loss contributing to the sustained degradation of this grazing land.

TABLE 19: SUMMARY OF VELD CONDITION AT SITE 4

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score	Grazing capacity (ha/ large LSU)
8	*Sporobolus africanus (76%)*	3.2	957.5	21 Very Poor	12.6

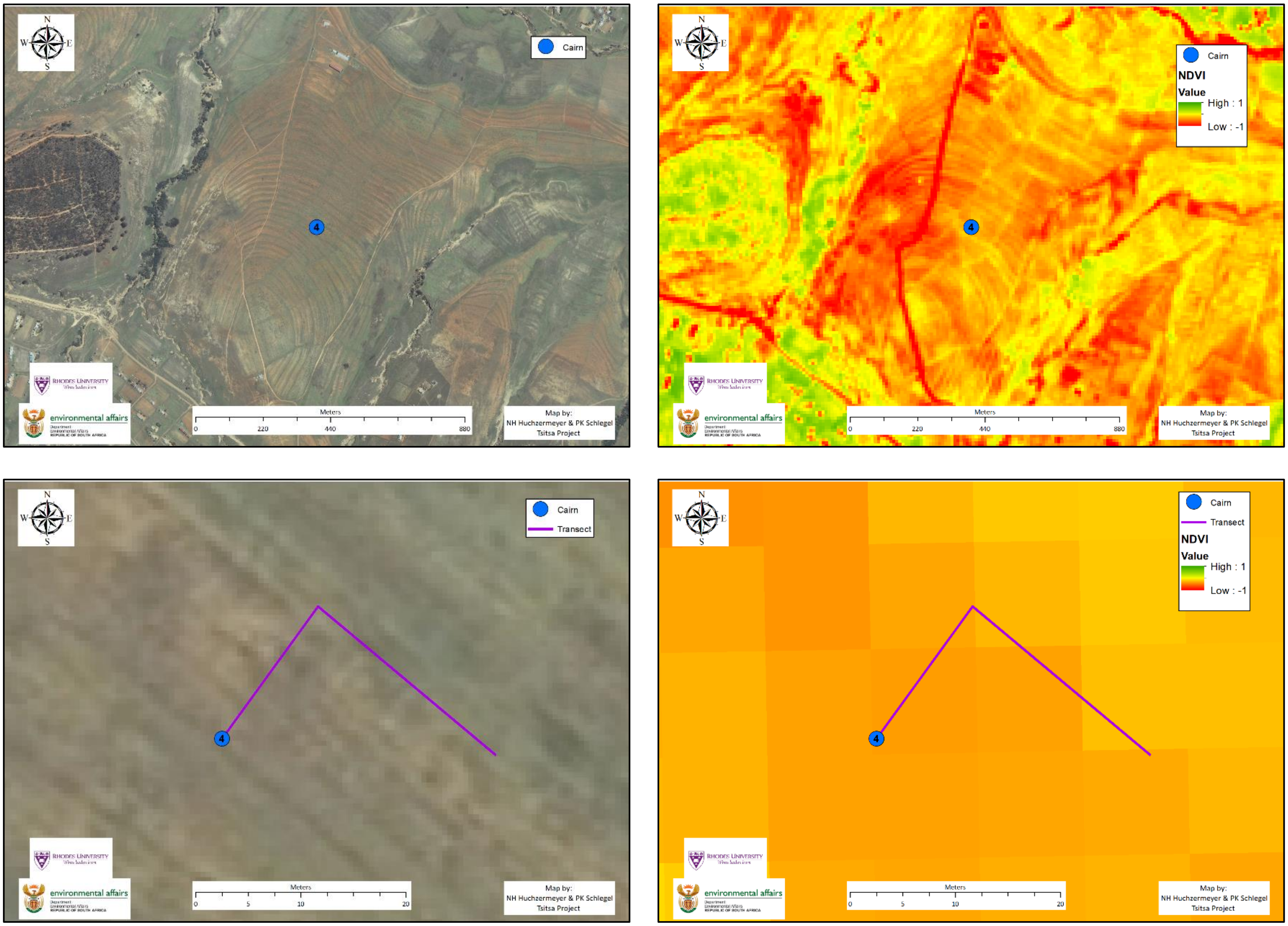


FIGURE 54: LOCATION OF VELD MONITORING SITE 4

16.4.1. Fixed point photography 01.05.2019 09h55

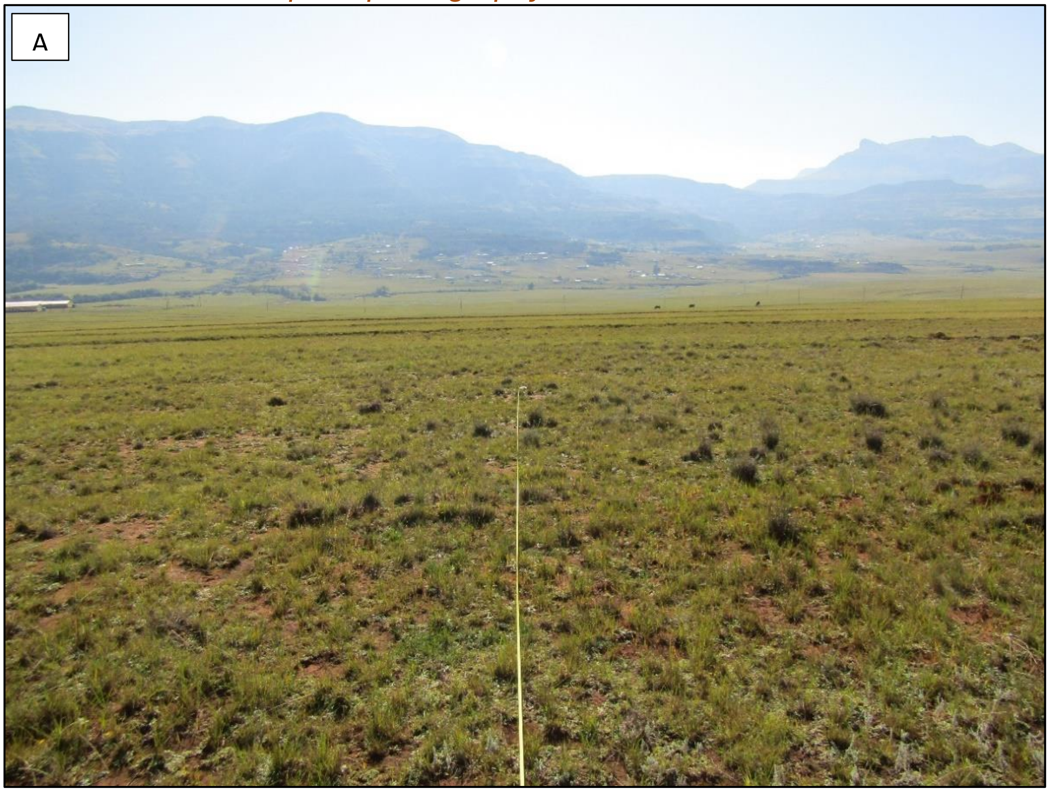


Figure 55: Landscape layout of site 4. A) 15 m transect downslope; B) 35 m transect perpendicular to the slope

FIGURE 56: PORTRAIT LAYOUT OF SITE 4. 15 M TRANSECT DOWNSLOPE.

Figure 57: Portrait layout of site 4. 35 m transect perpendicular to the slope.

16.4.2. Species Composition

Grass Species Transect Site name: Upper Tsitsana Site no. : 4 GPS: 30°51'23.0"S; 28°19'40.0"E

Date: 01/05/2019 Time: 09h40 Assessor: N Huchzermeyer

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total		Total	Total (%)
		Hit on bare ground	Hit on a forb						
1	*Sporobolus africanus*	IIIII IIIII IIIII IIII	IIIII III	27	IIIII IIIII I	11		38	76
2	*Eragrostis plana*	I		1		0		1	2
3	*Eragrostis chloromelas*	I		1		0		1	2
4	*Eragrostis gummiflua*	III	I	4	II	2		6	12
5	*Digitaria ternata*	I		1		0		1	2
6	*Andropogon eucomus*	I		1	I	1		2	4
7	*Agrostis montevidensis*	I		1		0		1	2
8	*Hyparhennia hirta*			0		0		0	0
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
	Total	27	9	**36**		**14**		**50**	
	Total (%)	54	18	**72**		**28**			**100%**

Figure 58: Field form showing grass species found at Site 4

16.4.3. Biomass & grazing capacity

The average disc pasture meter height for site 4 is 3.2 cm with a standard deviation of 2 cm. This can be converted to **957.5 kg.ha^{-1}**.

16.4.4. Multi-criteria assessment (Van Oudtshoorn, 2015)

Site Description Site 4:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage occurrence	Grazing potential
Sporobolus africanus	76	Poor
Eragrostis gummiflua	12	Poor
Andropogon eucomus	4	Poor
Eragrostis plana	2	Poor
Eragrostis chloromelas	2	Average
Digitraria ternate	2	Poor
Agrostis montevidensis	2	Poor

Common Trees on site:

- None

Percentage hits on Forbs along transect:

- 18% hits on Forbs

Comments:

Abandoned/discontinued cultivated land used for grazing. Very low biomass with a high percentage of bare ground and forbs.

Site 4 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	2
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	

B.	How many good grazing grasses are present? (quality grazing)		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	2
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	

C.	How good is the ground cover?		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	2
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	

D.	How much encroachment by unwanted plants is present?		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	4
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	

E.	How is the soil surface condition/erosion?		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	5
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	Soil Depth			Score F:
		Deep	Shallow	Gravelly	
1	Sandy soil (< 10% clay)	2-4	-3	-5	6
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	
Veld Condition Score = A+B+C+D+E+F					21
Veld Condition					Very Poor

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average rainfall (see Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity = 12.6 ha/large LSU

FIGURE 59: CATTLE GRAZING NEAR SITE 4

16.5. Veld monitoring Site 5

Site 5 is located on an abandoned cultivated land on the banks of the Tsitsana River. It is mostly utilized for grazing by sheep. Due to the fertile soils it exhibits good ground cover and biomass but the veld condition score is reduced by the presence of grasses and forbs that have low grazing value.

TABLE 20: SUMMARY OF VELD CONDITION AT SITE 5

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score	Grazing capacity (ha/ large LSU)
8	*Digitaria ternata (36%)*	6.6	2 079.2	38 Poor	6.8

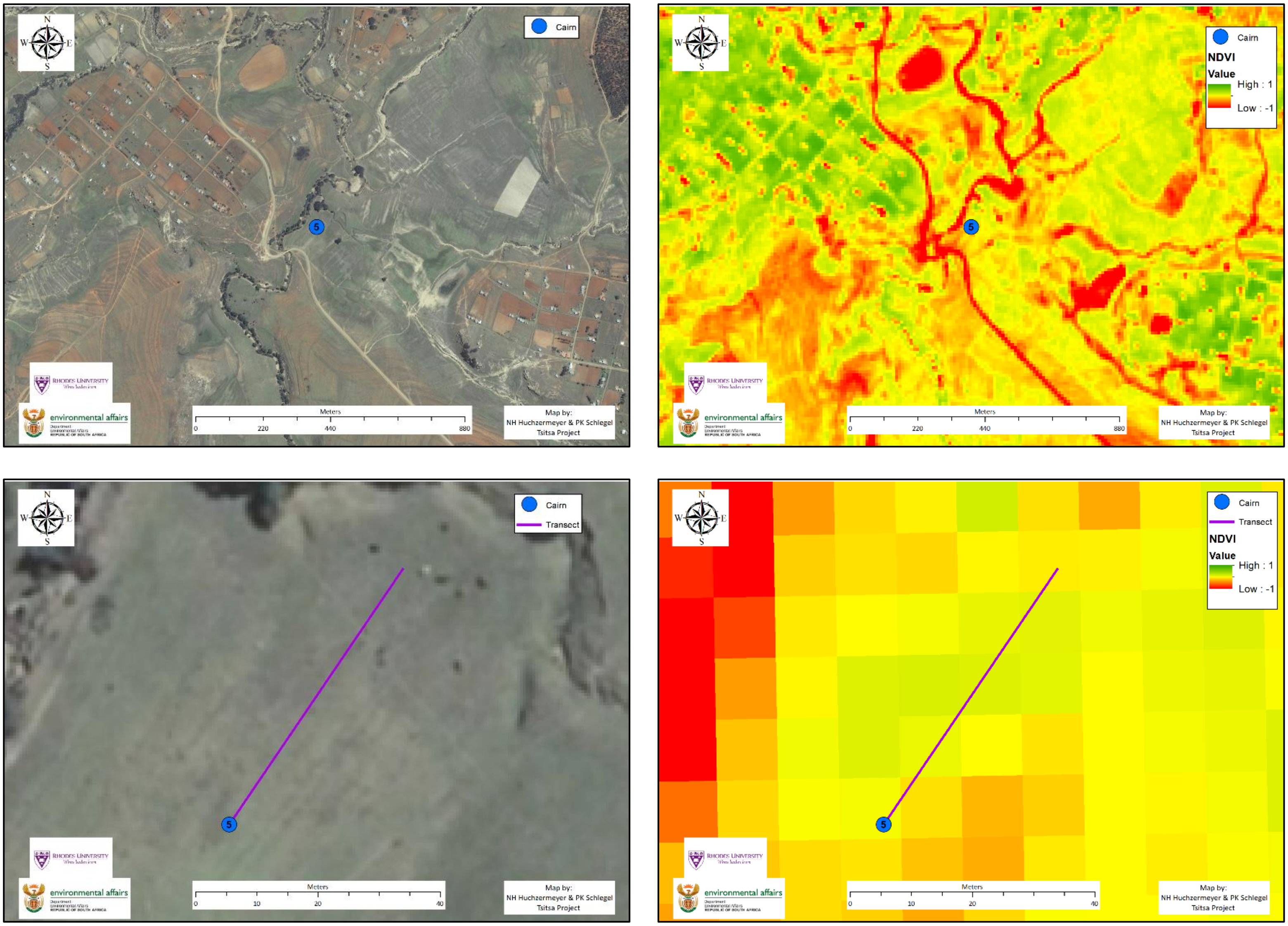


FIGURE 60: LOCATION OF VELD MONITORING SITE 5

16.5.1. *Fixed point photography 01.05.2019 13h30*

FIGURE 61: LANDSCAPE LAYOUT OF SITE 5 ACROSS THE FLOODPLAIN.

Figure 62: Portrait layout of site 5 across the floodplain.

environmental affairs
Department: Environmental Affairs
REPUBLIC OF SOUTH AFRICA

RHODES UNIVERSITY
Where leaders learn

TSITSA PROJECT

16.5.2. Species Composition

Grass Species Transect **Site name:** Lower Tsitsana **Site no. :** 5 **GPS:** 30°53'33.7"S; 28°21'31.2"E

Date: 01/05/2019 **Time:** 13h00 **Assessor:** N Huchzermeyer

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total		Total	Total (%)
		Hit on bare ground	Hit on a forb						
1	*Cynodon dactylon*	I		1	IIIII IIIII	10		11	22
2	*Sporobolus africanus*		IIIII IIIII IIII	14	II	2		16	32
3	*Eragrostis plana*		I	1		0		1	2
4	*Digitaria ternata*		IIIII IIIII I	11	IIIII II	7		18	36
5	*Paspalum notatum*		III	3		0		3	6
6	*Eragrostis gummifloa*				I	1		1	2
7	*Aristida adscensionis*								
8	*Andropogon eucomus*								
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
	Total	1	29	**30**		**20**		**50**	
	Total (%)			**60**		**40**			**100%**

FIGURE 63: FIELD FORM SHOWING GRASS SPECIES FOUND AT SITE 5

16.5.3. Biomass & grazing capacity

The average disc pasture meter height for site 5 is 6.6 cm with a standard deviation of 1.7 cm. This can be converted to **2 079.2 kg.ha**$^{-1}$.

16.5.4. Multi-criteria assessment (Van Oudtshoorn, 2015)

Site Description Site 5:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	**Percentage occurrence**	**Grazing potential**
Digitaria ternata	36	Poor
Sporobolus africanus	32	Poor
Cynodon dactylon	22	Good
Paspalum notatum	6	Average
Eragrostis plana	2	Poor
Eragrostis gummifloa	2	Poor

Common Trees on site:

- *Salex* spp.
- *Querces* spp**.**
- *Acacia dealbata*
- *Leucosidea sericea* (Ouhout)

Percentage hits on Forbs along transect:

- 58% hits on Forbs

Comments:

Abandoned/deactivated low lying floodplain of the Tsitsana River. Good ground cover with a high percentage of Forbs. Used for livestock grazing including cattle and sheep.

Site 5 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	**Score A:**
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	8
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	

B.	How many good grazing grasses are present? (quality grazing)		
1	Mainly poor grazing grasses present	0-3	**Score B:**
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	3
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	

C.	How good is the ground cover?		
1	Very poor ground cover	1-2	**Score C:**
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	8
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	

D.	How much encroachment by unwanted plants is present?		
1	Heavy encroachment is present	1	**Score D:**
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	8
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	

E.	How is the soil surface condition/erosion?		
1	Severe levels of topsoil loss	1-2	**Score E:**
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	5
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	**Soil Depth**			**Score F:**
		Deep	**Shallow**	**Gravelly**	
1	Sandy soil (< 10% clay)	2-4	-3	-5	6
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	
Veld Condition Score = A+B+C+D+E+F					38
Veld Condition					Poor

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average rainfall (see Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity= 6.8 ha/large LSU

FIGURE 64: SHEEP GRAZING CLOSE TO SITE 5

16.6. Veld monitoring Site 6

Site 6 is situated on an abandoned cultivated land and is within the communal grazing land (Figure 65). Site 6 exhibits low biomass and groundcover and is dominated by grass species with poor grazing values which results in a low veld condition score (Table 20).

TABLE 21: SUMMARY OF VELD CONDITION AT SITE 6

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score	Grazing capacity (ha/ large LSU)
10	*Sporobolus africanus (36%)*	3.6	1 107.5	30 Poor	8.5

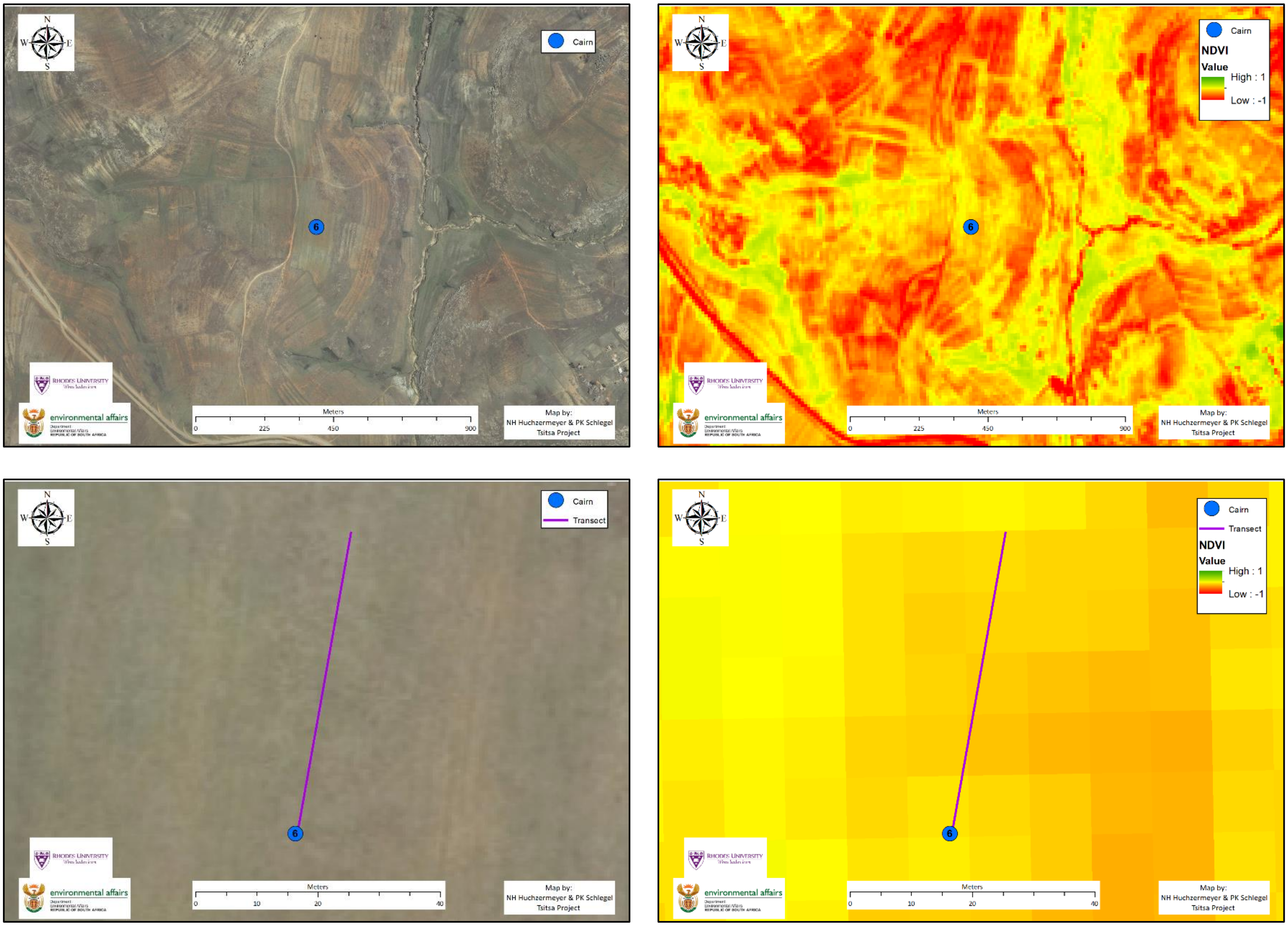


FIGURE 65: LOCATION OF VELD MONITORING SITE 6

16.6.1. Fixed point photography 02.05.2019 08h30

FIGURE 66: LANDSCAPE LAYOUT OF SITE 6 PERPENDICULAR TO THE SLOPE.

Figure 67: Portrait layout of site 6 perpendicular to the slope.

16.6.2. Species Composition

Grass Species Transect **Site name:** Batloaka **Site no.** : 6 **GPS:** 30°54'50.0"S; 28°27'04.9"E

Date: 02/05/2019 **Time:** 08h30 **Assessor:** N Huchzermeyer

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total	Total	Total (%)
		Hit on bare ground	Hit on a forb					
1	*Sporobolus africanus*	IIIII IIIII II	I	13	IIIII I	6	19	38
2	*Andropogon eucomus*	I	I	2	IIII	4	6	12
3	*Cynodon dactylon*	I		1		0	1	2
4	*Aristida adscensionis*	I		1		0	1	2
5	*Digitaria ternata*	IIIII		5	IIIII III	9	14	28
6	*Eragrostis plana*	III		3	IIII	4	7	14
7	*Hyparhennia hirta*			0	I	1	1	2
8	*Urochlea mosambicensis*			0	I	1	1	2
9	*Eragrostis gummiflua*							
10	*Eragrostis curvula*							
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Total			**25**		**25**	**50**	
	Total (%)							**100%**

Figure 68: Field form showing grass species found at Site 6

16.6.3. Biomass & grazing capacity

The average disc pasture meter height for site 6 is 3.6 cm with a standard deviation of 1.3 cm. This can be converted to **1 107.5 $kg.ha^{-1}$**.

16.6.4. Multi-criteria assessment

Site Description Site 6:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage occurrence	Grazing potential
Sporobolus africanus	38	Poor
Digitaria ternata	28	Poor
Eragrostis plana	14	Poor
Andropogon eucomus	12	Poor
Cynodon dactylon	2	Good
Aristida adscensionis	2	Poor
Urochlea mosambicensis	2	Average
Hyparhennia hirta	2	Average

Common Trees on site:

- None

Percentage hits on Forbs along transect:

- 4% hits on Forbs

Comments:

Heavily utilized especially by sheep. Creeping grasses forming mats on bare ground. Located on the fertile floodplain of the Tsitsana River.

Site 6 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	5
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	

B.	How many good grazing grasses are present? (quality grazing)		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	3
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	

C.	How good is the ground cover?		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	3
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	

D.	How much encroachment by unwanted plants is present?		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	8
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	

E.	How is the soil surface condition/erosion?		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	5
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	Soil Depth			Score F:
		Deep	Shallow	Gravelly	
1	Sandy soil (< 10% clay)	2-4	-3	-5	
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	6
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	

Veld Condition Score = A+B+C+D+E+F	30
Veld Condition	Poor

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average (see Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity = 8.5 ha/large LSU

16.7. Veld monitoring Site 7

Site 7 occurs in a valley close to an un-channeled valley bottom (Figure 69) and provides winter grazing to livestock. Table 22 summarises the veld condition at site 7. This area has good groundcover and biomass most likely to its location in the landscape but it also exhibits grasses with lower than average grazing potential.

TABLE 22: SUMMARY OF VELD CONDITION AT SITE 7

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score	Grazing capacity (ha/ large LSU)
5	*Eragrostis plana (44%)*	8.8	2 667.0	49 Moderate	5.3

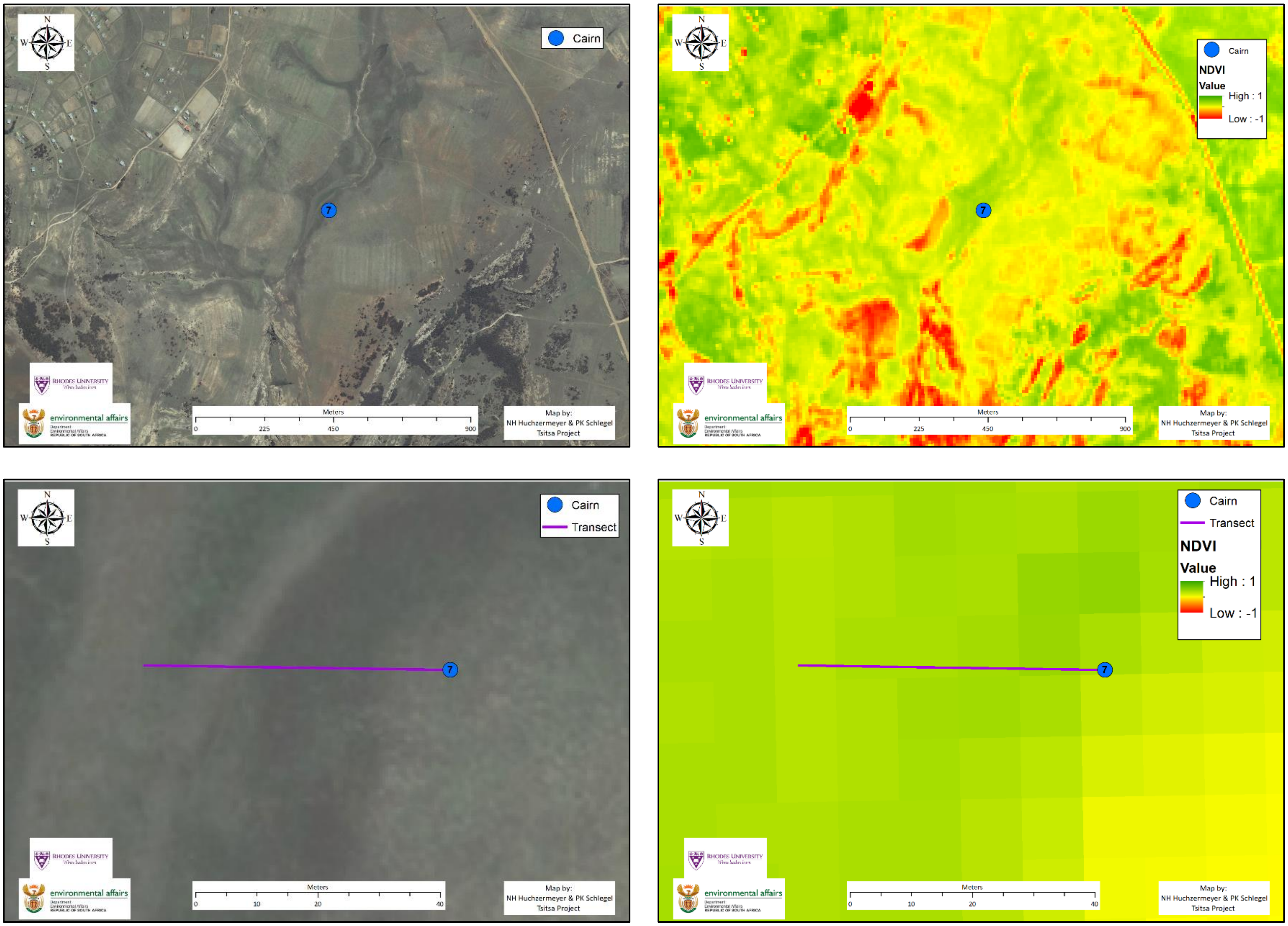


FIGURE 69: LOCATION OF VELD MONITORING SITE 7

16.7.1. Fixed point photography 02.05.2019 14h00

FIGURE 70: LANDSCAPE LAYOUT OF SITE 7. 50 M TRANSECT PERPENDICULAR TO THE SLOPE

Figure 71: Portrait layout of site 7. 50 m transect perpendicular to the slope.

16.7.2. Species Composition

Grass Species Transect Site name: Basuto 1 Site no. : 7 GPS: 30°55'00.5"S; 28°32'59.1"E

Date: 02/05/2019 Time: 13h52 Assessor: N Huchzermeyer

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total		Total	Total (%)
		Hit on bare ground	Hit on a forb						
1	*Eragrostis plana*	III	I	4	IIIII IIIII IIIII III	18		22	44
2	*Aristida adscensionis*	I		1	IIIII IIIII IIIII II	17		18	36
3	*Sporobolus africanus*			0	IIIII I	6		6	12
4	*Paspalum notatum*	I		1	I	1		2	4
5	*Agrostis montevidensis*			0	II	2		2	4
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
	Total	5	1	**6**		**44**		**50**	
	Total (%)			**12**		**88**			**100%**

FIGURE 72: FIELD FORM SHOWING GRASS SPECIES FOUND AT SITE 7

16.7.3. Biomass & grazing capacity

The average disc pasture meter height for site 7 is 8.8 cm with a standard deviation of 2.2 cm. This can be converted to **2 667.0 kg.ha^{-1}**.

16.7.4. Multi-criteria assessment (Van Oudtshoorn, 2015)

Site Description Site 7:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage occurrence	Grazing potential
Eragrostis plana	44	Poor
Aristida adscensionis	36	Poor
Sporobolus africanus	12	Poor
Paspalum notatum	4	Average
Agrostis montevidensis	4	Poor

Common Trees on site:

- None

Percentage hits on Forbs along transect:

- 2%

Comments:

Valley bottom proximal to a wetland. Used for livestock grazing particularly in winter months.

Site 7 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	12
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	
B.	**How many good grazing grasses are present? (quality grazing)**		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	1
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	
C.	**How good is the ground cover?**		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	9
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	
D.	**How much encroachment by unwanted plants is present?**		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	9
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	
E.	**How is the soil surface condition/erosion?**		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	10
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	**Soil Depth**			Score F:
		Deep	**Shallow**	**Gravelly**	
1	Sandy soil (< 10% clay)	2-4	-3	-5	8
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	
	Veld Condition Score = A+B+C+D+E+F				49
	Veld Condition				Moderate

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average (see Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity = 5.3 ha/large LSU

16.8. Veld monitoring Site 8

Site 8 is situated on a remote abandoned cultivated land (Figure 73). Table 22 summarises the veld condition at Site 8. The condition is very poor due to low biomass and groundcover, poor soils and a lack of good grazing grasses.

TABLE 23: SUMMARY OF VELD CONDITION AT SITE 8

Number of grass species	Dominant grass and % occurrence	Average disc-pasture meter height (cm)	Average biomass (kg.ha^{-1})	Veld condition score	Grazing capacity (ha/ large LSU)
7	*Sporobolus africanus (46%)*	3.0	880.6	21 Very poor	12.6

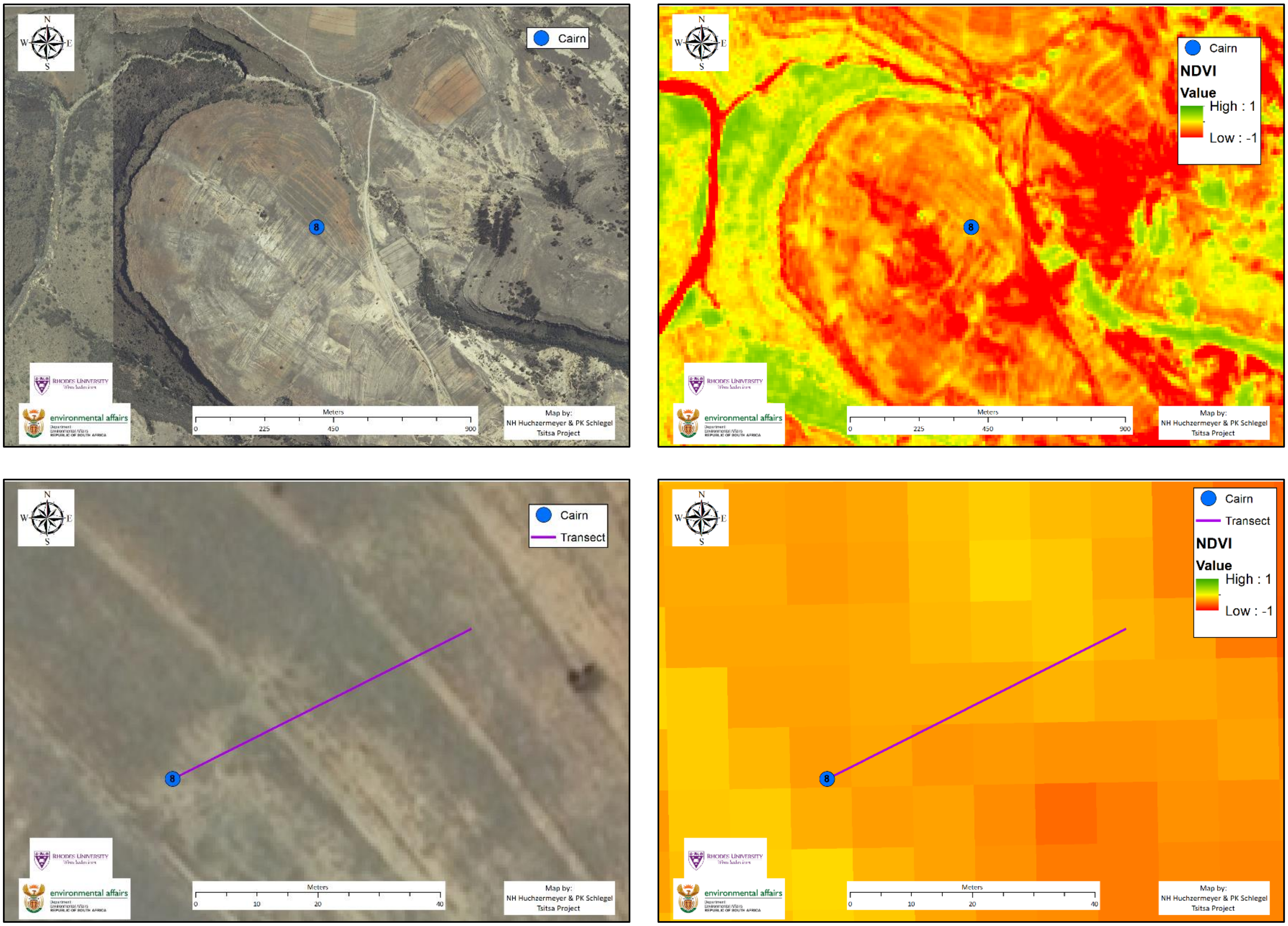


FIGURE 73: LOCATION OF VELD MONITORING SITE 8

16.8.1. Fixed point photography 02.05.2019 15h30

FIGURE 74: LANDSCAPE LAYOUT OF SITE 8. 50 M TRANSECT DOWNSLOPE.

FIGURE 75: PORTRAIT LAYOUT OF SITE 8. 50 M TRANSECT DOWNSLOPE

16.8.2. Species Composition

Grass Species Transect Site name: Basuto 2 Site no. : 8 GPS: 31°01'40.2"S; 28°30'18.9"E

Date: 02/05/2019 Time: 15h30 Assessor: N Huchzermeyer

	Plant name	Nearest Plant		Nearest Total	Hits	Hits Total		Total	Total (%)
		Hit on bare ground	Hit on a forb						
1	*Cynodon dactylon*	IIIII	IIIII II	12	IIII	4		16	32
2	*Sporobolus africanus*	IIIII	IIIII IIIII III	18	IIIII	5		23	46
3	*Hyparhenia hirta*	II	II	4	II	2		6	12
4	*Digitaria ternata*		I	1	I	1		2	4
5	*Agrostis montevidensis*		II	2		0		2	4
6	*Eragrostis plana*		I	1		0		1	2
7	*Aristida adscensionis*								
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
	Total	12	26	**38**		**12**		**50**	
	Total (%)	24	52	**76**		**24**			**100%**

Figure 76: Field form showing grass species found at Site 8

16.8.3. Biomass & grazing capacity

The average disc pasture meter height for site 8 is 3.0 cm with a standard deviation of 1.5 cm. This can be converted to **880.6 kg.ha^{-1}**.

16.8.4. Multi-criteria assessment

Site Description Site 8:

Terrain Unit	Crest	Midslope	Footslope	Valley bottom	
Slope	Steep	Medium	Gentle	Flat or Even	
Soil texture	Sandy	Sandy loam	Loam	Clay loam	Clay
Soil depth	Deep	Medium	Shallow	Gravelly/rocky	

Common Grasses:

Name	Percentage occurrence	Grazing potential
Sporobolus africanus	46	Poor
Cynodon dactylon	32	Good
Hyparhenia hirta	12	Average
Digitaria ternata	4	Poor
Agrostis montevidensis	4	Poor
Eragrostis plana	2	Poor

Common Trees on site:

- *Acacia dealbata*
- *Vachellia karoo*

Percentage hits on Forbs along transect:

- 52% hits on Forbs

Comments:

Located on an abandoned/deactivated field. Very little groundcover dominated by Forbs. Soil highly compacted

Site 8 Evaluation of Veld Condition:

A.	How much grass biomass is present? (grazing quantity)		
1	Very low levels of grass biomass	0-3	Score A:
2	Low levels of grass biomass	4-7	
3	Moderate levels of grass biomass	8-11	3
4	High levels of grass biomass	12-15	
5	Very high levels of grass biomass	16-20	

B.	How many good grazing grasses are present? (quality grazing)		
1	Mainly poor grazing grasses present	0-3	Score B:
2	Moderate and poor grazing grasses mixed	4-7	
3	Mainly moderate grazing grasses present	8-11	4
4	Good and moderate grazing grasses mixed	12-15	
5	Mainly good grazing grasses present	16-20	

C.	How good is the ground cover?		
1	Very poor ground cover	1-2	Score C:
2	Poor ground cover	3-4	
3	Moderate levels of ground cover	5-6	3
4	High levels of ground cover	7-8	
5	Very high levels of groundcover	9-10	

D.	How much encroachment by unwanted plants is present?		
1	Heavy encroachment is present	1	Score D:
2	Heavy to medium encroachment is present	2-3	
3	Medium encroachment is present	4-5	2
4	Medium to light encroachment is present	6-7	
5	Only light encroachment is present	8-9	
6	No encroachment is present	10	

E.	How is the soil surface condition/erosion?		
1	Severe levels of topsoil loss	1-2	Score E:
2	High levels of topsoil loss	3-4	
3	Moderate levels of topsoil loss	5-6	4
4	Slight levels of topsoil loss	7-8	
5	No topsoil loss	9-10	

F.	What is the soil type/agricultural potential?				
	Texture	Soil Depth			Score F:
		Deep	Shallow	Gravelly	
1	Sandy soil (< 10% clay)	2-4	-3	-5	
2	Sandy loam soil (10-15% clay)	5-6	-3	-5	
3	Loam soil (15-25% clay)	7-8	-3	-5	5
4	Clay loam soil (25-40% clay)	9-10	-3	-5	
5	Clay soil (40-50% clay)	7-8	-3	-5	
6	Heavy clay soil (>50%)	5-6	-3	-5	
Veld Condition Score = A+B+C+D+E+F					21

Veld Condition	Very Poor

Estimate of Grazing Capacity (ha/LSU):

Grazing capacity is **estimated** from the Veld Condition Score and long-term average rainfall (see Appendix 2). This grazing capacity value does not take into account recent rainfall fluctuations and may be influenced by grazing management systems.

Grazing Capacity = 12.6 ha/large LSU

17. APPENDIX 2: GRAZING CAPACITY

Step 3 Add below all the scores together to get the Veld Condition Score (VCS):

VCS = A + B + C + D + E + F = ___ + ___ + ___ + ___ + ___ + ___ = VCS = _______

Step 4 Use now the Veld Condition Score (VCS), and long-term average rainfall for the area, to get the estimated grazing capacity in ha/LSU or AU from the table below:

RAINFALL (mm/year)		300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750
VCS	Condition	GRAZING CAPACITY (ha/AU/year)																		
20 - 22	Very poor	50.3	45.2	40.2	35.2	32.7	30.2	27.6	26.4	25.1	23.9	22.6	21.4	20.1	18.8	17.6	16.3	15.1	13.8	12.6
23 - 24		45.3	40.7	36.2	31.7	29.4	27.2	24.9	23.8	22.6	21.5	20.4	19.3	18.1	17.0	15.9	14.7	13.6	12.5	11.4
25 - 27		40.2	36.2	32.2	28.1	26.1	24.1	22.1	21.1	20.1	19.1	18.1	17.1	16.1	15.1	14.1	13.1	12.1	11.1	10.1
28 - 29		37.2	33.5	29.8	26.0	24.2	22.3	20.5	19.5	18.6	17.7	16.8	15.8	14.9	14.0	13.1	12.1	11.2	10.3	9.3
30 - 32	Poor	34.2	30.8	27.3	23.9	22.2	20.5	18.8	17.9	17.1	16.2	15.4	14.5	13.7	12.8	12.0	11.1	10.3	9.4	8.5
33 - 34		31.6	28.5	25.3	22.1	20.6	19.0	17.4	16.6	15.8	15.0	14.3	13.4	12.7	11.9	11.1	10.3	9.5	8.7	7.9
35 - 37		29.0	26.1	23.2	20.3	18.9	17.4	16.0	15.3	14.5	13.8	13.1	12.3	11.6	10.9	10.2	9.4	8.7	8.0	7.3
38 - 39		26.9	24.2	21.5	18.8	17.5	16.1	14.8	14.2	13.4	12.8	12.1	11.4	10.8	10.1	9.4	8.7	8.1	7.4	6.8
40 - 42		24.7	22.2	19.8	17.3	16.0	14.8	13.6	13.0	12.3	11.7	11.1	10.5	9.9	9.3	8.6	8.0	7.4	6.8	6.2
43 - 44		23.5	21.1	18.8	16.5	15.2	14.1	12.9	12.4	11.7	11.2	10.6	10.0	9.4	8.8	8.2	7.6	7.1	6.5	5.9
45 - 47	Moderate	22.2	20.0	17.8	15.6	14.4	13.3	12.2	11.7	11.1	10.6	10.0	9.4	8.9	8.3	7.8	7.2	6.7	6.1	5.6
48 - 49		21.1	19.0	16.9	14.8	13.7	12.7	11.6	11.1	10.6	10.1	9.5	9.0	8.5	7.9	7.4	6.9	6.4	5.8	5.3
50 - 52		20.0	18.0	16.0	14.0	13.0	12.0	11.0	10.5	10.0	9.5	9.0	8.5	8.0	7.5	7.0	6.5	6.0	5.5	5.0
53 - 54		19.0	17.1	15.2	13.3	12.4	11.4	10.5	10.0	9.5	9.1	8.6	8.1	7.6	7.2	6.7	6.2	5.7	5.3	4.8
55 - 57	Good	18.0	16.2	14.4	12.6	11.7	10.8	9.9	9.5	9.0	8.6	8.1	7.7	7.2	6.8	6.3	5.9	5.4	5.0	4.5
58 - 59		17.2	15.5	13.8	12.1	11.2	10.3	9.5	9.1	8.6	8.2	7.8	7.4	6.9	6.5	6.0	5.6	5.2	4.8	4.3
60 - 62		16.4	14.7	13.1	11.5	10.6	9.8	9.0	8.6	8.2	7.8	7.4	7.0	6.6	6.1	5.7	5.3	4.9	4.5	4.1
63 - 64		15.7	14.1	12.5	11.0	10.2	9.4	8.6	8.2	7.9	7.5	7.1	6.7	6.3	5.9	5.5	5.1	4.7	4.3	3.9
65 - 67		14.9	13.4	11.9	10.4	9.7	8.9	8.2	7.8	7.5	7.1	6.7	6.3	6.0	5.6	5.2	4.8	4.5	4.1	3.7
68 - 69		14.3	12.8	11.4	10.0	9.3	8.5	7.9	7.5	7.2	6.8	6.4	6.1	5.7	5.4	5.0	4.6	4.3	3.9	3.6
70 - 72	Very good	13.6	12.2	10.9	9.5	8.8	8.1	7.5	7.1	6.8	6.4	6.1	5.8	5.4	5.1	4.7	4.4	4.1	3.7	3.4
73 - 74		13.0	11.7	10.4	9.1	8.4	7.8	7.2	6.8	6.5	6.2	5.9	5.5	5.2	4.9	4.5	4.2	3.9	3.6	3.3
75 - 77		12.3	11.1	9.9	8.6	8.0	7.4	6.8	6.5	6.2	5.9	5.6	5.2	4.9	4.6	4.3	4.0	3.7	3.4	3.1
78 - 79		11.8	10.6	9.5	8.3	7.7	7.1	6.5	6.2	5.9	5.6	5.4	5.0	4.7	4.4	4.1	3.9	3.6	3.3	3.0
80		11.2	10.1	9.0	7.9	7.3	6.7	6.2	5.9	5.6	5.3	5.1	4.8	4.5	4.2	3.9	3.7	3.4	3.1	2.8

NB: Please note that the grazing capacity is an estimate and that rainfall fluctuations and grazing system/management also have an influence on the grazing capacity.
Compiled by Frits van Oudtshoorn. Adapted from Erika A van Zyl (1989) as published in HOËVELDFOKUS Nr 1/89.
Version 11 (for the latest version email frits@alut.co.za)

FIGURE 77: TABLE USED TO ESTIMATE GRAZING CAPACITY (VAN OUDTSHOORN, 2015)

18. APPENDIX 3: SITE SPECIFIC WETLAND MONITORING

18.1. Wetland 1: Description of wetland condition & use

Wetland 1 represents one of many small hillslope seeps coming off the steep mountain sides onto the Tsitsa River floodplain (Figure 78). These hillslope seeps are used for dry season forage by livestock including cattle, goats and pigs. The toe of wetland 1 leads directly into the Tsitsa River. The Tsitsa River is incised at this point and there is presence of an erosion nickpoint where the wetland seeps into the Tsitsa River. The riparian zone of the Tsitsa River at this point is dominated by invasive wattle trees. These contribute to the reduction of natural grass and wetland plant cover at the toe of the wetland which causes an increased risk of headward erosion up the wetland. A gully pipe has formed at the spring at the head of the wetland but is stabilised by natural vegetation cover and rocks that have rolled downed from the steeper slopes. Sediment from livestock paths and hillslope runoff is deposited in the wetland before it can enter the river channel. It is important to ensure grass cover re-establishment at the toe of the wetland. If alien invasive clearing takes place on the riparian zone it is important that the trees are not clear felled leaving the erosion nickpoint exposed to no vegetation at all. A better solution is to bark-strip the trees allowing them to die standing. The natural vegetation cover will benefit from the slow release of nitrogen from the trees and the shade provided by the standing trees. This will reduce the possibility of headward erosion.

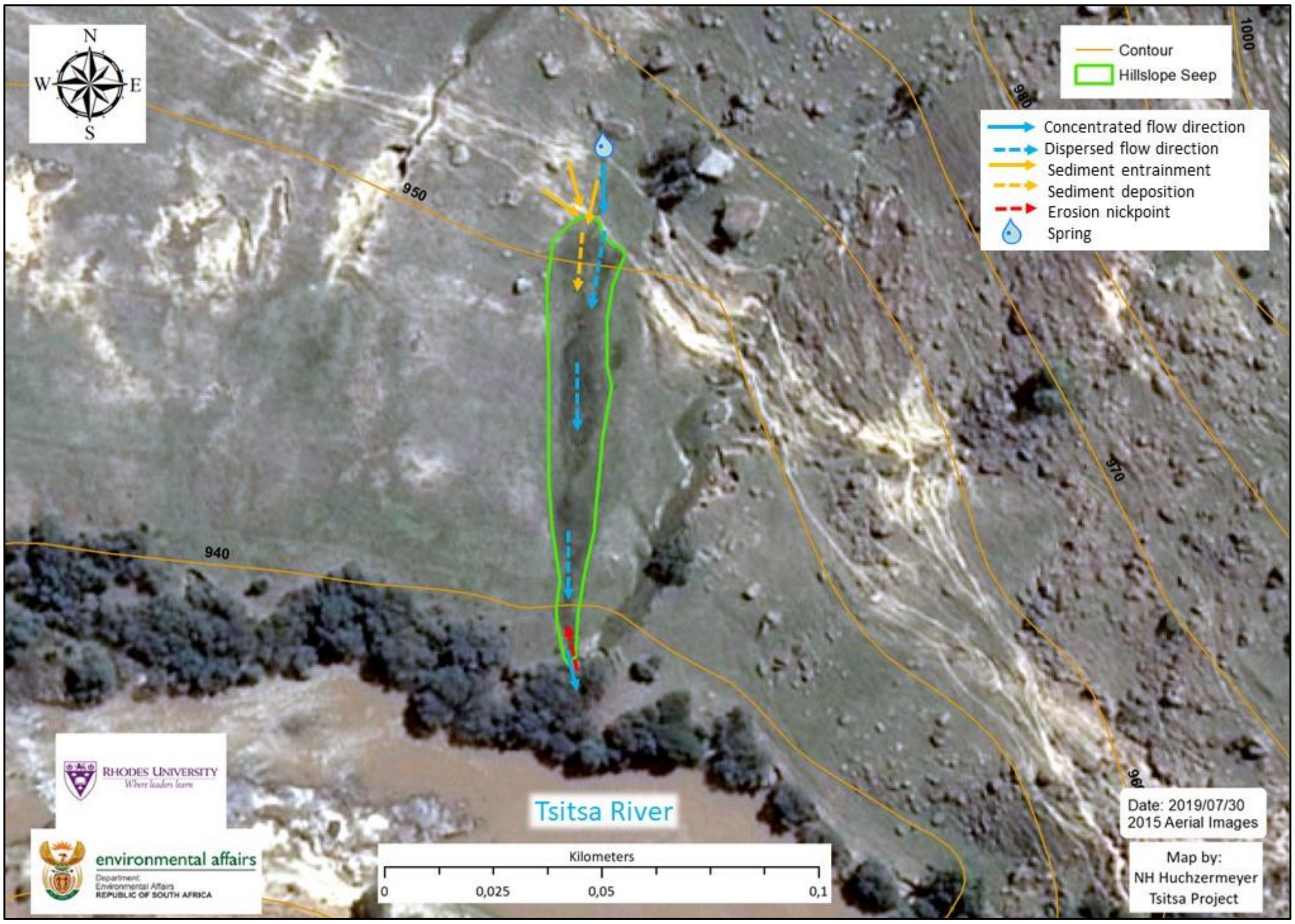


FIGURE 78: CURRENT CONDITION OF WETLAND 1

Wetland 1 is 0.1 ha in extent with a very steep catchment of 3 ha (Figure 79). Natural drainage lines run down the steep slopes and form the small hillslope seeps as they reach the lower gradients close to the Tsitsa River. Water inputs into Wetland 1 consists of hillslope runoff down natural drainage lines and livestock tracks during the rainy season as well as a spring at the head of the wetland which is fed by groundwater. Sediment inputs into Wetland 1 include erosion on the hillslope, soil slumps and livestock paths.

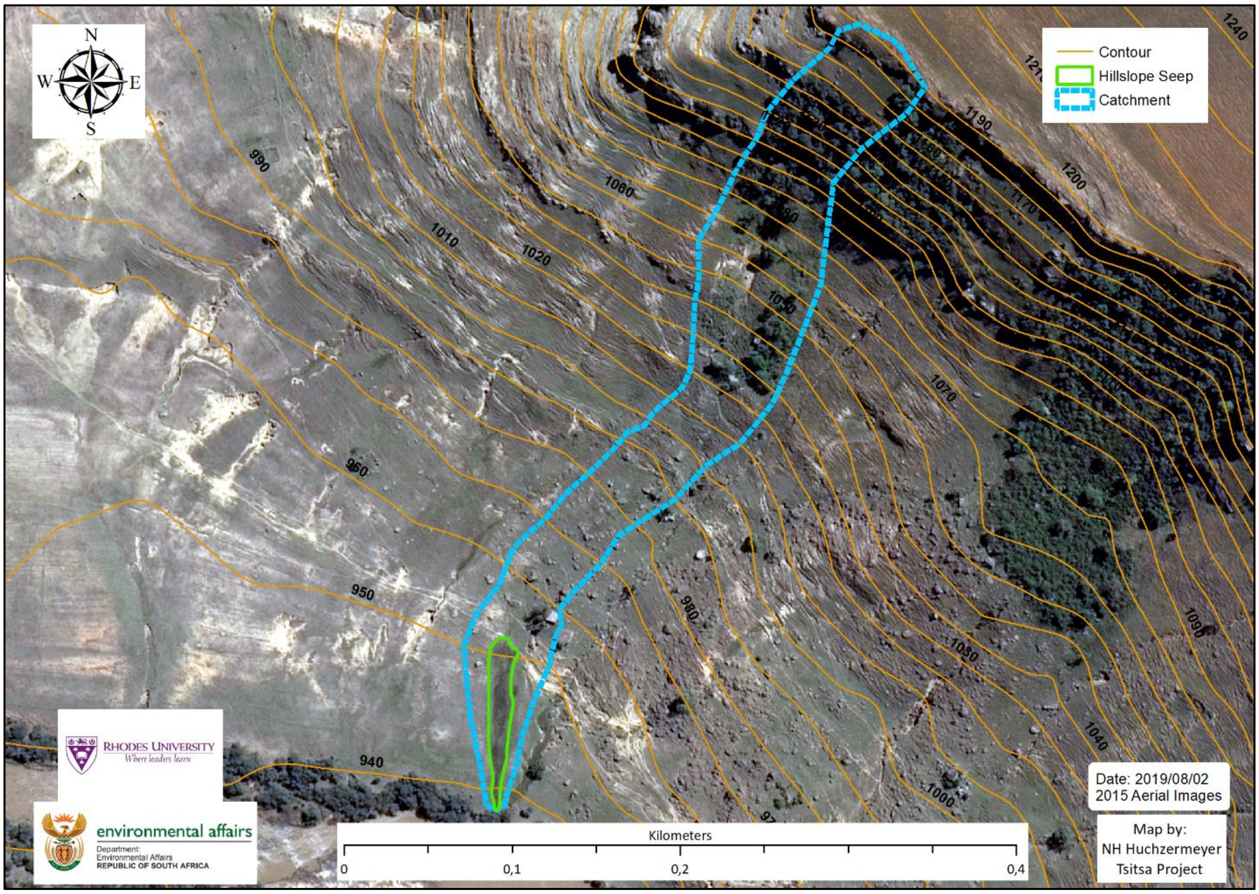


FIGURE 79: THE CATCHMENT AREA ABOVE WETLAND 1

Figure 80 shows the current condition of Wetland 1 exhibiting good vegetation cover and alien invasive trees at the toe of the wetland.

Figure 80: Landscape photograph of Wetland 1. Photo taken at 12h00 on the 26/04/201

Figure 81 shows the view up the wetland from the toe to the head. The steep catchment is visible in the background and it is clear that the wetland is forming on the lower gradient slopes of the Tsitsa River floodplain. Figure 82 shows how natural vegetation is suppressed by alien invasive trees (*Acacia dealbata*) resulting in an erosional nickpoint at the toe of the wetland where the wetland seeps into the Tsitsa River.

FIGURE 81: VIEW FROM THE TOE OF WETLAND 1 SHOWING THE STEEP CATCHMENT ABOVE AND LOWER GRADIENT ON THE FLOODPLAIN BELOW

FIGURE 82: RISK OF HEADWARD EROSION AT THE TOE OF WETLAND 1 DUE TO ALIEN INVASIVE TREES SUPRESSING THE NATURAL VEGETATION COVER

Video of spring and gully pipe (stable): https://youtu.be/IextvSJlbBo

Figure 83 shows the extent of erosion in a similar hillslope seep where headward erosion has cut into the soft sediment deposits of the wetland seep due to a disturbance of the natural vegetation cover. This likely occurred due to over-utlilisation and trampling of the wetland by livestock.

FIGURE 83: EROSION OF A HILLSLOPE SEEP RUNNING PARALLEL TO WETLAND 1 EXHIBITING A LOSS OF ECOSYSTEM SERVICES

Video of active headward erosion in ex-wetland seep: https://youtu.be/3Qg4KSYb_Zw

Common plant species in Wetland 1

Table 24 lists common plant species found in Wetland 1, indicating a seep in an open grassland with patches of permanent water. The grasses exhibit an average to poor grazing quality but are available in drier months due to the presence of water.

TABLE 24: COMMON WETLAND PLANTS FOUND IN WETLAND 1

Class	Species	Habitat
Wetland plants	*Pycreus polystachyos/intactus*	Open, moist and disturbed grasslands & shallow seeps
	Fimbristylis complanata/squarrosa	Damp grasslands an seeps, seasonally wet areas
	Schoenoplectus muriculatus	Permanent water
	Cyperus fastigiatus	Within and on margins of permanent water
	Schoenoplectus corymbosus/muricinux	Edges of permanent water
Grasses	*Paspalum distichum*	Near moist areas. Provide grazing for livestock during drier periods
	Eragrostis plana	Near moist areas

18.2. Wetland 2: Description of wetland condition & use

Wetland 2 is a small Hillslope seep wetland situated in a livestock grazing camp on a private farm (Figure 2). Livestock, including cattle and horses, graze in the wetland. The wetland also acts as one of the sources for a small dam situated at the toe of the wetland. The wetland allows for a steadier baseflow into the dam by releasing water slowly. This is advantageous during drier times of the year and essential as a source for livestock water. There is an erosion nickpoint at the toe of the wetland due to concentrated livestock paths going down to the dam for drinking (Figure 85). There are two springs at the head of the wetland which are causing gully pipes but these are stable and protected by a rock outcrop which also causes the water to reach the surface and seep into the wetland. Water input comes from both hillslope runoff and more permanently from the two springs at the head of the wetland. Sediment inputs come from sheet erosion from the grazing lands above the wetlands as well as livestock paths leading down to the wetland and dam. The livestock paths are causing water runoff and sediment to bypass the wetland which is situated in the natural drainage line. This may result in increased sedimentation rates in the farm dam which will reduce its longevity. Reduced sediment inputs into the wetland may also cause an increased risk in headward erosion from the erosion nickpoint at the toe of the wetland. It is important to ensure that livestock stay away from the toe of the wetland to reduce damage and erosion risk to the wetland. Herding strategies could reduce the impact that livestock paths are having on the functioning of the wetland.

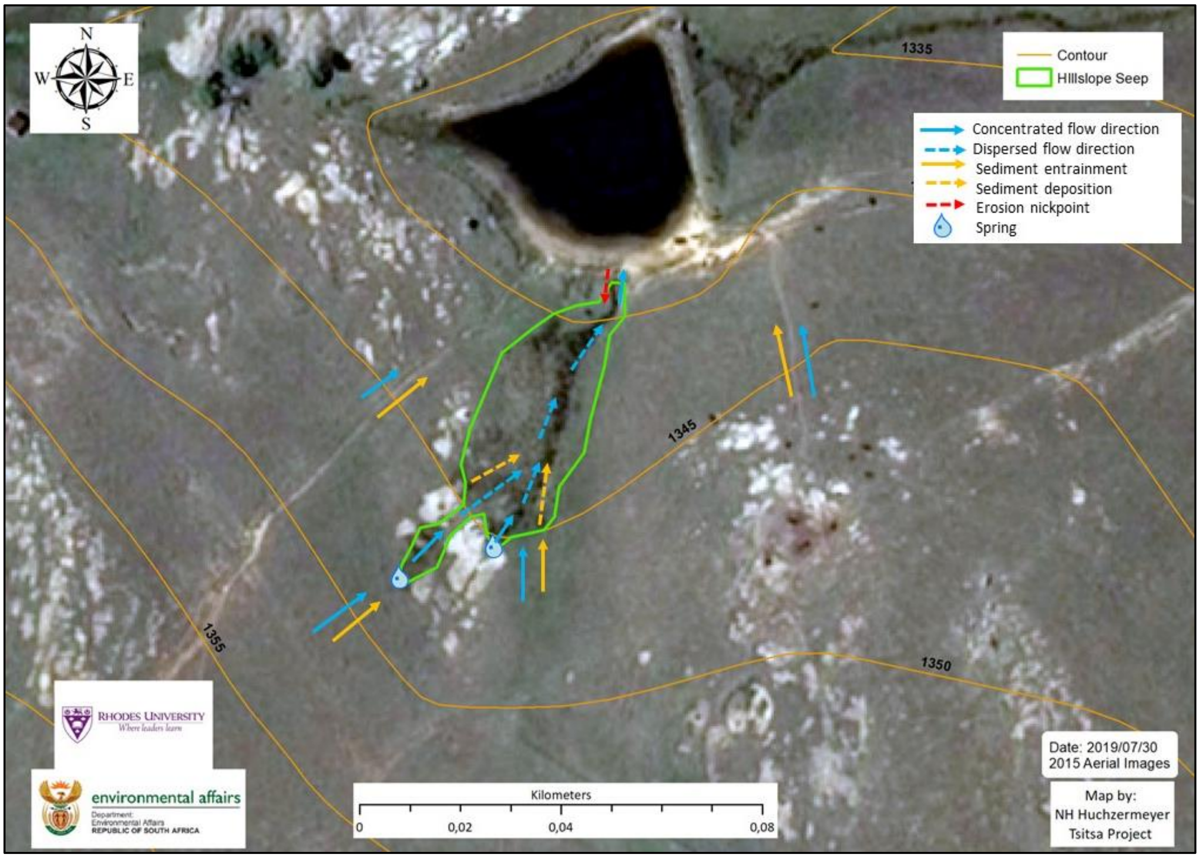


FIGURE 84: CURRENT CONDITION OF WETLAND 2

FIGURE 85: HEADWARD EROSION AT THE TOE OF WETLAND 2 DUE TO LIVESTOCK PRESSURES

FIGURE 86: FIXED POINT PHOTOGRAPH OF WETLAND 2. PHOTOGRAPH TAKEN AT 15H15 ON THE 29/04/2019

Figure 87 shows the catchment for Wetland 2 which is heavily modified by agriculutral activities. The catchment above Wetland 2 starts at the top of the ridge where a farmstead is situated. It moves down through several livestock paddocks and into a livestock grazing camp. The lower part of the catchment exhibits a rangeland with a moderate veld condition (see Chapter 17.3, Appendix 1). The presence of large alien invasive trees in and around the farmstead pose a risk to the water supply into the wetand (baseflow) due to high evapotranspiration rates.

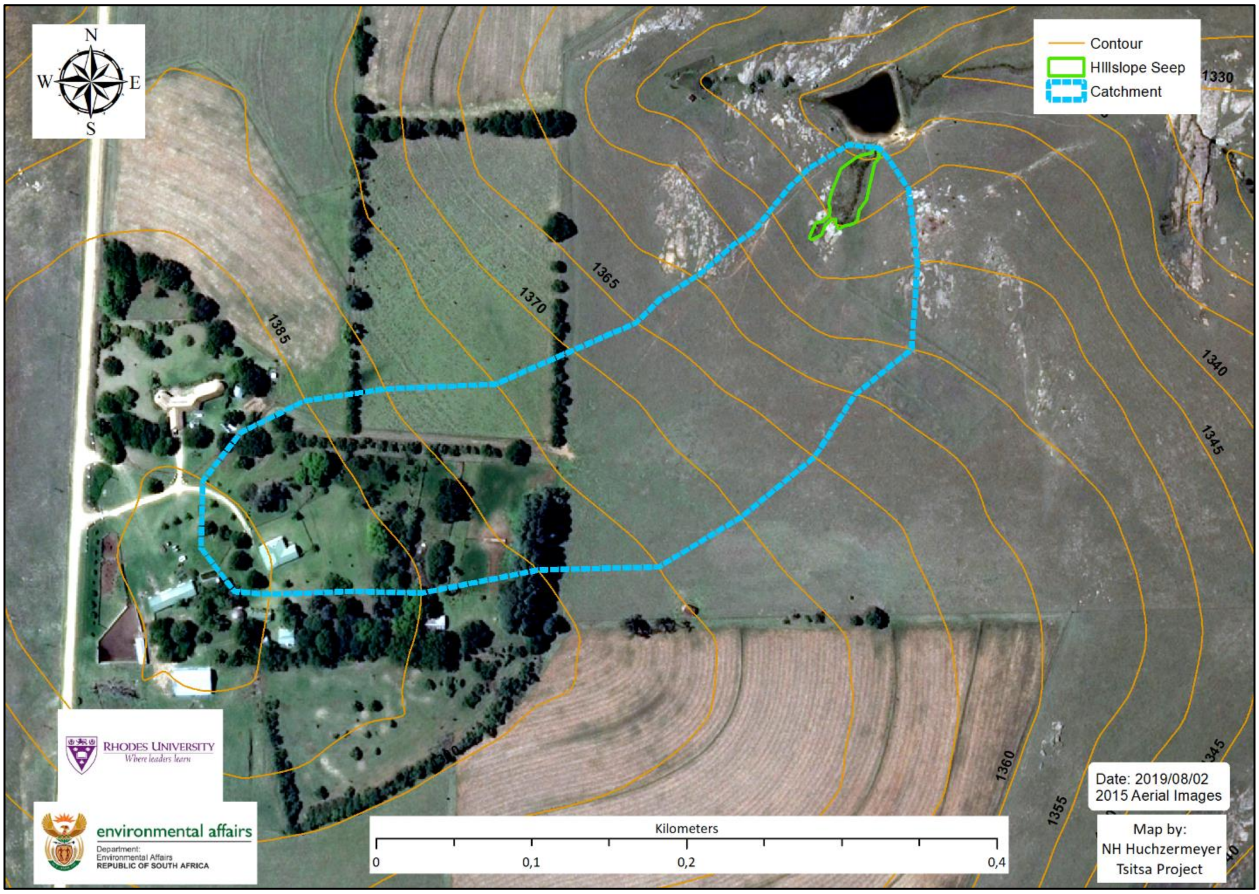


FIGURE 87: THE CATCHMENT AREA ABOVE WETLAND 2

Common plant species in Wetland 2

Table 25 lists the common plants found in Wetland 2. These indicate an area of permanent water and the grasses will provide grazing during drier months.

TABLE 25: COMMON WETLAND PLANTS FOUND IN WETLAND 2

Class	Species	Habitat
Wetland plants	*Schoenoplectus corymbosus/muricinux*	Edges of permanent water
	Juncus dregeanus	Edges of permanent water & among grasses

	Schoenoplectus brachyceras	Edges of permanent water
	Schoenoplectus muriculatus	Permanent water
	Cyperus longus L.var *tenuiflorus*	Seasonal and/or shallow water
Grass	*Stiburus alopecuroides*	Wet fertile soil at the edge of wetlands
	Paspalum dilatatum	Moist areas
	Eragrostis plana	Near moist areas
	Sporobolus africanus	Disturbed areas near damp places

18.3. Wetland 3: Description of wetland condition & use

Wetland 3 consists of a series of wetlands connected to natural drainage lines (Figure 88). Two un-channelled valley bottom wetlands are situated along the drainage lines and feed into the Tsitsana River. A depression wetland has formed between the two drainage lines. Wetland 3 acts as a sediment trap, the fringes are utilized by livestock, mostly sheep and it acts as a source of water for livestock (Figure 89). It is also a biodiversity hotspot for birds. The wetland area has been used and partly drained for cultivation in the past.

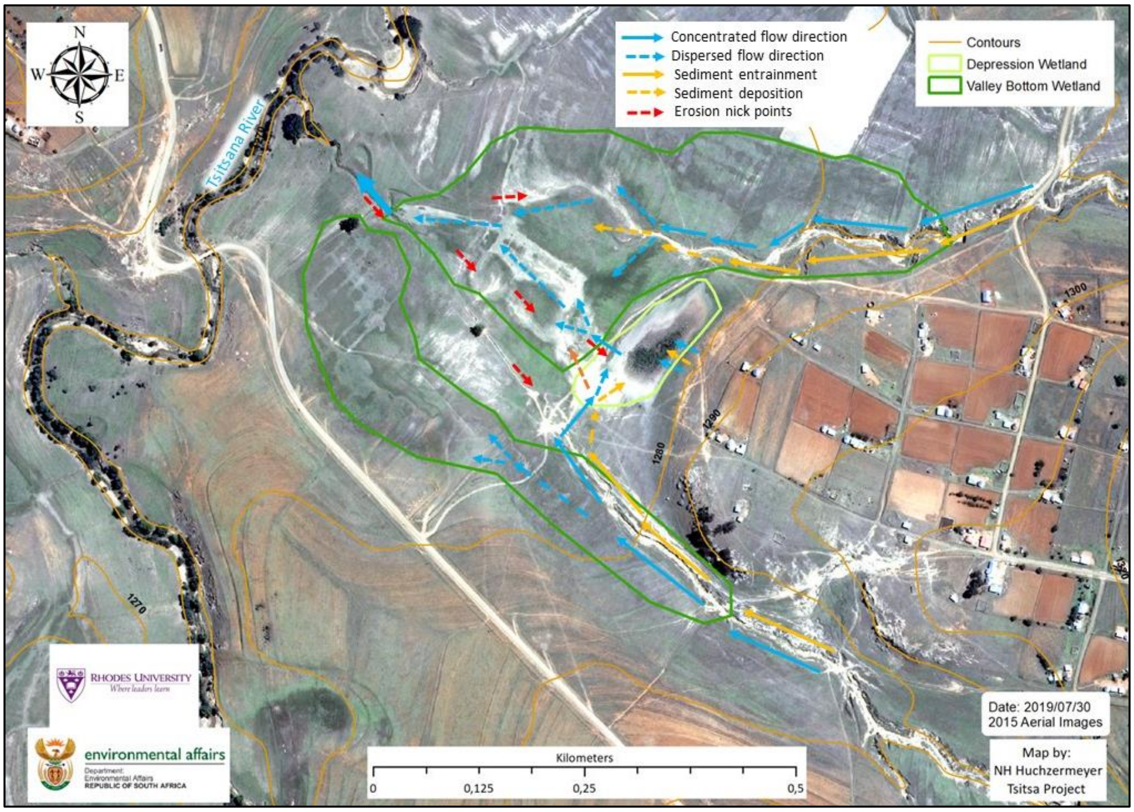


FIGURE 88: CURRENT CONDITION OF WETLAND 3

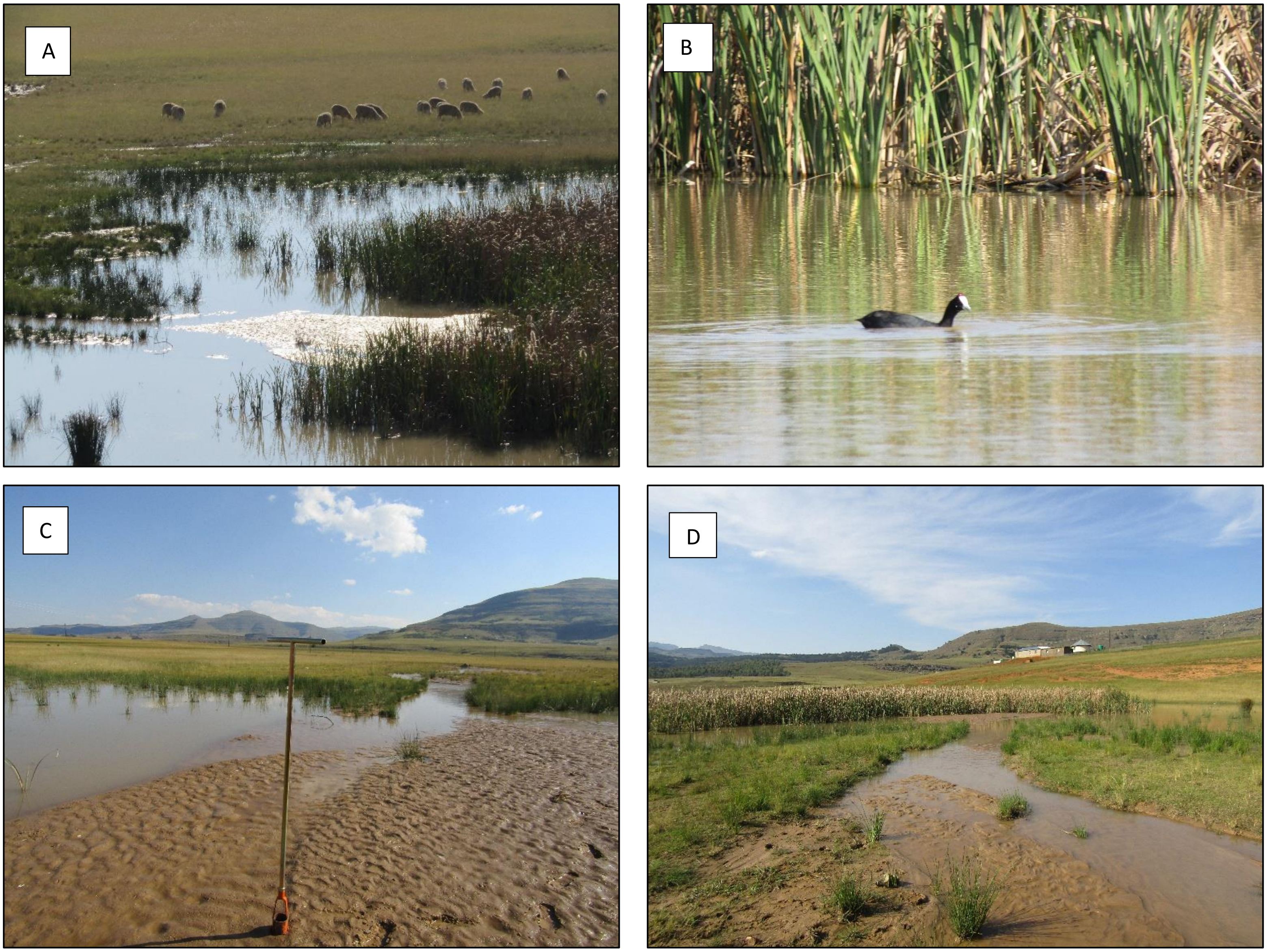


FIGURE 89: ECOSYSTEM SERVICES PROVIDED BY WETLAND 3. A: LIVESTOCK GRAZING AND DRINKING; B: PROVIDING HABITAT FOR BIRDS INCLUDING RED-KNOBBED COOTS AND WEAVER SPECIES; C & D: SEDIMENT AND NUTRIENT TRAPPING AS WELL AS CATCHING TOP SOIL BEFORE IT IS DEPOSITED IN THE RIVER SYSTEM

Figure 90: Landscape photograph of the depression wetland within the Wetland 3 system. Photograph taken at 15h30 on the 01/05/2019

Wetland 3 is at risk of erosion where the depression wetland runs into a drainage line as there is a combination of impacts from livestock paths and a vehicle crossing (Figure 91). Further down there is headward erosion within the un-channelled valley bottom wetland which has the potential to cut into the depression wetland (Figure 92). Once drained by a headcut the depression wetland can no longer supply as many ecosystem services.

The depression wetland is also at risk of incision of the drainage line feeding it in which case sediment will no longer be deposited in the depression wetland but rather bypass it straight into the Tsitsana River channel (Figure 92). There are signs of drains from discontinued fields that may have drained the wetland. However, the wetland seems to be recovering but is at risk if the drains wash open again.

FIGURE 91: SIGNS OF DEGRADATION IN WETLAND 3

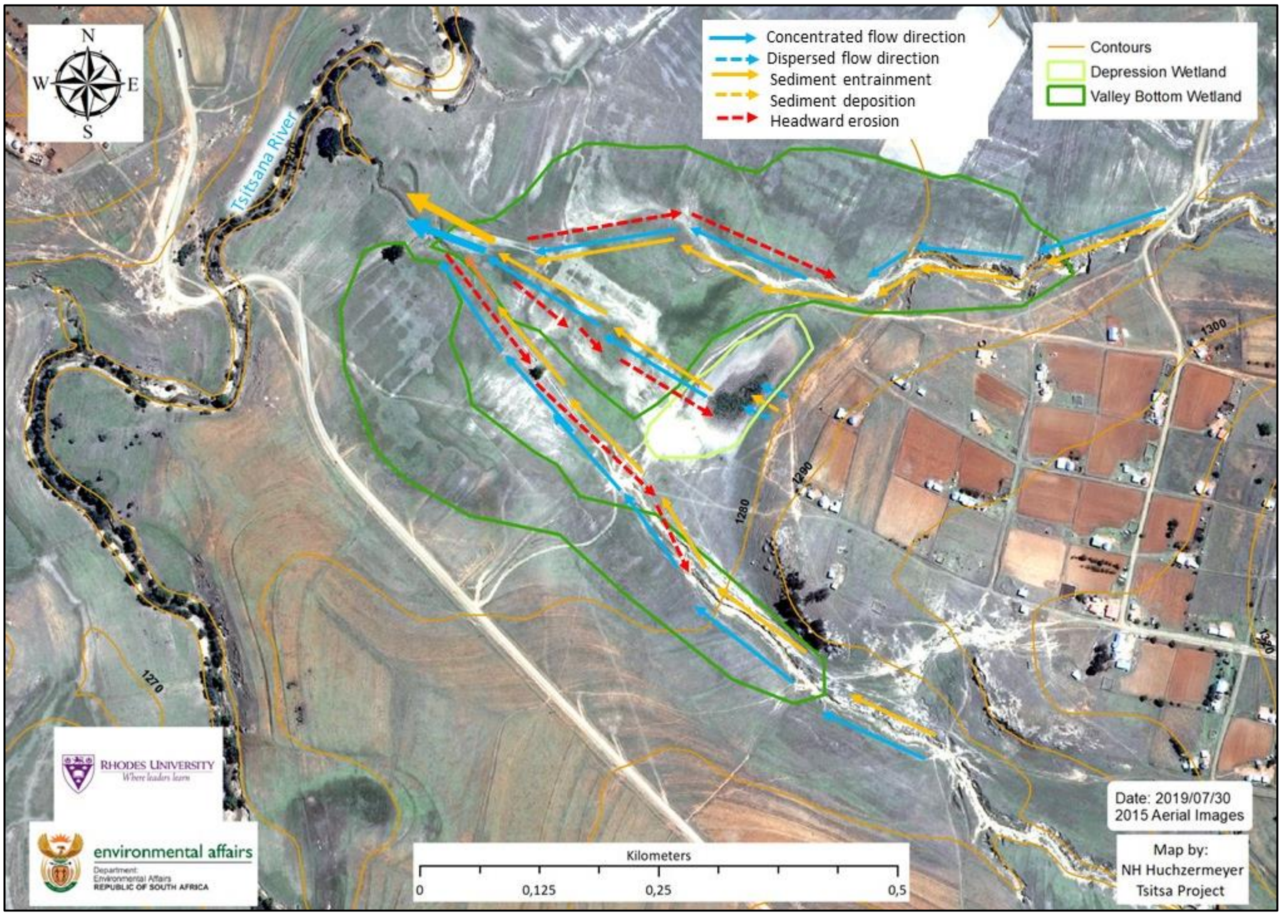


FIGURE 92: PREDICTED FUTURE VULNERABILITY OF WETLAND 3 IN THE ABSENCE OF ADDRESSING DRIVERS OF DEGRADATION

Wetland 3 has a large catchment (Figure 93) with water and sediment input from the surrounding mountains down two drainage valleys which merge and feed into the Tsitsana River. Within the catchment there is a settlement dotted with small cultivated lands and several roads. These all contribute to the overall sediment input into the wetlands and show how important the wetlands are as sediment buffers in small catchments and how they can reduce the amount of sediment reaching the main river channels.

FIGURE 93: THE CATCHMENT AREA ABOVE WETLAND 3

Common plant species in Wetland 3

Table 26 lists the common plants found in Wetland 3 in particular in and around the depression wetland. These indicate patches of permanent water and will sustain grazing during drier months.

TABLE 26: COMMON WETLAND PLANTS FOUND IN WETLAND 3

Class	Species	Habitat
Wetland plants	*Pycreus nitidus*	Permanent water
	Schoenoplectus brachyceras	Edges of permanent water
	Schoenoplectus corymbosus/muricinux	Edges of permanent water
	Juncus dregeanus	Edges of permanent water & among grasses
	Typha capensis	Watercourses and marshy areas
Grasses	*Paspalum distichum*	Near moist areas. Provide grazing for livestock during drier periods
	Cynodon dactylon	
	Eragrostis plana	Near moist areas
	Sporobolus africanus	Disturbed areas near damp places

18.4. Wetland 4: Description of wetland condition & use

Wetland 4 consists of several wetlands in and adjacent to a natural drainage line off a steep slope onto the floodplains of the Tsitsa River (Figure 94). Wetland 4 consists of an un-channeled valley bottom wetland running down the drainage line (Figure 95) as well as two hillslope seeps coming off the steeper slopes (Figure 96 & Figure 97). The wetlands seep into the Tsitsa River. There are several springs providing water input into the wetlands. Water and sediment input is also provided by the surrounding hillslopes. A bedrock intrusion at the toe of the un-channeled valley bottom plays a part in the formation of the wetland above it (Figure 98). The intrusion also creates a resistant layer at the toe of the wetland which inhibits headward erosion from the Tsitsa River which is incised. Erosional gullies at the head of the un-channeled valley bottom wetland occur as the gradient increases (Figure 99). Sediment from these gullies is deposited further down in the wetland where the gradient decreases (Figure 100). Small-scale informal sand mining was observed in this area.

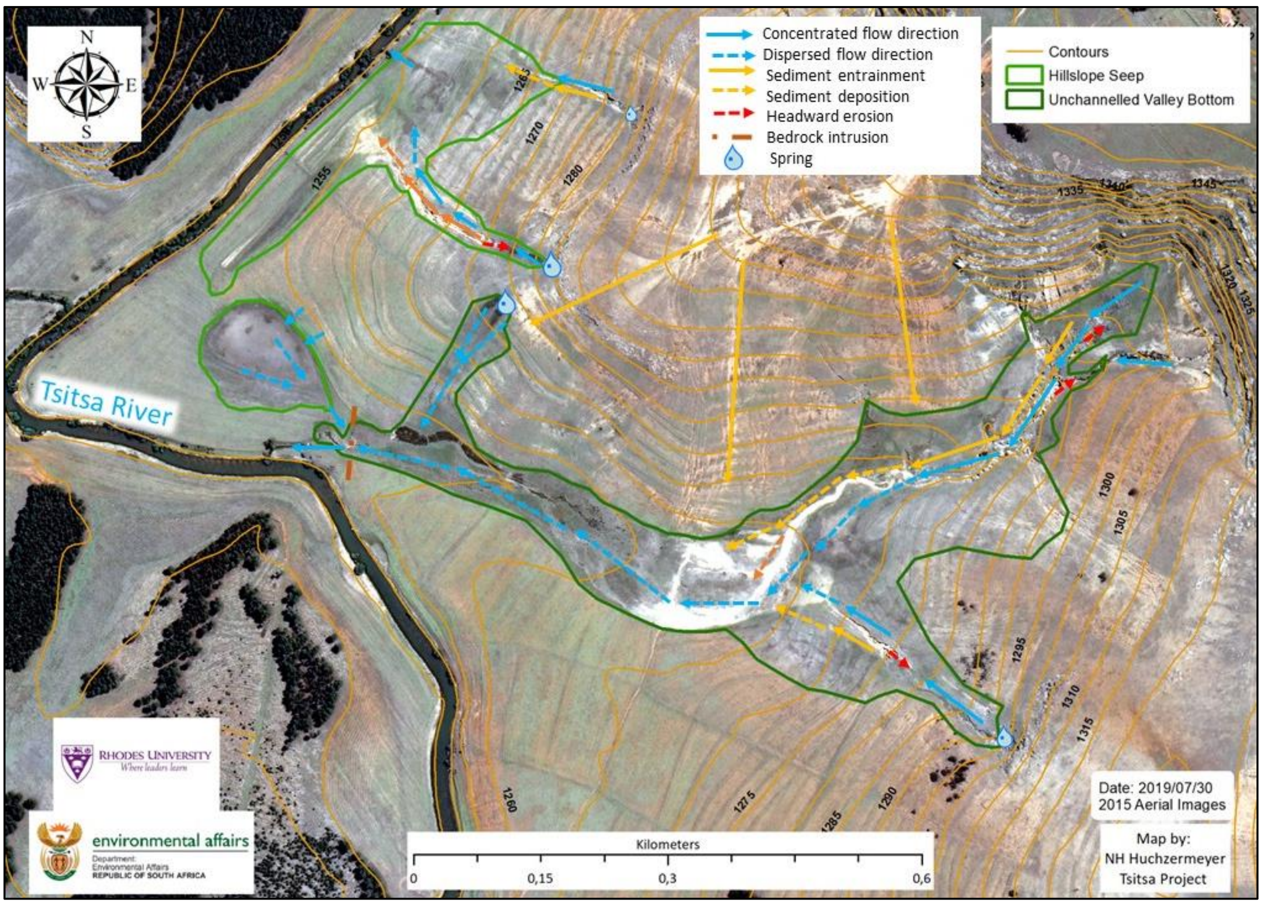


FIGURE 94: CURRENT CONDITION OF WETLAND 4

FIGURE 95: THE UN-CHANNELLED VALLEY BOTTOM WETLAND WITHIN THE WETLAND 4 SYSTEM. PHOTOGRAPH TAKEN AT 16H00 ON THE 01/05/2019

FIGURE 96: THE MIDDLE HILLSLOPE SEEP WETLAND WITHIN THE WETLAND 4 SYSTEM WHICH EXHIBITS A GOOD CONDITION.

FIGURE 97: THE RIGHT MOST HILLSLOPE SEEP AND SPRING, WITHIN THE WETLAND 4 SYSTEM, EXHIBITING HEADWARD EROSION TOWARDS THE SPRING

Figure 98: Bedrock intrusion at the base of the wetland protecting the wetland from headward erosion originating from the confluence of the wetland channel with the Tsitsa River

FIGURE 99: EROSION GULLIES AT THE HEAD OF THE WETLAND EXHIBITING STABLE SIDES

FIGURE 100: ALLUVIAL FAN AT THE FOOT OF THE SLOPE EXHIBITING GOOD VEGETATION GROWTH AND IT ALSO SHOWS SHEEP UTILIZING THE WETLAND FRINGES

The wetland catchment (Figure 101) drains off a steep peninsular mountain. The top of the catchment has a low gradient with some small cultivated fields and part of a village. The middle catchment is very steep with cliffs and the lower catchment exhibits a low gradient on the floodplain of the Tsitsa River. There are a multitude of livestock and human paths concentrating on a pass down the steep slope above the wetland. From that point the paths disperse into the valley. Livestock (Figure 102) use these paths both for moving to areas to drink and areas of better grazing. The local villagers use the paths to collect fire wood in the valley among other things (Figure 103). Wetland 4 is an important ecosystem for biodiversity. Birds such as herons, hadeda ibis and grey crowned cranes were present (Figure 104). Presence of these birds also indicate the presence of prey such as frogs, worms and insects which in turn indicate a healthy ecosystem. There are small populations of alien invasive wattle species present on the Tsitsa River riparian zone. These pose a risk if they spread into the wetland area. The wattle stands on the surrounding hillslopes are utilized by the local villagers and their spread is minimal at the moment.

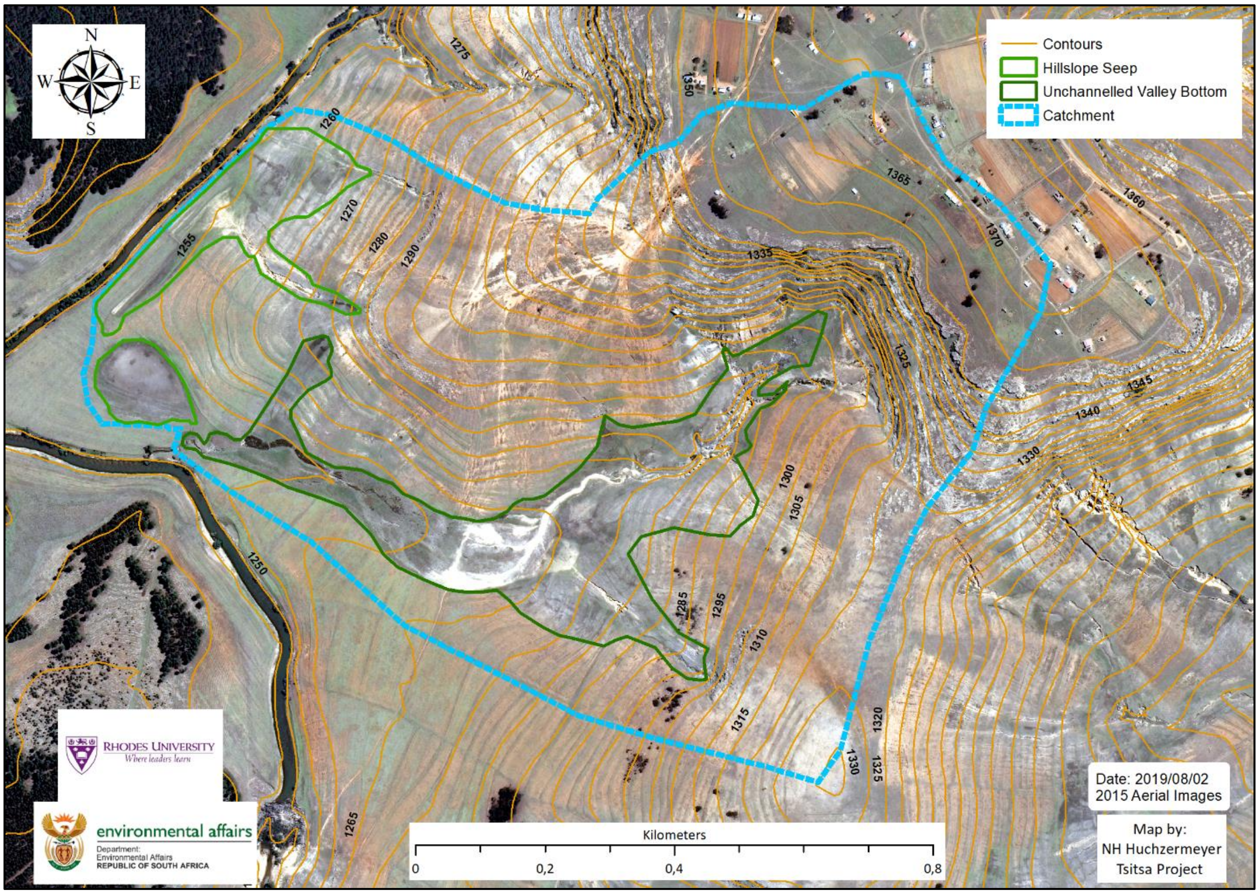


FIGURE 101: THE CATCHMENT AREA ABOVE WETLAND 4

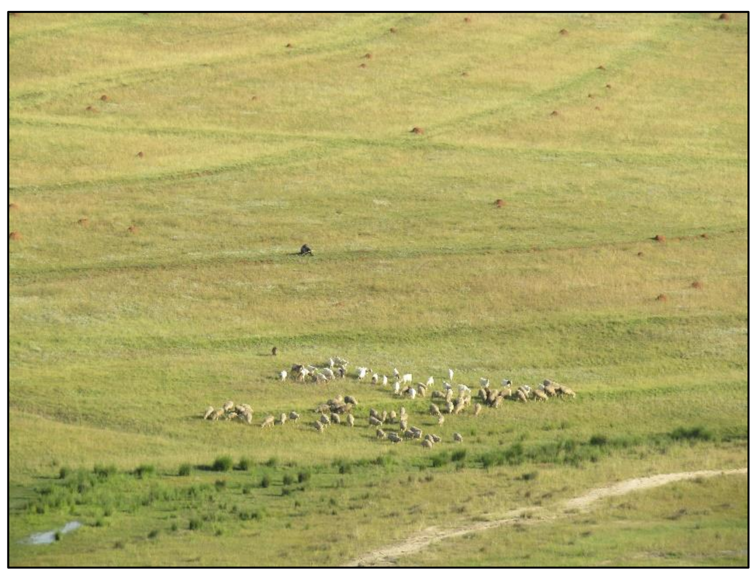


Figure 102: Livestock, including horses, goats and sheep, grazing within and around the wetland

Figure 103: Local villagers collecting firewood in the valley. Small-scale sand mining was also observed in the alluvial fan

FIGURE 104: PRESENCE OF BIRDS SUCH AS HERONS, HADEDA IBIS AND GREY CROWNED CRANES IN WETLAND 4.

Common plant species in Wetland 4

Table 27 lists the common plants found in the Wetland 4 system. The wetland plants indicate shallow to permanent water and marshy areas. The grasses indicate seasonally flooded areas but also indicate heavy grazing in the area.

TABLE 27: COMMON WETLAND PLANTS FOUND IN WETLAND 4

Class	Species	Habitat
Wetland plants	**Juncus effusus*	Large stands around permanent water
	Pycreus nitidus	Permanent water
	Persicaria limbata	Shallow water
	Juncus exertus	Permanent wet areas and shallow water
	Typha capensis	Watercourses and marshy areas
Grasses	*Panicum hymeniochilum*	Seasonally flooded areas
	Paspalum distichum	Near moist areas. Provide grazing for livestock during drier periods
	Eragrostis plana	Near moist areas
	Sporobolus africanus	Disturbed areas near damp places
	Andropogon eucomus	Moist disturbed soils

18.5. Wetland 5: Description of wetland condition & use

Wetland 5 is a Hillslope seep situated on a floodplain step of the Hlankomo River (Figure 105 and Figure 106). It is used by livestock for grazing and traps sediment from the surrounding landscape reducing sediment transport into the Hlankomo River. Wetland 5 is representative of several such wetlands found along the banks of the smaller rivers where they have a narrow valley surrounded by steeper slopes.

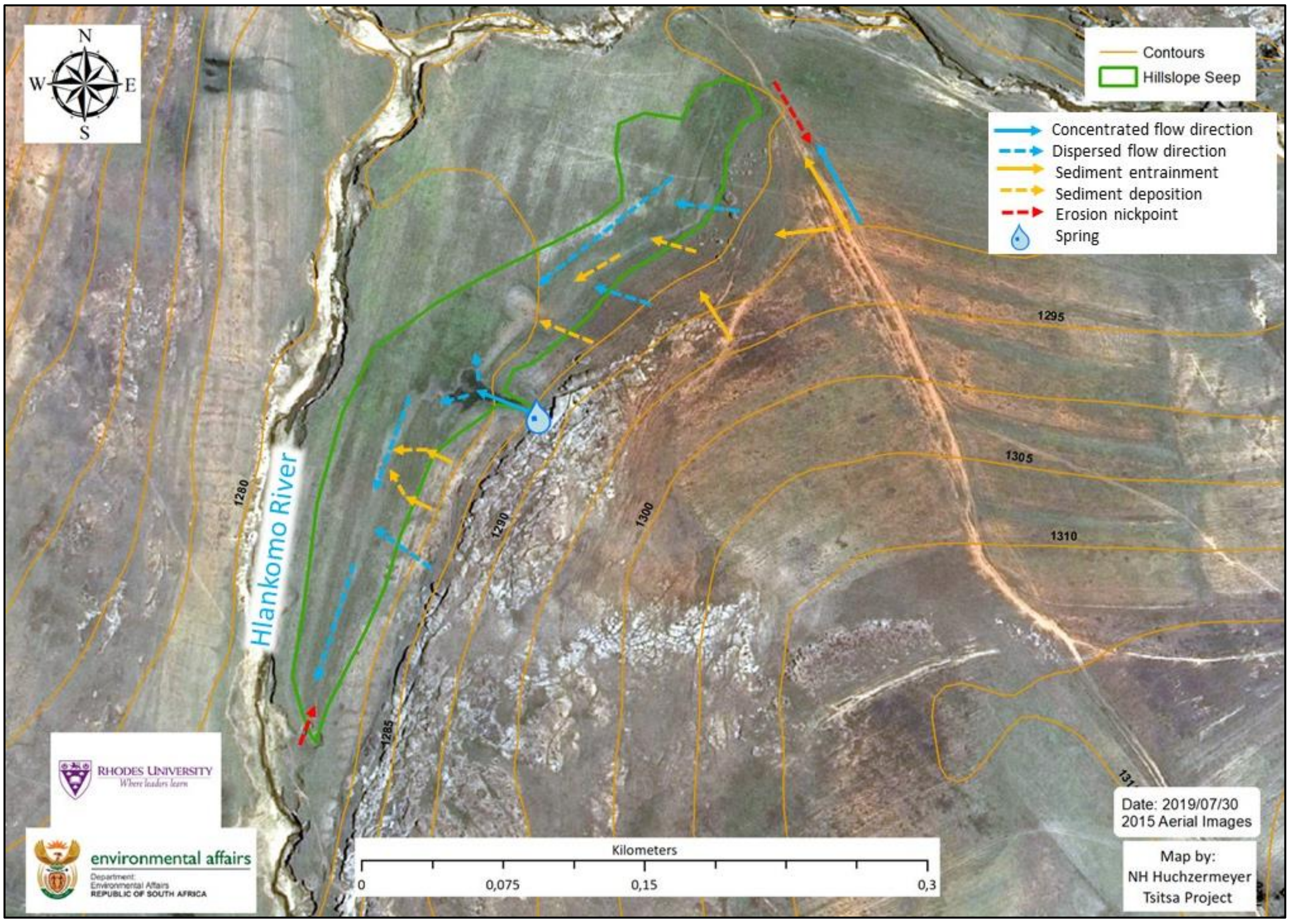


FIGURE 105: CURRENT CONDITION OF WETLAND 5

FIGURE 106: WETLAND 5 IS A HILLSLOPE SEEP WETLAND ON THE BANKS OF THE HLANKOMO RIVER. PHOTO TAKEN AT 09H45 ON THE 02/05/2019

FIGURE 107: PERMANENT WATER AND MARSHY AREA IN WETLAND 5

Wetland 5 has a small catchment on the hillslope above it. Sediment and run-off from the hillslope above is diverted by a prominent livestock path that leads to a river crossing and continues to grazing lands on the adjacent slopes. Erosion is likely to occur here as water is concentrated leading to an increase in sediment transport straight into the Hlankomo river. Erosional nickpoints at the toe of the wetland (Figure 109) are stable but could become active due to riparian and bank disturbances. Wetland 5 receives water from a spring coming out of the rocks at the edge of the mountain (Figure 110).

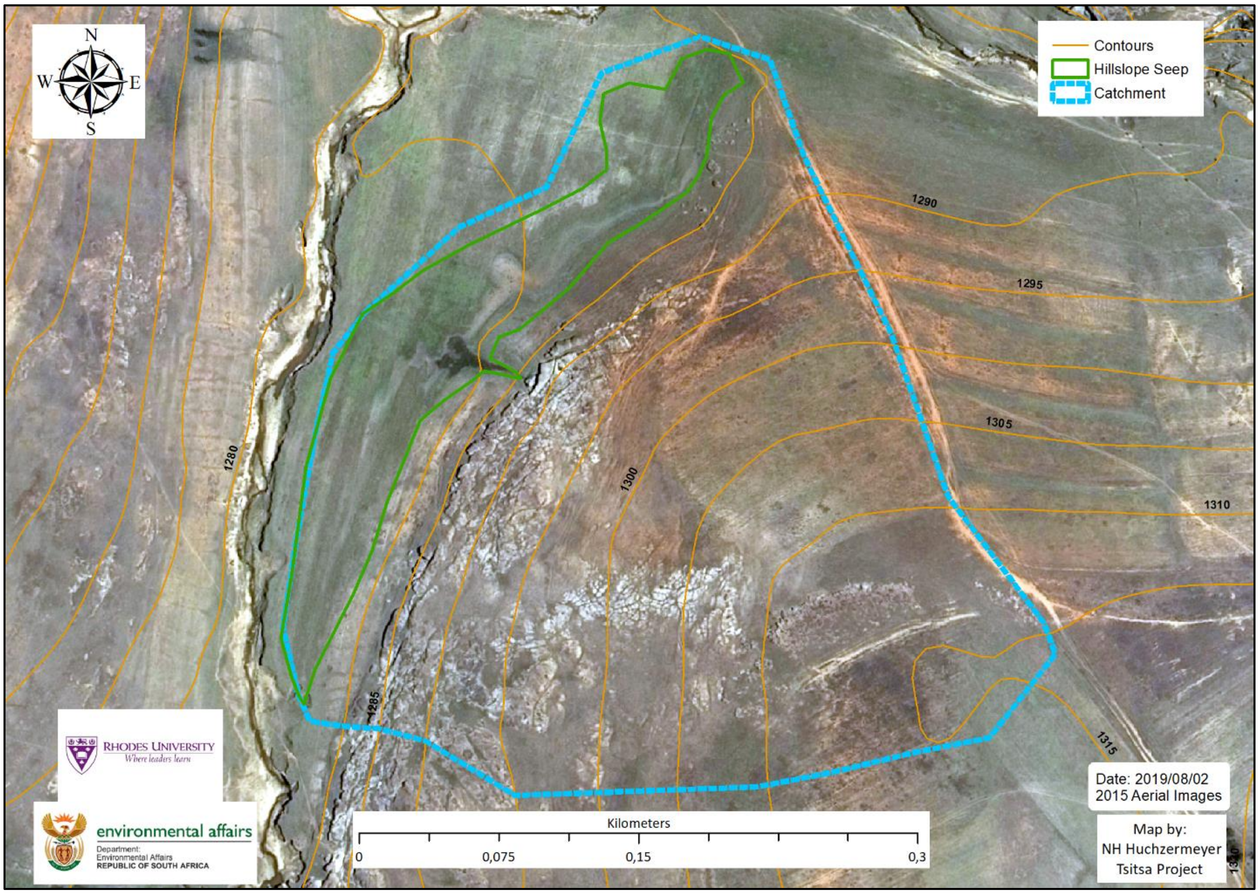


FIGURE 108: CATCHMENT AREA ABOVE WETLAND 5

FIGURE 109: STABLE EROSIONAL NICK POINTS AT THE TOE OF WETLAND 5

FIGURE 110: IN WETLAND 5 THE WATER REACHES THE SURFACE BETWEEN A ROCK OUTCROP AND SEEPS ONTO THE LOW GRADIENT FLOODPLAIN BELOW

Video of spring: https://youtu.be/6pvW4KJLytg

Common plants species in Wetland 5

Table 28 lists the common plants found in Wetland 5. These indicate permanent water and moist areas providing good grazing and water during dry spells.

TABLE 28: COMMON WETLAND PLANTS FOUND IN WETLAND 5

Class	Species	Habitat
Wetland plants		Permanent water
	**Juncus effusus*	Large stands around permanent water
	Schoenoplectus brachyceras	Edges of permanent water
	Fimbristylis dichotoma	Wet seepage areas, moist grasslands
	Pycreus nitidus	Permanent water
Grasses	*Cynodon dactylon*	

	Eragrostis plana	Near moist areas
	Sporobolus africanus	Disturbed areas near damp places

18.6. Wetland 6: Description of wetland condition & use

Wetland 6 is a large (43 ha) un-channelled valley bottom wetland (Figure 111). Wetland 6 is used by livestock grazing and has several springs (Figure 114) that are used by the local villagers for water collection and by livestock for drinking. Wetland 6 catches sediment from the surrounding landscape. There is headward erosion present in the wetland but it is situated on the higher slopes. Erosion around the springs should be monitored. Wetland 6 is controlled by bedrock at the toe of the wetland protecting it from headward erosion at the toe.

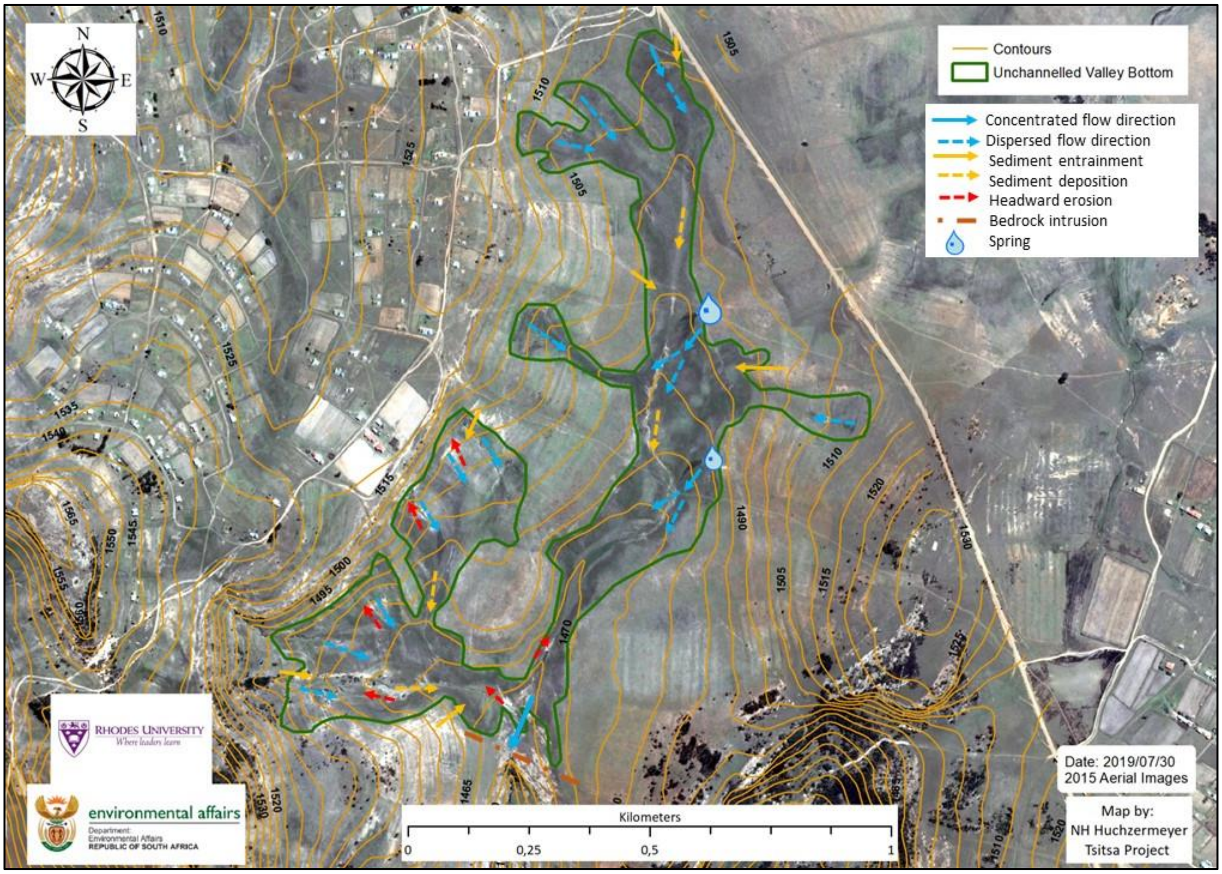


FIGURE 111: CURRENT CONDITION OF WETLAND 6

Wetland 6 has a catchment area of 161 ha which includes a main district road and a village with cultivated lands that contribute sediment into the wetland system (Figure 112). The local village could benefit from proper management of the springs which can include, a pond to catch water, easier access, dedicated livestock drinking area etc.

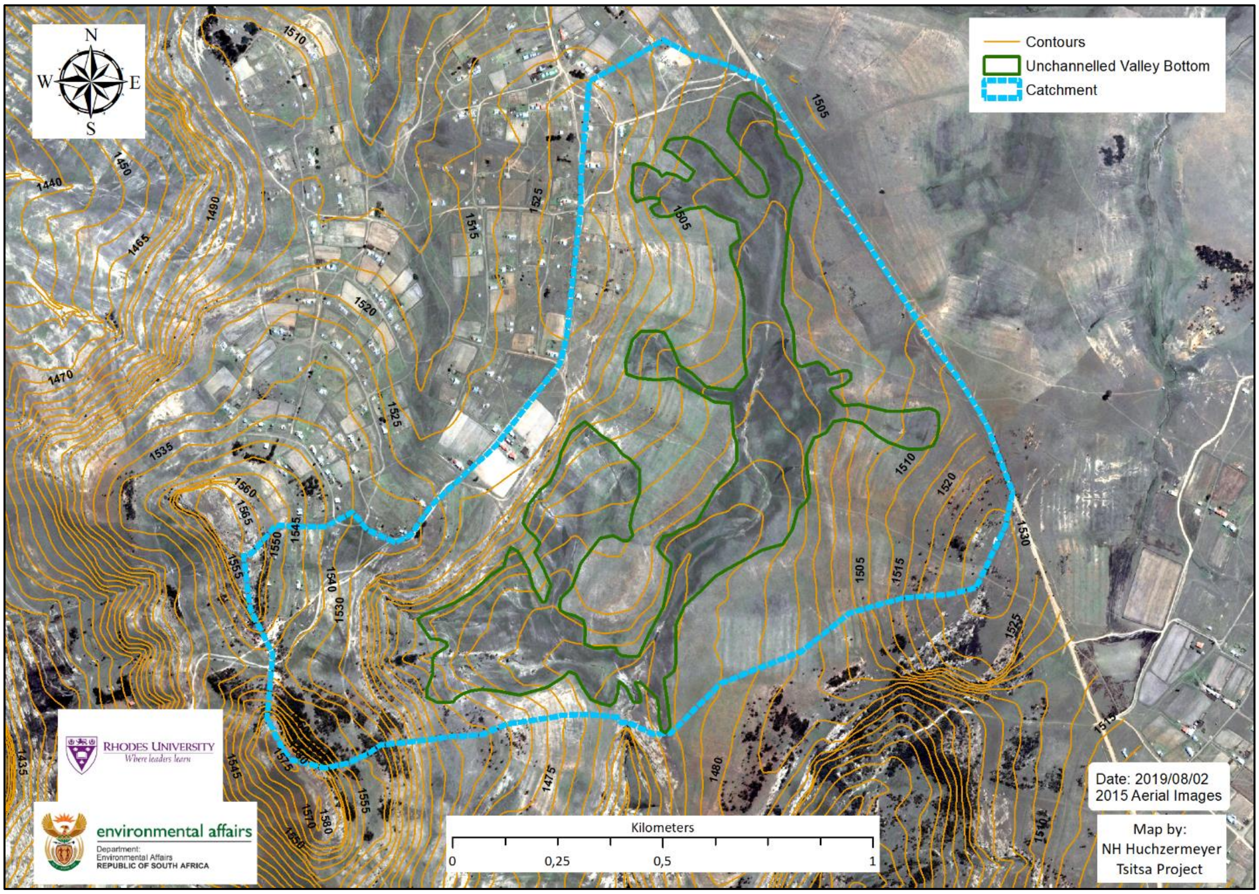


FIGURE 112: CATCHMENT AREA ABOVE WETLAND 6

FIGURE 113: CROSS-SECTIONAL VIEW ACROSS THE MIDDLE OF THE UN-CHANNELLED VALLEY BOTTOM WETLAND (WETLAND 6)

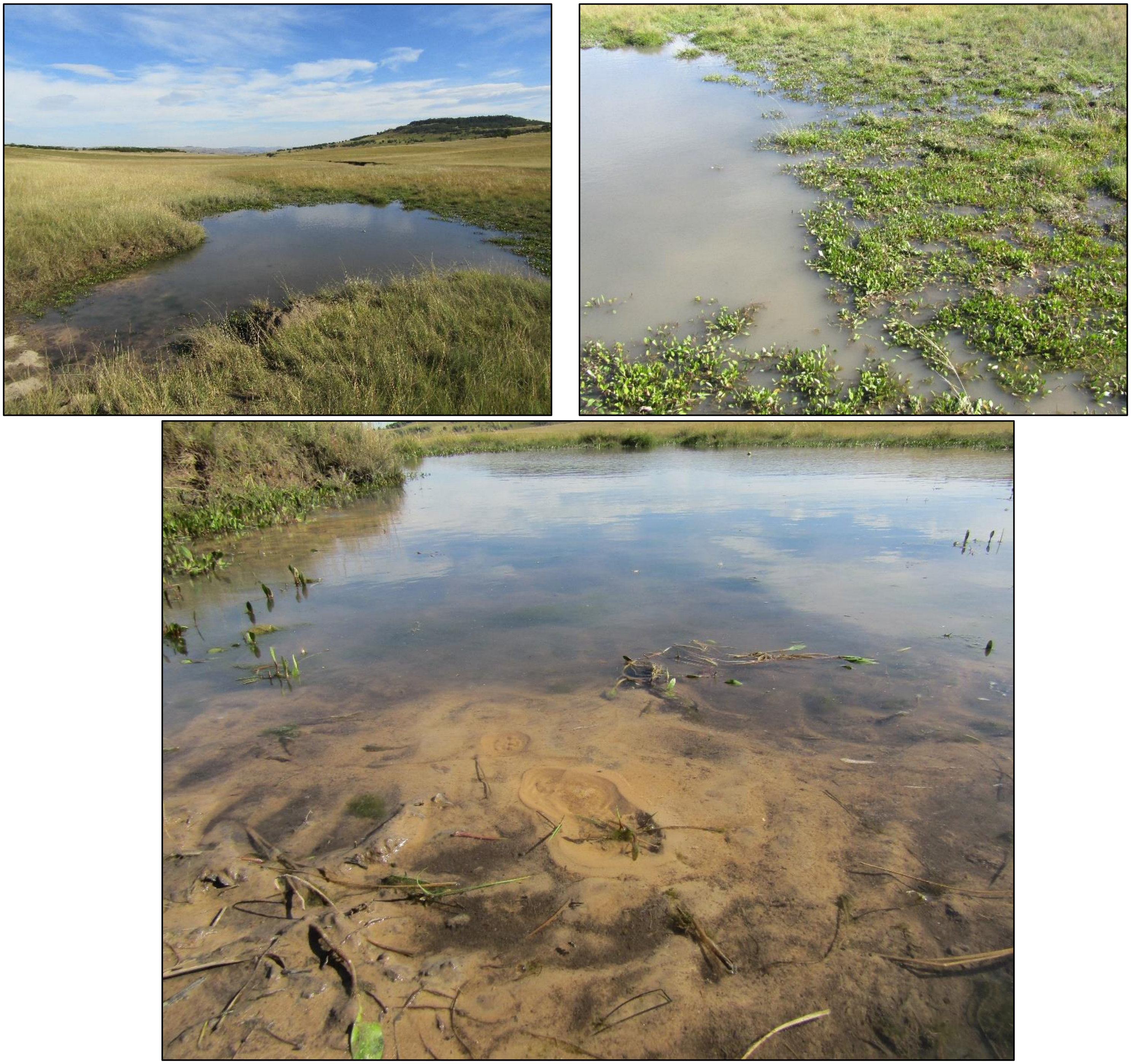


FIGURE 114: SPRING AT THE TOP OF WETLAND 6

Video of spring: https://youtu.be/BLhuLAWleG0

Common plant species in wetland 6

Wetland plants in wetland 6 are indicative of an area that has permanent water.

TABLE 29: COMMON WETLAND PLANTS FOUND IN WETLAND 6

Class	Species	Habitat
Wetland plants 6	*Juncus punctorius*	Permanent water
	Persicaria amphibia	Marshy and wet places
	Schoenoplectus muriculatus	Permanent water
	Cyperus marginatus	Shallow water
Grasses	*Eragrostis plana*	Near moist areas
	Sporobolus africanus	Disturbed areas near damp places

18.7. Wetland 7

Wetland 7 is a large floodplain wetland comprising of an area of approximately 290 ha. Wetland 7 is used by commercial farms for grazing during the winter months. Because of the large size of the wetland both the flow and sediment dynamics within the wetland are complex. An NRF research project has been started that will focus on understanding these floodplain systems and their effectiveness at trapping sediment in the long-run.

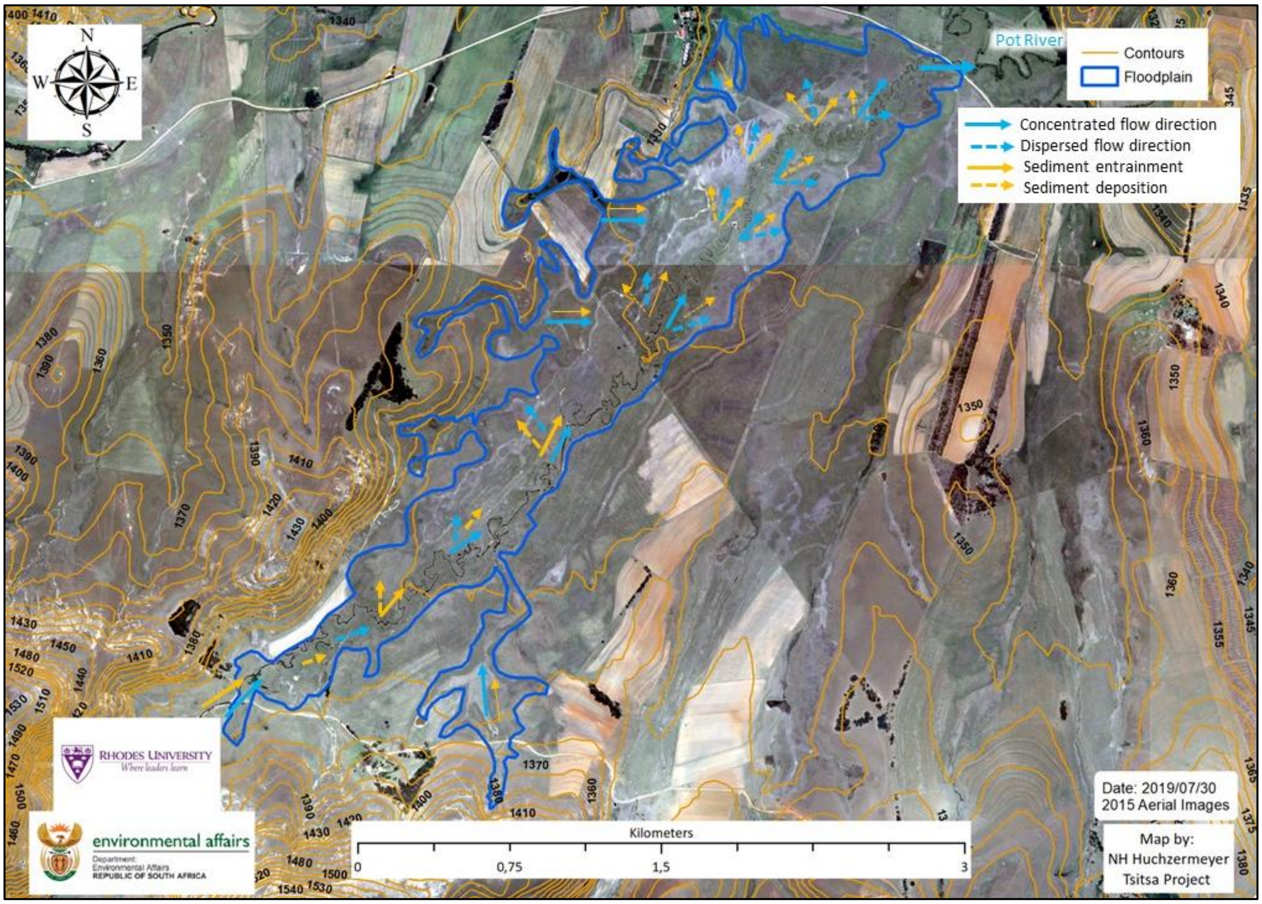


Figure 115: Current condition of Wetland 7

Wetland 7 has a very large catchment area of 2 945 ha (Figure 116). The headwaters are very steep with lots of tributaries. This area is mostly used for livestock grazing during the summer months and is very remote. Wetland 7 has formed where the river comes off the escarpment onto a low gradient valley. Many years of sediment accumulation has formed the floodplain system one can observe today.

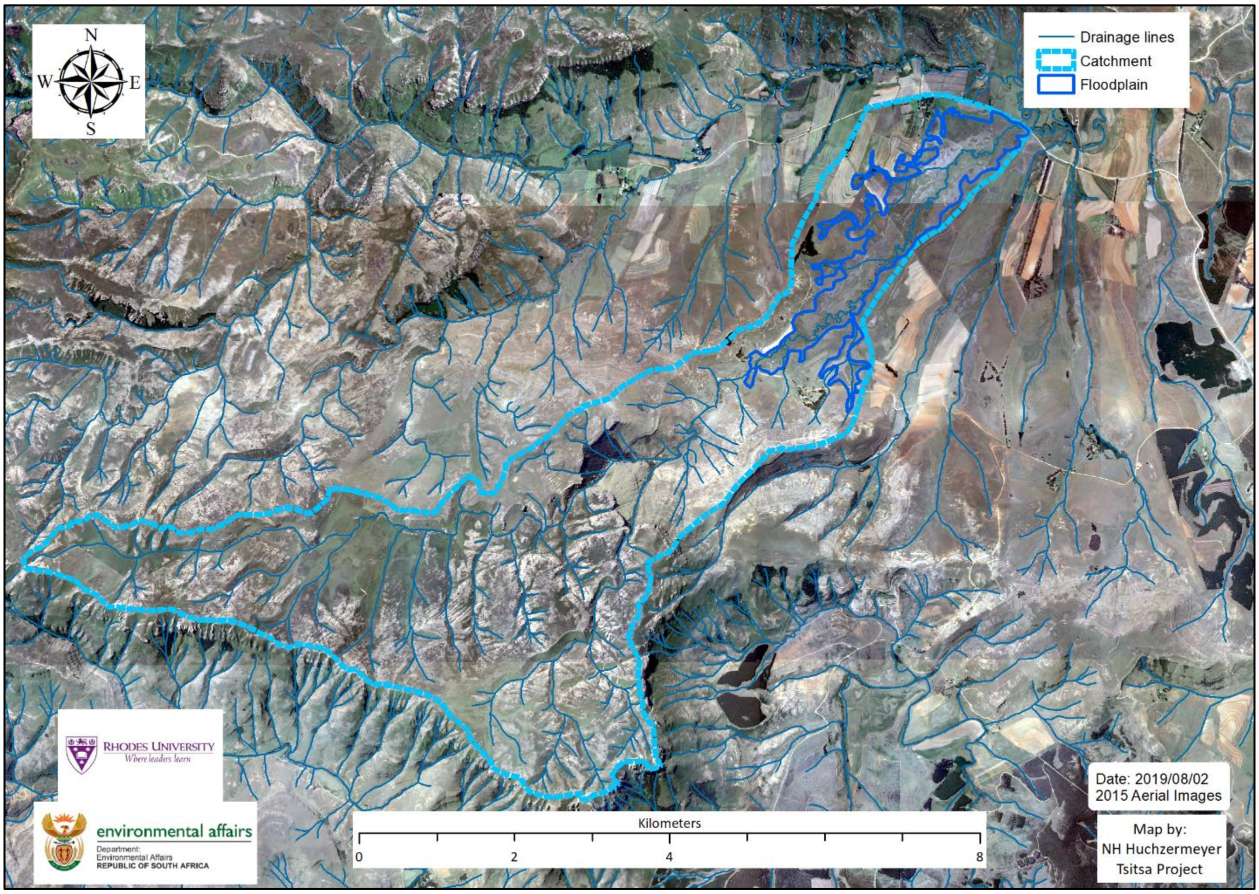


FIGURE 116: CATCHMENT AREA ABOVE WETLAND 7

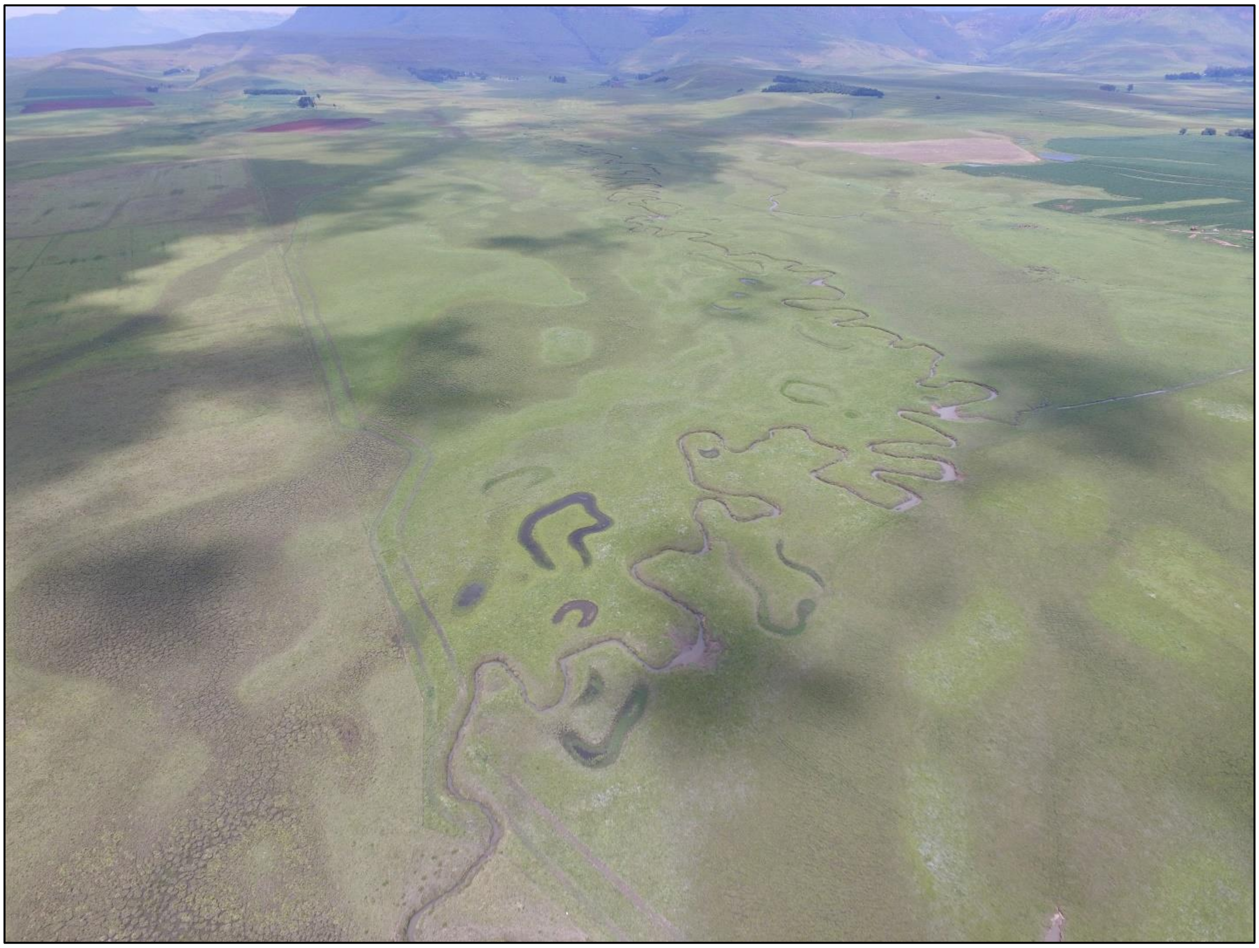


FIGURE 117: AERIAL IMAGE OF A SECTION OF WETLAND 7

FIGURE 118: MEANDER BENDS PRESENT IN THE FLOODPLAIN WETLAND

Common plant species in wetland 7

Wetland plant species indicative of permanent wet areas. Good grazing grasses present.

TABLE 30: COMMON WETLAND PLANTS FOUND IN WETLAND 7

Class	Species	Habitat
Wetland plants 7 (incomplete list)	*Cyperus fastigiatus*	Permanent pools and wet marshy areas
Grasses	*Eragrostis plana*	Near moist areas
	Sporobolus africanus	Disturbed areas near damp places
	Monocymbium ceresiiforme	Near moist areas. Good grazing when young
	Themeda triandra	Soils with high organic content. Good grazing grass

19. APPENDIX 4: RAINFALL TRENDS PER HYDROLOGICAL YEAR FROM 2015-2019

TABLE 31: RAINFALL DATA FROM OCTOBER 2015-SEPTEMBER 2016

	Elevation (m.a.s.l)	Total yearly rainfall (mm) Oct 2015-Sep 2016	Average monthly rainfall (mm) Oct 2015-Sep 2016	Max monthly rainfall (mm) Oct 2015-Sep 2016	Min monthly rainfall (mm) Oct 2015-Sep 2016	Max daily rainfall Oct 2015-Sep 2016	Max hourly rainfall Oct 2015-Sep 2016	Max 5 minute rainfall Oct 2015-Sep 2016
T35 A: Tsitsana	1 340	459	46	153	0	38	18	6.0
T35 B: Woodcliff	1 360	809	67	156	22	46	16	7.4
T35 C: Mooi	1 330	715	55	196	6	40	13	4.4
T35 D: Tsitsa Falls	1 185	571	44	114	2	38	34	14.6
T35 E: Sinxaku	1 030	667	56	134	0	35	21	12

TABLE 32: RAINFALL TRENDS FROM OCTOBER 2016-SEPTEMBER 2017

	Elevation (m.a.s.l)	Total yearly rainfall (mm) Oct 2016- Sep 2017	Average monthly rainfall (mm) Oct 2016- Sep 2017	Max monthly rainfall (mm) Oct 2016- Sep 2017	Min monthly rainfall (mm) Oct 2016- Sep 2017	Max daily rainfall Oct 2016- Sep 2017	Max hourly rainfall Oct 2016- Sep 2017	Max 5 minute rainfall Oct 2016- Sep 2017
T35 A: Tsitsana	1 340	765	64	183	0.2	52	29	7.2
T35 B: Woodcliff Blocked	1 360	615	51	262	0	53	34	6.8
T35 C: Mooi	1 330	754	63	182	1.4	26	21	7.4
T35 D: Tsitsa Falls Blocked	1 185	557	43	161	0	38	21	13.2
T35 E: Sinxaku Missing data	1 030	468	52	118	3.2	27	16	9
T35 F: Morven	1 391	766	64	161	4.8	34	20	7.0
T35 G: Montgomery Blocked	1 316	340	28	63	5	19	11	4.8
T35 H: Nolutando/Mpele	1 512	699	54	182	0.4	31	22	8
T35 J: Nosandise Faulty	1 004	207	17	56	1.6	8	6	5
T35 K: Nkosana Missing data	9 88	384	43	124	2	29	18	6.0

Table 33: Rainfall trends from October 2017-September 2018

	Elevation (m.a.s.l)	Total yearly rainfall (mm) Oct 2017- Sep 2018	Average monthly rainfall (mm) Oct 2017-Sep 2018	Max monthly rainfall (mm) Oct 2017-Sep 2018	Min monthly rainfall (mm) Oct 2017-Sep 2018	Max daily rainfall Oct 2017-Sep 2018	Max hourly rainfall Oct 2017-Sep 2018	Max 5 minute rainfall Oct 2017-Sep 2018
T35 A: Tsitsana	1 340	761	63	223	1.6	38	16	6
T35 B: Woodcliff Blocked	1 360	764	64	209	6.2	40	29	7.4
T35 C: Mooi	1 330	831	69	203	2.2	31	22	10.8
T35 D: Tsitsa Falls Blocked	1 185	378	31	223	0.2	39	15	6.4
T35 E: Sinxaku Missing data	1 030	164	13	80	0	40	20	7.2
T35 E: Gqukunqa Jan 2018-Sep 2019	1 170	595	66	249	0.6	49	29	11
T35 F: Morven	1 391	906	76	281	0.4	49	29	7.8
T35 G: Montgomery Blocked	1 316	614	51	264	4.4	50	21	10.8
T35 H: Nolutando/Mpele Missing data	1 512	540	77	177	14.4	32	27	7.9
T35 J: Nosandise-Faulty	1 004	21	7	21	0	22	15	7.6
T35 K: Nkosana	9 88	592	46	160	1.8	34	14	4.6

TABLE 34: RAINFALL TRENDS FROM OCTOBER 2018-AUGUST 2019

	Elevation (m.a.s.l)	Total yearly rainfall (mm) Oct 2018-Aug 2019	Average monthly rainfall (mm) Oct 2018-Aug 2019	Max monthly rainfall (mm) Oct 2018-Aug 2019	Min monthly rainfall (mm) Oct 2018-Aug 2019	Max daily rainfall Oct 2018-Aug 2019	Max hourly rainfall Oct 2018-Aug 2019	Max 5 minute rainfall Oct 2018-Aug 2019
T35 A: Tsitsana	1 340	583	53	125.4	0	35	17	14.2
T35 B: Woodcliff	1 360	737	67	159	0.2	41	27	13.4
T35 C: Mooi	1 330	822	75	200	0	48	28	7.4
T35 D: Tsitsa Falls	1 185	472	39	145	0	47	23	8.2
T35 E: Sinxaku	1 030	450	64	133	1.4	52	16	5.2
T35 E: Gqukunqa	1 170	622	52	167	0	49	28	8.4
T35 F: Morven	1 391	495	55	190	0	58	25	7.8
T35 G: Montgomery	1 316	401	37	146	1	26	18	9.2
T35 H: Nolutando/Mpele Missing data	1 512	6	2	6	0	4	4	1.4
T35 J: Nosandise- Faulty	1 004	82	12	70	0	14	13	4
T35 K: Nkosana Oct 2018-March 2019	9 88	555	79	164	7.4	64	17	6.2

20. APPENDIX 5: RIVER SPECIFIC LONG-PROFILES

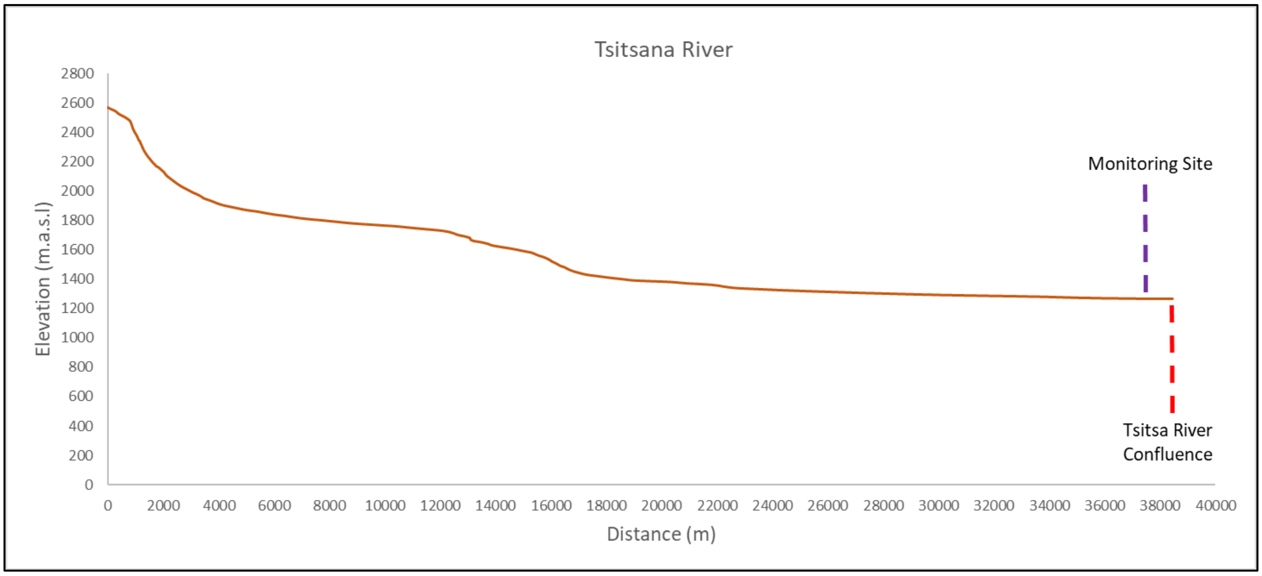


FIGURE 119: LONGITUDINAL PROFILE OF THE TSITSANA RIVER

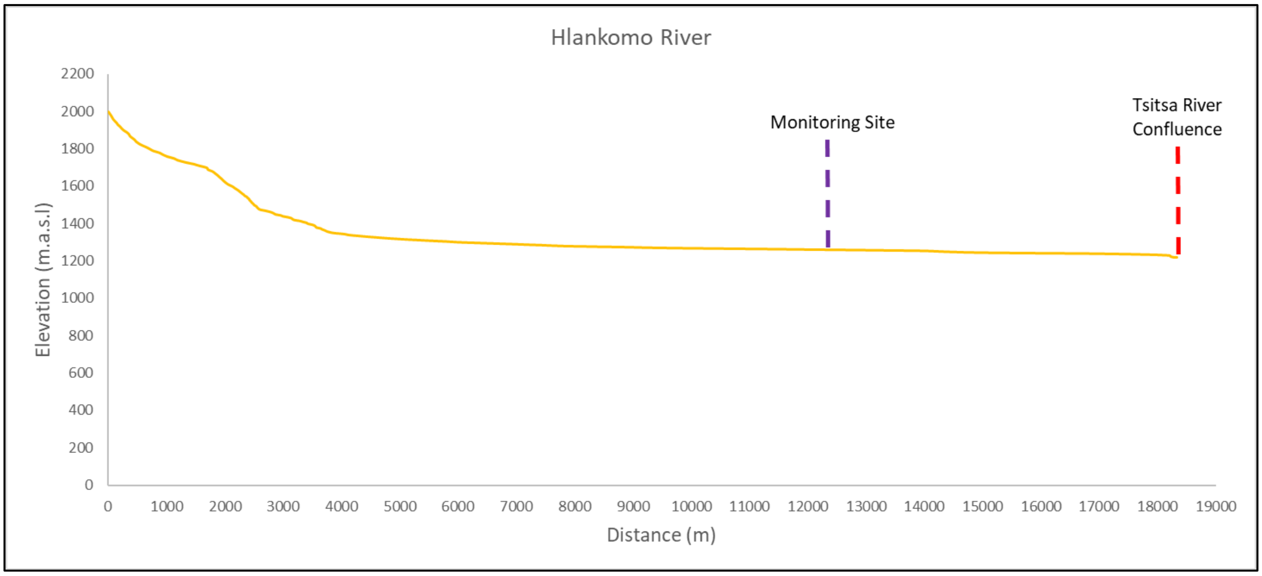


FIGURE 120: LONGITUDINAL PROFILE OF THE HLANKOMO RIVER

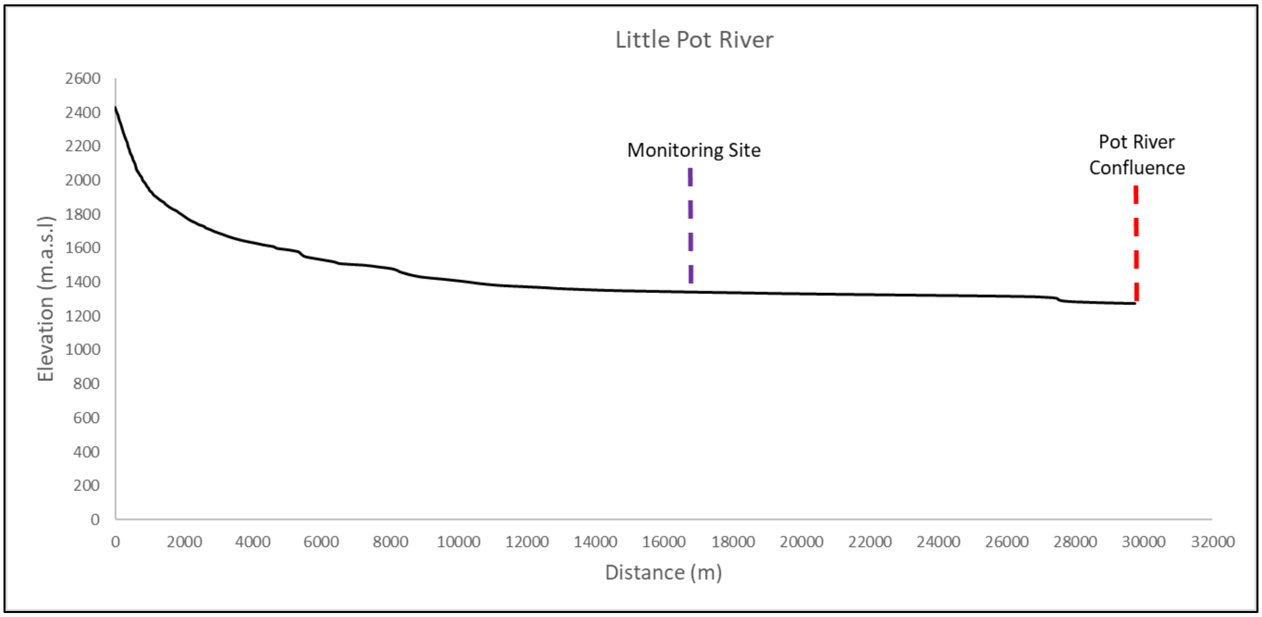


FIGURE 121: LONGITUDINAL PROFILE OF THE LITTLE POT RIVER

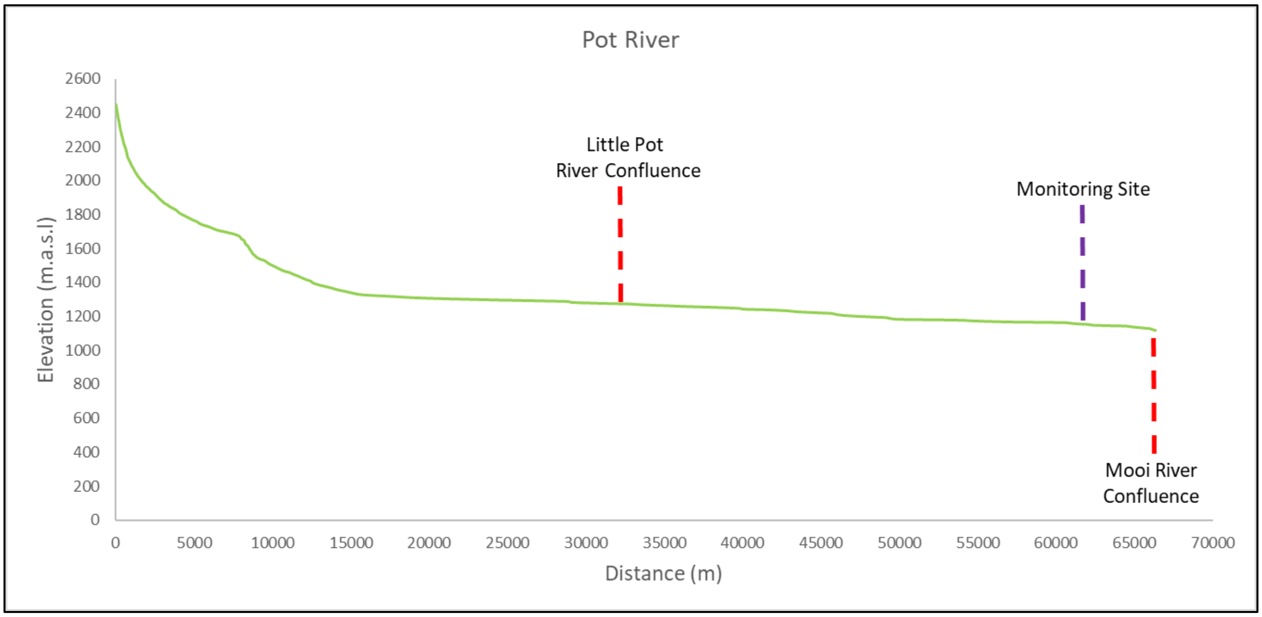


FIGURE 122: LONGITUDINAL PROFILE OF THE POT RIVER

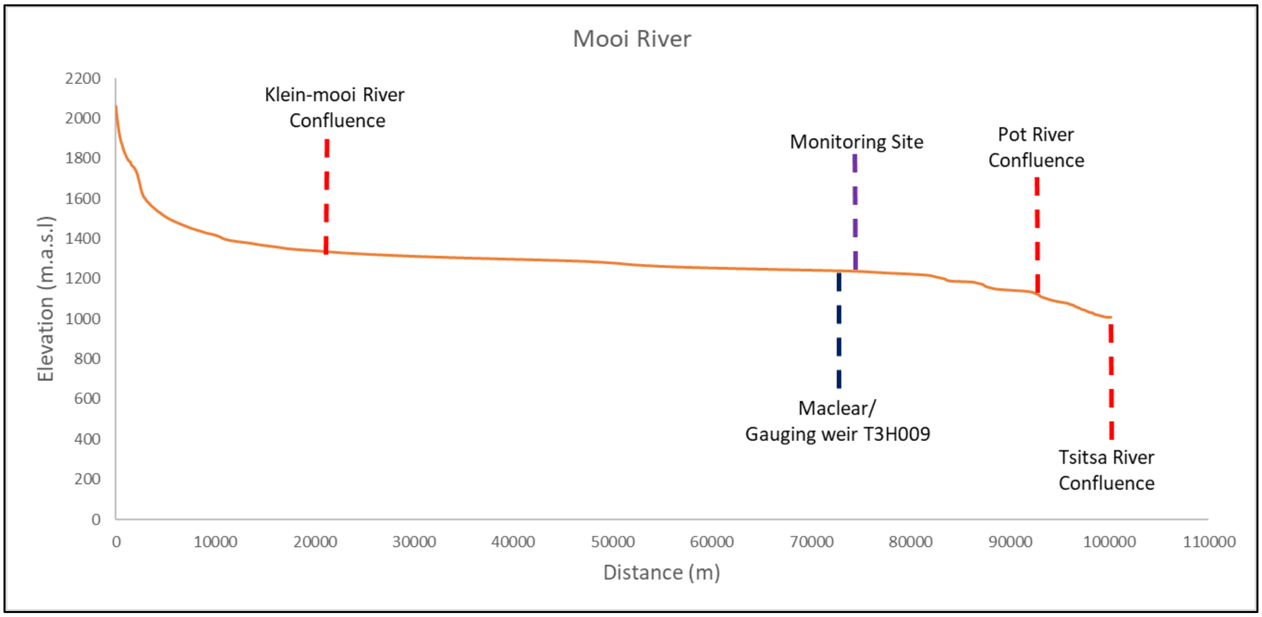


Figure 123: Longitudinal Profile of the Mooi River

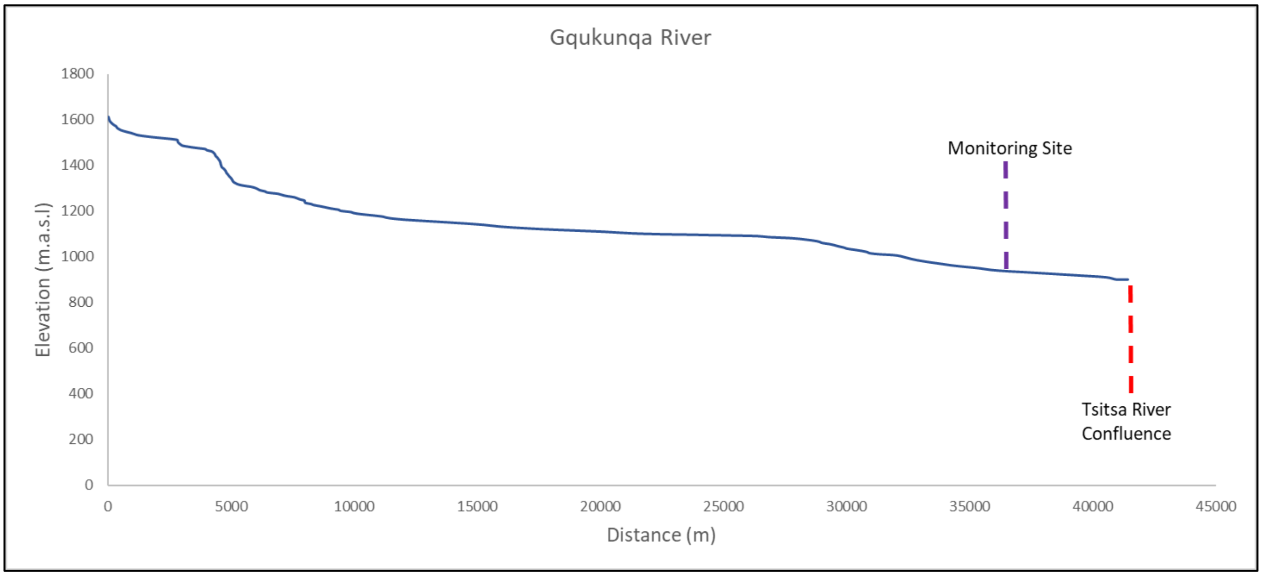


Figure 124: Longitudinal Profile of the Gqukunqa River

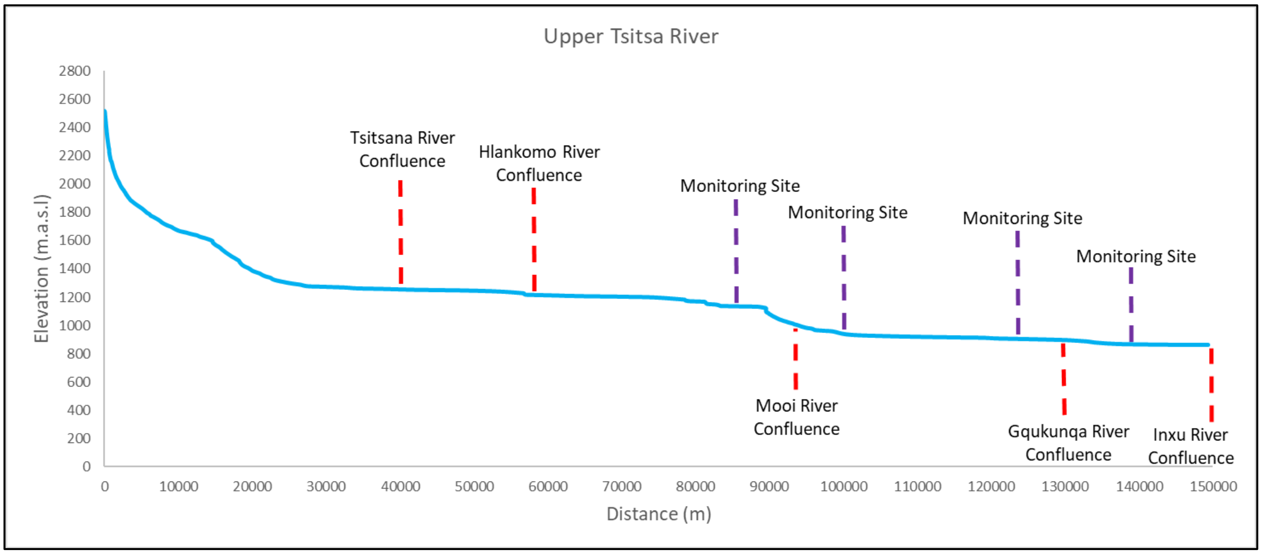


Figure 125: Longitudinal Profile of the Upper Tsitsa River in Catchment T35 A-E

21. APPENDIX 6: A REVIEW OF THE COMMON MACROINVERTEBRATE FAMILIES OF THE UPPER TSITSA RIVER CATCHMENT AND THEIR ASSOCIATED HABITATS WITH AN EMPHASIS ON FINE SEDIMENT ACCUMULATION (DRAFT VERSION-FOLLOWING ON WORK FROM HUCHZERMEYER, 2017)

Background

Macroinvertebrates provide barometers of river health as they are the first to register ill effects of negative impacts on a river system. Changes in water quality and habitat result in changes in types of organisms and give a clear indication of the current condition of a river channel.

River health, in terms of water quality, can be rapidly assessed by looking at the taxa richness of macroinvertebrate species sensitive to water quality (Dickens & Graham, 2002). Macroinvertebrates are therefore the most preferential group of aquatic organisms to use in the biomonitoring of streams due to their range of family related sensitivities (Dickens & Graham, 2002; Türkmen & Kazanci, 2010).

In the Tsitsa River macroinvertebrate community structure and abundance changes seasonally (Huchzermeyer, 2017). Summer months naturally show the highest abundance of macroinvertebrates due to increased water temperatures despite the presence of highly turbid flows. These turbid flows only affect the river channel for short periods of time after which the river runs clearer again (Huchzermeyer, 2017). Huchzermeyer (2017) established that within the range of parameters monitored over his study period, water quality could be discounted for having any noticeable effects in altering the types of macroinvertebrates that would naturally occur in the river. This corresponds to the findings of Madikizela & Day (2003) in the Mzimvubu River and its tributaries including the Tsitsa River. Madikizela & Day (2003) recognised that macroinvertebrate families in the Mzimvubu River and its tributaries were not found in abundance however, species sensitive to poor water quality were present. Madikizela & Day (2003) identified that the secondary effects of sedimentation and reduction in habitat played an important role in the ecological health of a river and might cause a reduction in the abundance of certain macroinvertebrate families. Huchzermeyer (2017) showed that over his monitoring period in the Tsitsa River, the combination of low discharges causing an increase in bed sediment storage and the lack of influence from water quality variables on macroinvertebrate community structure made conditions ideal for researching the effect that bed sediment was having on river habitats and macroinvertebrate communities.

Common macroinvertebrate families of the upper Tsitsa River

When exposed to a change in habitat, for example due to an increase in sediment deposition on the river bed or suspended sediment concentration, macroinvertebrates respond with a change in community structure (Türkmen & Kazanci, 2010; Jones *et al*., 2011).

The different macroinvertebrate classes and their common constituent families found in the upper Tsitsa River are reviewed below. A statement of the distinguishable features of each macroinvertebrate family and the optimal habitat in which each macroinvertebrate occurs is given (from: Gerber & Gabriel, 2002), followed by the habitat conditions, with regard to fine sediment concentration, in which each family found in the Tsitsa River was observed (from: Huchzermeyer, 2017). Macroinvertebrates found in the least abundance will be reviewed first, followed by macroinvertebrate classes more tolerant to fine sediment concentrations.

Phylum: Annelida

Class

Hirudinae (Leeches)

Distinguishing features

- Flattened with no legs
- Suckers on both ends of body
- Pale brown or grey. Commonly with bright spots or stripes

Overall Habitat

- Found in shallow pools or areas of the river with reduced flow.
- Commonly latch onto substrate and are found under stones.

Tsitsa River

- A low abundance of Hirudinae are found in habitats with a low concentration of surface sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Class: Turbellaria

Family

Planaria (Flatworms)

Distinguishing features

- Elongated and flat worms
- Triangular head with two eye-spots
- Darkly coloured above, white underneath

Overall Habitat

- Sensitive to strong light, and are found under stones or other solid objects

Tsitsa River

- Low abundance of Turbellaria are found in habitats with less embeddedness of coarse substrates and a low to medium concentration of sediment drape.
- Turbellaria also cling onto vegetation during higher flows.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
	High	8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
	High	2 000.1 – 4 000.0	4
	High	1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
	Moderate	200.1 – 400.0	8
	Moderate	100.1 – 200.0	9
↓	Low	<100	10

Order: Decapoda

Family

Potamonautidae (Crabs)

Distinguishing features

- 4 pairs of jointed legs attached to a broad body
- Pair of pinchers
- Eyestalks

Overall Habitat

- Found under or among rocks

Tsitsa River

- Found in rocky habitats with low to medium concentrations of surface sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
	High	8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
	High	2 000.1 – 4 000.0	4
	High	1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
	Moderate	200.1 – 400.0	8
	Moderate	100.1 – 200.0	9
	Low	<100	10

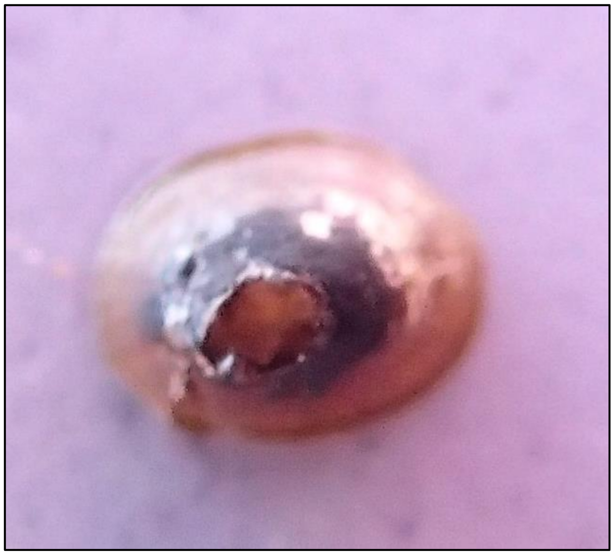
Class: Gastropoda

Family

Ancylidae (Limpets)

Distinguishing features

- Shell narrowing upwards from base of shell
- Resembles a sand dune from the side
- Moves slowly over coarse substrate
- Brown to black in colour



Overall Habitat

- Occur on rocks or any other submerged object

Tsitsa River

- Found in rocky habitats with low to medium concentrations of fine sediment drape, with a higher abundance in low concentrations.
- Not found in habitats with high concentrations of fine sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Class: Bivalvia

Family

Sphaeriidae (Pill clams)

Distinguishing features

- Small smooth shells
- Whitish to brown with speckles

Overall Habitat

- Occur in coarse sands and fine gravels

Tsitsa River

- Occur in medium concentrations of fine sediment drape.
- Not found in habitats with high concentrations of fine sediment drape

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Sub-order: Zygoptera (Damselflies)

Family

Coenagrionidae

Distinguishing features

- Slender body
- Three leaf-like gills narrowing towards the tip
- Pale, green to brown

Overall Habitat

- Found in vegetation or organic matter in slower moving water

Tsitsa River

- Found in low, medium and high concentrations of fine sediment with abundance being lower at a higher concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Plecoptera (Stoneflies)

Family

Perlidae

Distinguishing features

- Double tail
- Segmented upper body
- Moves body up and down when stationary
- Brown or black with yellow

Overall Habitat

- Occur under stones in rocky habitats
- Plecoptera are very sensitive to pollutants and make useful indicators of water quality

Tsitsa River

- Low, medium and high concentrations of surface sediment.
- Not found in high abundance.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Order: Trichoptera (Caddisflies)

Family

Hydropsychidae species (Caseless caddisflies)

Distinguishing features

- Several species
- Gills on body
- Claws on last segment
- Distinctive head patterns

Overall Habitat

- Rocky habitats, under stones (commonly have shelters made of fine gravel)
- Fast flowing water

Tsitsa River

- Found under stones in habitats with low to high concentrations of fine sediment drape.
- More species were found in habitats with low fine sediment drape concentrations.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
1 sp 2 sp >2 sp	Low	<100	10

Family

Ecnomidae (Caseless caddisflies)

Distinguishing features

- Soft smooth body with no gills along abdomen
- Three hardened segments behind the head

Overall Habitat

- Occur in slow moving streams or pools
- Found among stones or submerged aquatic vegetation

Tsitsa River

- Found under stones in habitats with low to high concentrations of fine sediment drape

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Leptoceridae (Cased caddisflies)

Distinguishing features

- Cases constructed from plant material or sand
- Long swimming legs (swim with case)

Overall Habitat

- Construct cases from plant material and occur in vegetation.

Tsitsa River

- Found under varying fine sediment concentrations with an increase in abundance at lower sediment concentrations.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Order: Ephemeroptera (Mayflies)

Ephemeroptera (Mayflies) including Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Prosopistomatidae and Tricorythidae vary greatly in shape and size, with each family being well adapted to suit the variety of habitats in which they occur. Ephemeroptera generally prefer habitats with lower fine sediment concentrations, however different families have different tolerances to sediment concentrations.

Family

Caenidae (Cainflies)

Distinguishing features

- Prominent square gills
- Humped back and swim in a dolphin-style

Overall Habitat

- Occur in stones or muddy areas
- In slow moving water

Tsitsa River

- Found to be relatively tolerant to high sediment concentrations and occurred relatively abundantly.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Heptageniidae (Flat-headed mayflies)

Distinguishing features

- Broad head with spreading tail and flat body
- Large eyes

Overall Habitat

- Occur in fast flowing habitats with stone substrates or amongst submerged coarse organic matter

Tsitsa River

- Were found in habitats with a high sediment concentration, however their abundance was higher the lower the concentration of fine sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Leptophlebiidae (Prongills)

Distinguishing features

- Square heads and long spreading tails
- Feathery gills along abdomen

Overall Habitat

- Occur in gentle flow in rocky substrates

Tsitsa River

- Found in relatively high abundance in low to high concentrations of sediment drape; however abundance decreases with an increase in the concentration of fine sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Oligoneuridae (Brushlegged mayfly)

Distinguishing features

- Large with long tufts of hair on each foreleg
- Large leaf shaped gills along abdomen

Overall Habitat

- Occur in fast flowing streams in patches of coarse sand or gravels

Tsitsa River

- Found in summer in patches of gravel in fast flowing areas of the river. Oligoneuridae were not found in habitats with a high concentration of fine sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m^2) in habitat		Sensitivity score
	High	>10 000.1	1
	High	8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
	High	2 000.1 – 4 000.0	4
	High	1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
	Moderate	200.1 – 400.0	8
	Moderate	100.1 – 200.0	9
	Low	<100	10

Family

Prosopistomatidae (Water specs)

Distinguishing features

- Small oval shaped bodies
- Short tail with no legs visible

Overall Habitat

- Occur under stones in fast flow

Tsitsa River

- Found in habitats with a low to medium concentration of fine sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
	High	8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
	High	2 000.1 – 4 000.0	4
	High	1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
	Moderate	200.1 – 400.0	8
	Moderate	100.1 – 200.0	9
	Low	<100	10

Family

Tricorythidae (Stout crawlers)

Distinguishing features

- Strong muscular legs and body
- Large eyes
- Three tails tilt upwards when at rest

Overall Habitat

- Occur in fast flow under or around rocky substrates

Tsitsa River

- Found in habitats with a low to high concentration of fine sediment drape, with abundance decreasing with an increase in sediment concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Order: Hemiptera (True bugs)

Hemiptera (Bugs) including Belostomatidae, Corixidae, Gerridae, Naucoridae, Nepidae, Notonectidae and Veliidae are only partly adapted to aquatic habitats. Some types occur on the surface of the water and have respiratory characteristics of terrestrial insects while others live below the surface but are air breathers and need to go to the surface at intervals for oxygen (Gerber & Gabriel, 2002).

Family

Belostomatidae (Giant water bug)

Distinguishing features

- Large with prominent eyes
- Forelegs adapted to catch and hold prey

Overall Habitat

- Occur in shallow pools and slow moving areas of the river

Tsitsa River

- Found in low abundance in low to medium concentrations of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Corixidae (Water boatmen)

Distinguishing features

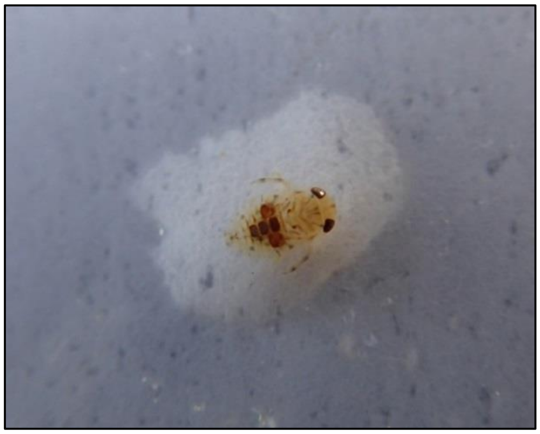
- Small slender body
- Long hind legs used for swimming

Overall Habitat

- Shallow pools in low flow areas and backwaters

Tsitsa River

- Low to high concentrations of fine sediment with the highest abundance found in habitats with a high sediment concentration.



Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
↑	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Gerridae (Pond skater)

Distinguishing features

- Short forelegs
- Middle and hind legs long and thin

Overall Habitat

- Occur on the surface of pools in shaded areas

Tsitsa River

- Low abundance in habitats with low concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
↓	Low	<100	10

Family

Naucoridae (Creeping water bug)

Distinguishing features

- Oval bodies and broad head
- Prominent forelegs for holding prey

Overall Habitat

- Occur in dense vegetation in shallow water

Tsitsa River

- Found in low to high concentrations of fine sediment with an increase in abundance with an increase in sediment concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m^2) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Nepidae (Water scorpions)

Distinguishing features

- Body shape varies depending on species
- Modified forelegs for catching prey
- Long respiratory tube on end of abdomen

Overall Habitat

- Occur in vegetation in pools or shallow water

Tsitsa River

- Found in low abundance in habitats with low to medium concentrations of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Notonectidae (Back swimmers)

Distinguishing features

- Very large eyes
- Long hind legs face forward
- Swim on their backs

Overall Habitat

- Occur in pools and backwaters

Tsitsa River

- Found in habitats with low to high concentrations of fine sediment with little variation in abundance between the different habitats.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Veliidae (Broad-shouldered water strider)

Distinguishing features

- Legs adapted for running and run along the surface of the water
- Small bodies

Overall Habitat

- Pools and small riffles

Tsitsa River

- Found in habitats with low to high concentrations of fine sediment and their abundance was not affected by an increase in sediment concentration

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Order: Coleoptera (Beetles)

Coleoptera (Beetles), including Dytiscidae, Elmidae, Gyrinidae, Hydrophilidae and Psephenidae, occupy a variety of habitats, from fast flowing streams to backwater ponds (Gerber & Gabriel, 2002). Several Coleoptera are aquatic in both their larval and adult stages and many are air breathers. Due to the ability of some families of Hemiptera and Coleoptera to breath air as well as live on the surface of the water they show a general trend of being tolerant to or not affected by different levels of sediment concentrations and occur abundantly.

Family

Dytiscidae (Predacious diving beetle)

Distinguishing features

Larvae

- Spindle-shaped body
- Large head with well-developed mouthparts

Adult

- Oval shape
- Rounded backs with elongated hind legs

Overall Habitat

- Occur on the edges of streams in vegetation as well as in pools with reduced flow

Tsitsa River

- Found in vegetation habitats with low to high concentrations of sediment with an increase in abundance with an increase in the concentration of surface sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
↑	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Elmidae (Riffle beetles)

Distinguishing features

Larvae

- Body shape varies between species
- Body segments hardened
- Anal gill tufts

Adult

- Very small with long antenna

Overall Habitat

- Occur in rocky substrates in fast flows

Tsitsa River

- Not found in habitats with a high sediment concentration

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Gyrinidae (Whirligig beetle)

Distinguishing features

Larvae

- Slender bodies with feathery gills along abdomen
- Strong mouth parts and hooks on last segment of abdomen

Adult

- Oval, streamlined bodies
- Hind legs fringed and eyes are divided to in opposite directions
- Can climb onto emerging objects and fly

Overall Habitat

- Larvae occur under stones or other objects in slow to moderate streams
- Adults occur on the surface of the water in slow moving water and pools

Tsitsa River

- Found in habitats with low to high concentrations of sediment with a low abundance in habitats with a high sediment concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Hydraenidae (Minute moss beetles)

Distinguishing features (Adult)

- Minute
- Mouthparts longer than antenna
- Antenna club shaped

Overall Habitat

- Around rocks in stagnant pools and slow moving water on the edges of streams

Tsitsa River

- Found in medium to low concentrations of sediment with abundance increasing with lower sediment concentrations

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Hydrophilidae (Water scavenger beetle)

Distinguishing features

Larvae

- Soft and worm like
- Distinct mouth parts

Adult

- Oval body with rounded back
- Mouthparts longer than antenna

Overall Habitat

- Occur in vegetation and muddy patches along river banks in slow moving water or pools

Tsitsa River

- Found in similar abundance in low to high concentrations of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m^2) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Psephenidae (Water penny beetles)

Distinguishing features (Larvae)

- Disc-like body
- Head, legs and gills not visible from above
- Clings to rocks

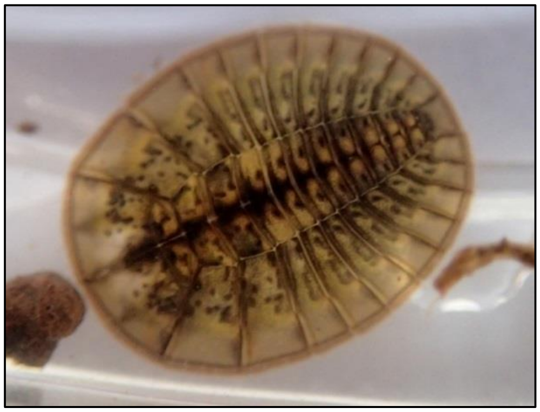
Overall Habitat

- Occur on rocks in shallow fast flowing water

Tsitsa River

- Found in habitats with low to medium concentrations of fine sediment drape.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10



Phylum: Annelida

Class

Oligochaeta (Aquatic earthworms)

Distinguishing features

- Long, thin and soft with a translucent body wall
- Commonly coiled up

Overall Habitat

- Occur in fine substrates in pools and areas of little flow in a river

Tsitsa River

- Found in sandy and muddy habitats with low to high concentrations of fine sediment concentration with an increase in abundance with an increase in sediment concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Sub-order: Anisoptera (Dragonflies)

Anisoptera (Dragonflies), including Aeshnidae, Corduliidae, Gomphidae and Libellulidae, occur both under stones and in sandy habitats. In the Tsitsa River Anisoptera show a general trend of being more abundant in habitats with medium to high concentrations of fine sediment concentrations.

Family

Aeshnidae

Distinguishing features

- Large and long, tapering body
- Thin antenna and large eyes

Overall Habitat

- Under stones in slow to fast moving water

Tsitsa River

- Found in low to high concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Corduliidae

Distinguishing features

- Oval bodies with very long legs
- Rounded head with eyes that resemble sunglasses

Overall Habitat

- Found among stones in slower moving water

Tsitsa River

- Found in a low abundance in low to high concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Gomphidae

Distinguishing features

- Body shapes vary depending on species
- Large eyes with short stubby antenna
- Legs adapted to digging in sand

Overall Habitat

- Occur on sand banks on the edge of the river

Tsitsa River

- Found in very high abundance in sandy habitats with low to high concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Libellulidae

Distinguishing features

- Oval bodies with shorter legs than Corduliidae
- Triangular head with bulging eyes

Overall Habitat

- Occur amongst stones and coarse sand in areas of reduced flow

Tsitsa River

- Found in low to high concentrations of fine sediment with an increase in abundance with a decrease in fine sediment concentrations.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Baetidae (Small minnow flies)

Distinguishing features

- Small spindle-shaped bodies
- Leaf-shaped gills on the sides of the abdomen
- Shape varies between species

Overall Habitat

- Occur in a variety of habitats including rocks, sand and vegetation

Tsitsa River

- Only 1-2 species were found in abundance in habitats with high concentrations of fine sediment.
- The presence of more than 2 species indicated a habitat with lower fine sediment concentrations.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
1 sp, 2 sp, >2 sp	High	>10 000.1	1
	High	8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
	High	2 000.1 – 4 000.0	4
	High	1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
	Moderate	200.1 – 400.0	8
	Moderate	100.1 – 200.0	9
	Low	<100	10

Order: Diptera (Flies, mosquitoes, midges)

Diptera (Flies) including Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Muscidae, Psychodidae, Simuliidae, Tabanidae and Tipulidae occur in a wide variety of habitats from stagnant pools to areas of high flow. In the Tsitsa River Diptera occur in abundance in low to high concentrations of fine sediment.

Family

Athericidae (Snipe flies)

Distinguishing features

- Body elongated and cylindrical
- Head retractable and abdomen forks into two fringed appendages
- Paired prolegs on abdomen

Overall Habitat

- Occurs in vegetation and organic matter

Tsitsa River

- Low abundance found in medium concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Ceratopogonidae (Biting midges)

Distinguishing features

- Thin and hair-like
- Swim in a slithering motion like a snake

Overall Habitat

- Occur in sand and mud at the edges of a river

Tsitsa River

- Found in low to high concentrations of fine sediment with an increase in abundance with an increase in fine sediment concentration

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
	High	8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
	High	2 000.1 – 4 000.0	4
	High	1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
	Moderate	200.1 – 400.0	8
	Moderate	100.1 – 200.0	9
	Low	<100	10

Family

Chironomidae (Midges)

Distinguishing features

- Slender and elongated body
- Small heads with prolegs and gills on the tip of the abdomen
- Colour varies and can be yellow, brown, green or red
- Entire body flicks back and forth

Overall Habitat

- Commonly found in any water body and in rivers are generally found in pools

Tsitsa River

- A high abundance of Chironomidae were found with an increase in abundance with an increase in fine sediment concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m^2) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Culicidae (Mosquito)

Distinguishing features

- Elongated body covered in tufts of hair
- Large head and respiratory tube on tip of abdomen
- Pupae have large head and abdomen curves around head

Overall Habitat

- Floats under the surface of any water body and in rivers commonly occurs in pools or temporary backwater puddles

Tsitsa River

- A low abundance of Culicidae were found in low to high concentrations of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m^2) in habitat		Sensitivity score
↑	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Dixidae (Meniscus midges)

Distinguishing features

- Long, slender bodies
- Clearly defined head
- Fringed lobes on end of abdomen
- Brown or black

Overall Habitat

- Occurs in slow streams and backwater areas of fast flowing rivers

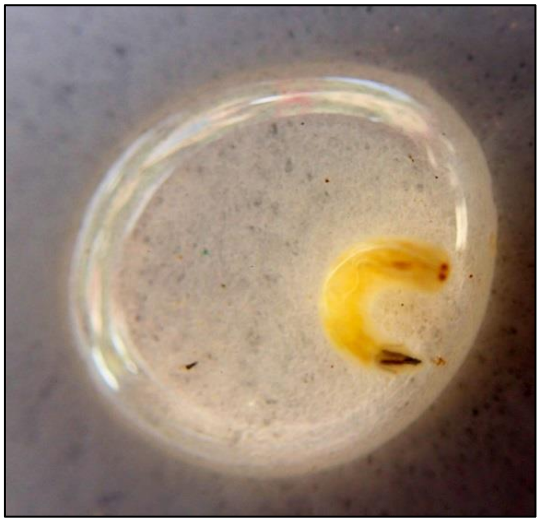
Tsitsa River

- A low abundance of Dixidae were found in medium concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m^2) in habitat		Sensitivity score
		>10 000.1	1
		8 000.1 – 10 000.0	2
	High	4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
		800.1 – 1 000.0	6
	Moderate	400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Muscidae (House flies)



Distinguishing features

- Soft tapered bodies
- Retractable heads with black mouth hooks

Overall Habitat

- Occur in shallow water commonly with the presence of organic matter or algae

Tsitsa River

- Low abundance of Muscidae were found in low to high concentrations of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Psychodidae (Moth flies)

Distinguishing features

- Slender body covered in fine hairs
- Small hardened head
- Dark hard plates on each segment
- Single tuft of hair on end of abdomen

Overall Habitat

- Occur in stagnant puddles commonly with decaying organic matter
- Occur in various habitats in streams

Tsitsa River

- A low abundance of Psychodidae were found in medium concentrations of fine sediment

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Simuliidae (Black flies)

Distinguishing features

- Soft bodies, swollen at base
- Single round and hooked sucker at base
- Single proleg behind the head

Overall Habitat

- Attach themselves to substrates in shallow areas with increased flow

Tsitsa River

- Found in areas of low to high concentrations of fine sediment, with an increase in abundance with a reduction in the concentration of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Tabanidae (Horseflies)

Distinguishing features

- Large cylindrical bodies pointed at both ends
- Small retractable head
- Creeping ridges encircling all abdominal segments
- Short siphon at tip of abdomen

Overall Habitat

- Occur in muddy areas of pools

Tsitsa River

- Low abundance of Tabanidae were found in low to medium concentrations of fine sediment concentration.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

Family

Tipulidae (Crane flies)

Distinguishing features

- Large cylindrical and soft body
- Small retractable head
- Inflated segment on the end of the abdomen

Overall Habitat

- Tipulidae species are habitat specific and occur at the bottom of streams, muddy edges of streams or in aquatic vegetation

Tsitsa River

- Found in medium to high concentrations of fine sediment.

Macroinvertebrate abundance	Surface sediment drape (g/m²) in habitat		Sensitivity score
	High	>10 000.1	1
		8 000.1 – 10 000.0	2
		4 000.1 – 8 000.0	3
		2 000.1 – 4 000.0	4
		1 000.1 – 2 000.0	5
	Moderate	800.1 – 1 000.0	6
		400.1 – 800.1	7
		200.1 – 400.0	8
		100.1 – 200.0	9
	Low	<100	10

General Trends

In the Tsitsa River the shallow pool areas and areas of reduced flow are highly embedded with high concentrations of sediment drape and commonly not suitable for many families of macroinvertebrates that prefer some sort of coarse substrate or aquatic vegetation to cling onto. In areas where flow velocity was sufficient to wash away fines (eg. cobble riffles), macroinvertebrate abundance and diversity increased and the river maintained a more natural condition. Macroinvertebrates seek refuge in aquatic and marginal vegetation during highly turbid flows. Presence of vegetation in sites containing fine sediment deposits increased the macroinvertebrate diversity. Lack of vegetation, low flows and depths and high concentrations of fine sediment with a low substrate diversity decreased macorinvertebrate diversity. In rocky habitats in the Tsitsa River, the presence of diverse macroinvertebrate families was found to be mainly affected by substrate diversity. The more diverse the substrate the more habitats are available for colonisation by macroinvertebrate families. However, excessive deposition of fine sediment on the bed of the river decreased the substrate diversity and available habitats, in turn reducing the number of macroinvertebrate families present that were sensitive to sediment drape and in some cases increasing the number of less sensitive families. In habitats dominated by fines macroinvertebrate families that were less sensitive to fine sediment drape become more abundant. In patches where fine sediment accumulation was excessive, such as on thick silt deposits, macroinvertebrate abundance was observed to decrease. Excessive sedimentation in a river system has a direct impact on various aquatic trophic levels. Macroinvertebrates that naturally occur in rocky habitats decreased in abundance with an increase in fine sediment accumulation, due to a reduction of habitats through the filling of interstitial spaces and rocky substrates becoming draped by fine sediment. Macroinvertebrates that naturally occur in sandy habitats and crawl along substrate or are air breathers, diving in the water column or thriving on the surface of the water, are less affected and are possibly benefited by an increase in fine sediment accumulation.