EVALUATION OF IRON-COATED TUBES TO DETECT REDUCTION IN SOILS FOR WETLAND IDENTIFICATION IN THE KRUGER NATIONAL PARK

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Summary

The identification of hydric soils is important for wetland delineation and protection. South Africa currently uses the Department of Water Affairs and Forestry (DWAF, 2005) delineation guidelines which can be subjective in certain cases. A robust technical standard that can be legally conclusive is required. The National Technical Committee of Hydric Soils (NTCHS) in the United States of America has accepted the IRIS tube methodology as a technical standard. This method has not yet been tested or accepted in South Africa. IRIS is an acronym for Indicator of Reduction in Soils and the IRIS tubes consist of PVC conduit piping, coated in a synthesised Fe oxide paint comprising of mainly ferrihydrite. These tubes are installed in the soil and if reducing conditions are present, the paint will be removed from the tubes. The following study took place in the Kruger National Park and the IRIS tubes were tested in three different wetland systems, namely Malahlapanga, Nshawu and the Tshuthsi spruit. Four wetness zones were identified, based on vegetation, at each wetland and with three repetitions. Water table monitoring wells were installed, the soils were classified, soil wetness indicators were identified, vegetation was described, soil analyses were undertaken and the pH and Eh of the water table was recorded monthly in order to calculate rH values. The study took place from September 2012-September 2013. The area percentage of paint removed from the top 300 mm of the IRIS tubes was quantified by scanning the tubes and using Adobe Photoshop. The IRIS results were compared to the DWAF indicators and it was found that the methods were in agreement, however, it was found that the conditions at the Tshutshi spruit were not favourable for Fe reduction due to the high pH values recorded. The limitations and advantages of the method are explored. It was found that the wetter summer months were the most favourable months for the installation of the tubes. The success of the DWAF (2005) wetland indicators was evaluated for each wetland's lithology and when consulting the ancillary data, potential ancillary variables were identified. There were trends in the pH, organic carbon as well as the exchangeable sodium at all of the wetlands (with the exception of the upland zone at the Basaltic wetland). At the Gneiss and Basalt lithologies, there were similarities in the patterns of Fe and Mn distribution along the catena, however, the opposite trend was observed at the Granitic wetland. The IRIS tubes are thought to be a useful tool for wetland delineation in South Africa, however, further research is required over a wider geographical area to determine where they will work and also to test the MIRIS tube methodology (Manganese Indicators of Reduction in Soils) in wetlands which are unfavourable to the reduction of Fe.

Key words: IRIS tubes, wetland delineation, reduction in soil, redox features, soil morphology, iron oxide, Kruger National Park, soil wetness indicator, soil form indicator

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Contents

List of Figures

List of Tables

Abbreviations and Definitions

CEC: Cation Exchange Capacity

Chroma: The Munsell chroma of a colour indicates its strength or departure from a neutral of the same lightness

DPI: Dots per Inch

DWA: Department of Water Affairs (SA)

DWAF: Department of Water Affairs and Forestry (SA)

Eh: Redox potential

ESP: Exchangeable Sodium Percentage

Hue: The hue of a colour indicates its relation to red, yellow, green, blue, and purple

IRIS: Indicator of Reduction in Soils

KNP: Kruger National Park

MIRIS: Manganese Indicator of Reduction in Soils

NPA: National Prosecuting Agency (SA)

NTCHS: National Technical Committee of Hydric Soils (USA)

NWA: National Water Act (SA)

pH: Hydrogen potential

PVC: Polyvinyl chloride

rH: The negative logarithm of a hypothetical hydrogen pressure corresponding to given Eh and pH conditions

SAR: Sodium Adsorption Ratio

Value: The Munsell value of a colour indicates its lightness

WRB: World Reference Base Soil Classification for Soil Resources

XRD: X-ray Diffraction

1. Introduction

1.1. Water, wetlands and South Africa

South Africa is a country very conscious of water particularly due to its climatic disposition, as well as factors such as its political history and a growing economy. In addition to this, the Government is attempting to redress social issues through various strategies, including providing previously excluded people with potable water and, allocating water equitably amongst people, industries and the environment, as well as creating jobs through mining and agriculture (National Water Act, 1998). All of these factors place pressure on the national water resources and, consequently, the environment as a whole. The Government has acknowledged the important role that water plays through the National Water Act (1998) which is internationally held in high esteem. In recent years, there has been a growing recognition regarding wetland ecosystems and the services they provide. Valuable functions include flood attenuation, maintenance of river low flows, aquifer recharge, carbon sequestration, immobilisation of potentially harmful pollutants and sediment trapping. Wetlands support a diverse group of organisms and provide a habitat to many endangered species. In rural communities wetlands are utilised for community vegetable gardens, reeds are used for construction and indigenous plants are used in traditional medicines. If managed correctly, wetlands are capable of supporting rural communities and their livelihoods (DWAF, 2005). Wetlands are, however, integral in regulating water quantity as well as quality and, therefore, need to be protected from exploitation under the National Water Act (1998).

1.2. Pressures placed on South African wetlands

Forestry, mining and agriculture all impact on wetland function. Forestry has been declared a stream-flow reduction activity and has been forced to apply a minimum buffer of 20 m between the edge of a wetland and the planted trees (DWAF, 2005). It is speculated that the sugar cane industry will be the next target as the Department of Water Affairs (DWA/DWAF) grapples with the implementation of the National Water Act (1998). Mining is a large stakeholder in South Africa's economy with a Gross Domestic Product (GDP) of 18%, providing approximately 1 million jobs (Kearney, 2012). Wetlands are therefore not always protected or prioritised due to the conflict of interests between the mining industry and the environment. South Africa has a growing population and economy which contributes to urban and industrial expansion. There is growing evidence to suggest that climate change is occurring, with a resultant change in global temperatures and rainfall patterns (IPCC AR4 SYR, 2007). All of these factors pose a major threat to South African wetlands and highlight the importance of identifying, delineating and protecting wetlands.

1.3. Wetland delineation in South Africa

The National Water Act (1998) defines wetlands as:

"Land which is transitional between terrestrial and aquatic ecosystems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil."

Wetlands are currently being delineated using four wetland indicators which are described in "A practical field procedure for identification and delineation of wetlands and riparian areas" published by DWAF (2005). These indicators are namely the:

- Terrain unit indicator
- Soil form indicator
- Soil wetness indicator
- Vegetation indicator

The terrain unit (MacVicar *et al*., 1977) refers to the position in the landscape where wetlands are likely to occur, which DWAF (2005) define as position 5 on a slope (Valley bottom).

The soil form indicator refers to the soil classification according to "Soil Classification - A taxonomic system for South Africa" (Soil Classification Working Group, 1991) also known as "The Blue Book" where *signs of wetness* are included at the soil form or family level and can assist in estimating the degree of water saturation i.e. permanently, seasonally or temporarily saturated.

The soil wetness indicator is the most crucial indicator in practice and refers to the soil morphology resulting from prolonged saturation of the soil i.e. in hydromorphic soils. When soils are saturated for a period of time atmospheric O_2 is excluded from the soil and the system will shift from an aerobic state to an anaerobic state (Verpraskas and Faulkner, 2001). The chemical process which characterises wetland soils is called reduction and will be explained in further detail later in Chapter 2. The DWAF (2005) manual stipulates that hydromorphic soils should show signs of wetness within the top 0.5 m of the soil because this is assumed to be the hydrophilic and hydrophytic vegetation rooting depth. There are, however, exceptions such as the lack of features noted in recent alluvial deposits, sandy soils in coastal aquifer systems and soils derived from dolomite and quartzite in the Mpumalanga province as explained later.

In order to apply the vegetation indicator the wetland system should ideally be undisturbed and the wetland practitioner should have an expert knowledge of the plants in the region. Distinct changes in species composition provide valuable clues as to subtle changes in topography, soils and hydrology. It is important to acknowledge if the species are predominantly hydrophilic or upland. One must take all four indicators into account when deciding whether or not an area is a wetland.

When making this decision, at least the soil wetness indicator or the vegetation indicator must be present but the level of confidence increases with the addition of the terrain unit and soil form indicators. It must be noted that wetland identification and delineation can pose challenges and there are circumstances where these guidelines need to be more objective.

1.4. Problems encountered with the current wetland delineation guidelines

In certain cases, vegetation may not be present or convincing, as it can be very easily destroyed or altered through human activities such as burning and clearing the land for agricultural crops. In this case a wetland practitioner has to rely on the soil indicators. In most cases, it is quite simple to apply the guidelines, although there have been some exceptions. There have been cases where, despite there being hydrophilic vegetation and a sufficient period of water saturation, evidence of reduction in the soil is absent and the soil morphological features expected are not expressed (such as in recent alluvial deposits and sandy coastal aquifer systems). Possible reasons for a lack of redox features can be attributed to low organic carbon levels, high pH values, large amounts of Mn oxides and high dissolved oxygen levels in the water (Vepraskas, 2001). An anthropogenic factor which contributes to difficulties in delineation, such as ploughing, can also disrupt the soil morphology making it difficult to identify mottling. If the hydrology of an area is altered (through the installation of dams and drains, or the planting of alien species with high water-use demands), it may take many years for the soil morphology to re-establish an equilibrium that reflects this change. Relic morphological features may further cause confusion by making the soil appear wetter than it really is. Other challenges encountered are soils which are either very red (dolomite derived) or very grey (quartzite derived) as seen in the Mpumalanga Province (DWAF, 2005). In red soils, mottles and gleyed morphology may be obscured by the red colour, while in very grey soils there may be insufficient Fe to express the morphological features associated with the hydrological regime. In these cases, wetland practitioners rely heavily on their experience. However, this means that there is room for individual bias. A more objective method to delineate wetlands is therefore required – one that can be defended in a court of law. One manner may be to introduce a technical standard to directly quantify the degree of water saturation and reduction.

1.5. Examples of court cases in South Africa

1.5.1. Pan African Parliament site

The Pan African Parliament (PAP) site was in the development phase when contractors raised concern about the amount of waterlogging. An investigation was initiated into the mandatory wetland study that had taken place before the development was approved and this eventually led to legal prosecution in 2011. The crux of the case was the interpretation of the Kroonstad [Luvic stagnosol (albic)] and Longlands [Stagnic plinthosol (albic)] soil forms (State vs Frylinck and Another, 2011; IUSS Working Group WRB, 2014). This court case highlighted the weaknesses of the guidelines currently used for wetland delineation in South Africa. The soil scientists were not in agreement in the hydrological interpretation of these soils, indicating the need for a rigid and objective method to definitively verify whether the site was or was not a wetland. The current wetland delineation manual, while invaluable, leaves room for individual interpretation, which is a weakness in situations such as described above.

1.5.2. Further examples

In recent years the National Prosecuting Agency or NPA has been clamping down on companies and individuals violating the National Environmental Management Act 107 of 1998 (NEMA, 1998). High profile wetland cases include those of Anker Coal and Golfview Mining (The State vs Anker Coal and Mineral Holdings S.A. (Pty) Ltd, 2010). Unlawful development within the Isimangaliso Wetland Park has not gone unpunished (Isimangaliso Wetlands Park Authority and Others v Mthembu and Another (3188/2010)) and the fight between environmentalists and mining giants over the coal-rich Wakkerstroom wetlands in Mpumalanga is intensifying (Marshall, 2008). With those responsible for the destruction of wetlands receiving criminal charges and hefty financial penalties it is essential that environmental practitioners are able to definitively identify and delineate wetlands.

1.6. Potential solution: IRIS tubes

The use of dyes, pH/Eh stability diagrams, soil morphology, chemical methods and Fe nails have all been used to detect reducing conditions, however, not without limitations which will be later explored in Chapter 2. Practical technical standards, in which soils can be classified as hydromorphic or reduced, have remained elusive. However, a fairly recent advance in wetland delineation is the use of IRIS tubes developed by Jenkinson and Franzmeier (2006); (Jenkinson, 2002). **IRIS** is an acronym for **I**ndicator of **R**eduction **I**n **S**oils and comprise of PVC tubes coated in a synthesized Fe-oxide paint. These tubes are placed in the soil and the paint will be removed in reducing conditions. This method has been accepted in the United States of America as a technical standard by the National Technical Committee of Hydric Soils (NTCHS, 2007), but has not been tested in South Africa. It is a promising tool for wetland practitioners in South Africa to address atypical cases that arise, which our current guidelines fail to address.

1.7. Potential study site: The Kruger National Park

The Kruger National Park is largely unmodified and in a near natural state in terms of development, hydrology and vegetation. It also has a large variation in terms of lithology, climate, and hydrology, resulting in a number of different wetland types e.g. Channelled and un-channelled valley bottom wetlands and hillslope seeps. There is also a current drive to characterise the wetlands in the Kruger National Park to assist in management and, in a few cases, rehabilitation. This presented an opportunity to test the IRIS tube methodology over a wide ecological range and to relate the data to the traditional wetland delineation methods.

1.8. Problem statement

Wetlands are valuable resources and there is a need for them to be delineated to enable protection against threats such as agriculture, forestry, mining, development, over-utilisation, and climate change. Challenges encountered in the delineation process include the presence of relic features, problematic parent materials and morphology that is not always well expressed in the soil. These problems are exacerbated by individual bias. A robust method or technical standard is therefore required to definitively document reducing conditions.

1.9. Hypothesis

Indicator of reduction in soils (IRIS) tubes (Jenkinson and Franzmeier, 2006; Jenkinson, 2002) provide a useful tool for detecting reducing conditions in wetlands occurring on various lithologies in the Kruger National Park.

Wetlands with high Fe yielding parent material will have more prominent soil wetness indicators than those without.

1.10. Objectives

a) To characterise the physical, chemical, mineralogical, and hydrological properties of the three different wetland types, with differing lithologies (Basalt, Gneiss, and Granite), in the Kruger National Park.

b) To evaluate the use of IRIS tubes as a technical standard for wetland delineation in South Africa.

2. Literature Review

2.1. Introduction

Reduction is the chemical process behind the formation of hydromorphic soils that occurs in wetlands, under certain conditions. Therefore wetland identification and delineation hinges on the measurement and characterisation of these reducing conditions. Reducing conditions are, however, the result of four coinciding factors namely, the presence of microbes, organic material to be oxidised, the availability of electron acceptors and the degree of saturation (Meek *et al*., 1968; Bouma 1983, as cited by Verpraskas & Faulkner, 2001)

2.2. Redox chemistry in wetlands

2.2.1. Chemical conceptual understanding

Redox reactions refer to reduction and oxidation half reactions where there is a transfer of electrons among atoms. This causes a change in valence state of an atom as electrons are gained or lost. During oxidation there is a loss of electrons and in reduction there is a gain of electrons. Oxidation and reduction reactions are catalysed by microbes in the soil which utilise organic material as a source of energy during respiration. These microbes require oxygen to complete the reaction and oxygen is reduced in the complementary reduction half reaction. However, when a soil becomes saturated, the oxygen in the soil becomes depleted, resulting in the microbes seeking alternate electron acceptors. If conditions are ideal there is a preferential sequence whereby compounds will be theoretically utilised once the oxygen is depleted. The sequence is as follows: O_2; NO_3^-; MnO_2^-; $Fe(OH)_3$, FeOOH, Fe_2O_3; SO_4^{2-}, CO_2 (Table 1). As duration of saturation increases so does the intensity of these reducing conditions provided there is sufficient microbes, organic material, temperature, and oxygen-deprived water (Verpraskas & Faulkner, 2001).

Table 1 Half reactions of important elements in soils (McBride, 1994)

Half reactions	
$Mn^{3+} + e^- = Mn^{2+}$	$Fe^{3+} + e^- = Fe^{2+}$
$MnOOH(s) + 3H^+ + e^- = Mn^{2+} + 2H_2O$	$1/2O_2(g) + H^+ + e^- = 1/2H_2O_2$
$1/5NO_3^- + 6/5H^+ e^- = 1/10N_2(g) + 3/5H_2O$	$1/8SO_4^{2-} + 5/4H^+ e^- = 1/8H_2S + 1/2H_2O$
$1/2MnO_2(s) + 2H^+ + e^- = 1/2Mn^{2+} + H_2O$	$1/6N_2(g) + 4/3H^+ e^- = 1/3NH_4^+$
$1/4O_2(g) + H^+ e^- = 1/2H_2O$	$1/8CO_2(g) + H^+ e^- = 1/8CH_4(g) + 1/4H_2O$
$Fe(OH)_3(s) + 3H^+ + e^- = Fe^{2+} + 3H_2O$	$H^+ + e^- = 1/2H_2(g)$
$1/2NO_3^- + H^+ e^- = 1/2NO_2^- + 1/2H_2O$	

2.2.2. Reduced soils

When Fe and Mn are in their oxidised states (Fe^{3+} and Mn^{4+}) they are immobile, meaning that they are precipitated. However, when they become reduced, they are mobile and can be leached or translocated. A soil that is saturated for long periods will therefore become grey in colour or gleyed. This is because all the Fe has been removed, exposing the grey colour of the quartz (sand) particles in the soil. If there is a fluctuating water table, Mn and Fe can be precipitated when the soil is aerated, leading to high chroma mottled colour patterns. The Mn will be seen as black while the Fe can range from brown, red, orange or yellow depending on the Fe-oxide formed. When S is reduced this indicates a severe reducing environment and is associated with a "rotten egg odour" and dark black colours. When carbon dioxide is reduced, also indicative of highly reducing conditions, the by-product is methane which can be seen as bubbles rising to the water surface. It is not possible to see or smell nitrogen in its reduced form and therefore scientists focus on Mn and particularly Fe, due to its abundance in the environment, when determining if a soil is reduced or not (Verpraskas & Faulkner, 2001).

2.2.3. Iron and manganese oxides

Fe and Mn are excellent electron acceptors in anaerobic conditions, due to their thermodynamic and kinetic properties (Nealson & Myers, 1992). Fe and Mn oxides play a significant role in the identification of wetland boundaries when they are expressed in the soil morphology and their mineralogy is of particular interest. The main difference between Fe and Mn in an anaerobic environment is that Fe can form insoluble sulphide precipitates whereas Mn never precipitates as a sulphide form (Nealson & Myers, 1992). Table 2 below shows the important Fe oxide minerals involved in the soil environment.

Table 2 Fe-oxide minerals their formulae and colours (adapted from Schwertmann & Taylor, 1989)

Mineral Properties	Mineral Name						
	Hematite	Maghemite	Magnetite	Goethite	Lepidocrocite	Ferrihydrite	Green Rust
Formulae	α-Fe_2O_3	γ-Fe_2O_3	Fe_3O_4	α-FeOOH	γ-FeOOH	$Fe_5HO_8 \cdot 4H_2O$ $Fe_5(O_4H_3)_3$	$Fe^{2+}Fe^{3+}$ hydroxy compound
Colour (Munsell)	5R-2.5YR bright red	Reddish brown	Black	7.5YR-10YR yellowish-brown	5YR-7.5YR orange	5YR-7.5YR reddish-brown	Greenish-blue

2.2.4. Ferrolysis: a hydromorphic soil forming process

The term ferrolysis was coined by Brinkman in 1970 to explain the duplex or texture contrast hydromorphic soils in Bangladesh. He proposed ferrolysis as a hydromorphic soil forming process. The process occurs in soils with seasonally fluctuating water tables with an underlying impermeable layer, where Fe drives the chemical process whereby H^+ ions are liberated and attack the clay lattice, resulting in clay destruction and secondary quartz accumulation. Reported clay loss through ferrolysis is approximately 1.5 kg/dm^3 (Brinkman, 1977). The resulting soils typically have a low cation exchange capacity (CEC), are sandy or silty in texture and are physically unstable. Not all scientists are in agreement and some have argued that these texture contrast soils cannot be attributed to ferrolysis but rather to illuviation processes such as clay translocation (van Ranst & De Coninck, 2002), probably also enhanced by Fe reduction. If this hydromorphic soil forming process was dominant at any of the three wetland sites selected for the study, it would be expected that there would be a relationship between texture and CEC in the seasonal wetland zone which would not be apparent in the permanent or terrestrial zones.

2.3. Redox and wetland delineation

2.3.1. Chemical methods

Redox reactions can be expressed using thermodynamics in the form of redox potential (Eh) and pH. Eh is the electrode potential (voltage) of a platinum (Pt) electrode immersed in the soil solution and can be measured in the field. Based on the Nernst equation, each element has a specific Eh value at equilibrium when reduced. The Eh value is dependent on soil pH and the concentration of reduced and oxidised species in the soil (Verpraskas & Faulkner, 2001). The Eh value can be used in conjunction with pH to construct pH/Eh stability diagrams which can be used to predict the phases of various elements. However, in reality there are problems in using these diagrams in the field as they cannot deal with mixed redox couples and cannot take into account reactions which occur at differing rates. One can, however, measure the concentrations of reduced species in the soil through chemical analyses. This can give an idea as to the extent of reduction. This is, however, a costly exercise and there are exceptions to the assumptions that can be drawn. A less costly chemical method of detecting reduced Fe^{2+} is the use of dyes such as α, α'-dipyridyl and 1, 10-phenanthroline (Childs, 1981; Richardson & Hole, 1979). These dyes can only detect Fe^{2+} at the moment it is applied. False positive and false negative results can be observed for various reasons.

2.3.2. rH values

Redox potential (Eh) can be used to measure the tendency of certain elements to reduce or oxidise (Fiedler & Sommer, 2004; Fiedler *et al.,* 2007). Due to the fact that Eh is pH dependant, a measure of oxidation intensity comprising of both Eh and pH, termed rH, was developed. The rH was defined as the negative logarithm of a hypothetical hydrogen pressure (in bars) corresponding to given Eh and pH conditions (Clark, 1923). When an rH of <20 is recorded the system is said to be reducing.

2.3.3. Reduced soil morphology

There are various morphological features that are associated with reduced wetland conditions. These can be related to organic material, Mn, Fe and S and can give an indication as to the extent of water saturation and reduction as well as the hydrological regime. Organic material can accumulate under saturated or non-saturated conditions but is usually associated with the saturation of water for long periods in most years. E (albic) horizons can indicate periodic saturation of water and can contain mottling and streaking associated with Fe and Mn reduction and oxidation. G (stagnic) horizons are saturated with water for long periods and have grey low chroma colours, with or without mottling. Hard and soft plinthic B (pisoplinthic and petroplinthic) horizons are indicative of a fluctuating water table and Fe and Mn oxides can accumulate to form concretions. Signs of wetness can be observed in unconsolidated and unspecified material in the form of low chroma colours and sesquioxide mottles (Soil Classification Working Group, 1991; IUSS Working Group WRB, 2014). The WRB (IUSS Working Group WRB, 2014) defines Gleyic soils as having a layer ≥25 cm thick, and starting ≤75 cm from the soil surface, that has gleyic properties throughout and reducing conditions in some parts of every sublayer. The WRB (IUSS Working Group WRB, 2014) defines reductimorphic and oximorphic colour patterns: Reductimorphic colours are indicative of permanently wet conditions and have predominately blue-green colours in loam, black colours in sulphur-rich material, or whitish colours calcareous material. These can readily oxidise upon exposure to air, yielding bright colours. Oximorphic colours are indicative of altering oxidising and reducing conditions and show reddish brown, bright yellowish brown, orange, or pale yellow colours. Examples of redox morphology (reductimorphic) resulting from prolonged saturation of the soil are shown in Figure 1.

A 

T Johnson

B 

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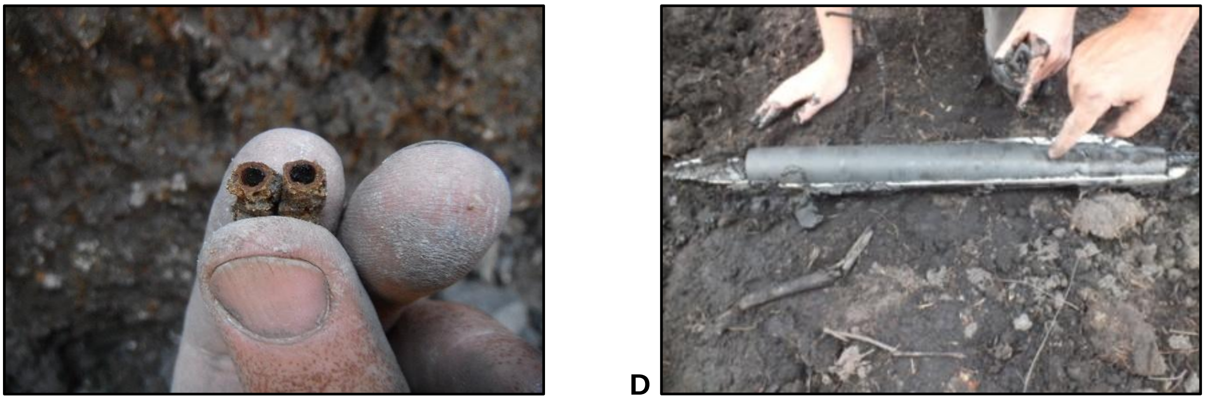

C D

CW Van Huyssteen R Taylor

Figure 1 Examples of redox morphology/soil wetness indicators: Fe oxide mottles (A), Gley morphology (B), Rusty root channels (C), Peat (D)

2.3.4. International wetland delineation methods

In the United States of America there are 2 valuable documents that have been developed which use soil morphology to delineate wetlands and are accepted as Technical Standards. Namely, the "Corps of Engineers Wetlands Delineation Manual" (United States Army Corps of Engineers, Environmental Laboratory, 1987) and "Field Indicators of Hydric Soils in the United States" (United States Department of Agriculture, Natural Resources Conservation Service, 2006). These documents have been developed specifically for the States, and define the criteria that determine whether a soil can be classified as a wetland soil or not.

2.3.5. IRIS tube concept

IRIS tubes detect the reduction of Fe and are a temporal measurement. Dyes enable the scientist to get a "snapshot" into the mineralogy at that point in time, whereas IRIS tubes give a time-integrated measurement.

2.4. IRIS tubes

2.4.1. Paint mineralogy

The paint mainly consists of ferrihydrite with small amounts of goethite. The paint is synthesised in the laboratory and becomes more crystalline with age. The recommended paint recipe is described by Rabenhorst (2008). It is based upon Schwertmann and Cornell (2000) method but has been modified to remove the salts which are a by-product of the reaction.

2.4.2. Protocol

The National Technical Committee of Hydric Soils (2007), hereafter referred to as the NTCHS, published a protocol for the use of IRIS tubes, which explains their construction, installation, the quantification of paint removal and the criteria for relating paint removal to reduction. Castenson and Rabenhorst (2006) also published a paper on the appropriate protocols to use which was summarised by Rabenhorst (2008). Both methods are in agreement except with regards to the criteria of relating paint removal to reduction.

2.4.3. Quantifying paint removal

The amount of paint removed from the tubes can be estimated visually using reference charts and taking an average of at least two observer's data sets to limit individual error. Another method is to scan the tubes on a modified flat-bed scanner (to limit distortion) and to use image analysis to accurately quantify the area percentage of paint removed. More recently Rabenhorst (2012) has proposed a method using transparent mylar grids to physically mark areas of paint removal so that the blocks can be counted. Another proposed method to avoid scanning and the error involved in estimating paint removal is by rather using two-dimensional Fe coated sheets as opposed to cylindrical tubes (Gale, 2008).

2.4.4. Relationship between paint removal and reduction

The NTCHS (2007) requires that at least 30% of the paint surface should be removed from a 150 mm zone within the top 300 mm of the tube. Conversely Castenson and Rabenhorst (2006) propose that there should be at least 20% paint removal from a 100 mm zone within the top 300 mm of the tube. This rule is much more sensitive to reducing conditions than the norm adopted by the NTCHS. In both cases three out of the five tubes installed at a site need to meet the criteria for the site to be classified as a wetland soil.

2.5. MIRIS tubes

There has been recent work into the use of MIRIS tubes (Manganese Indicators of Reduction In Soils) using the Mn-oxide mineral birnessite. Stiles *et al.* (2010) propose the use of MIRIS in wetlands that are unfavourable to Fe reduction, such as those encountered in the Brooks Range in Alaska. The conditions which are unfavourable for Fe reduction may be caused by excess free Fe or by high pH/Eh environments associated with soils with carbonate-rich parent materials. Dorau and Mansfield (2015) have also proposed the use of Mn-oxide-coated bars for short term monitoring and to identify weakly reducing conditions. The reason for this is because Mn is reduced more easily then Fe as it is higher up than Fe in the reduction reaction sequence, and hence provides a more sensitive measure of reducing conditions.

2.6. Conclusions

It is evident from the literature that IRIS tubes hold potential in the objective delineation of wetlands. Reducing conditions are maintained in wetland soils even if vegetation is cleared or disturbed. In special/certain cases where the chemistry of a wetland prevents the expression of redox morphology/soil wetness indicators, IRIS tubes provide a practical solution to assess if reducing conditions are in fact present. Although the method is relatively new, there already exist recommendations regarding the construction and analysis of the IRIS tubes. The use of pH/Eh stability diagrams has constraints due to problems associates with mixed redox couples and the prediction of reactions occurring at different rates. The direct measurement of the concentrations of reduced species in a soil is costly and there are exceptions to the assumptions that can be drawn. Dyes are a more cost effective option but only provide a snapshot into the soil mineralogy at a point in time, the measurement of false positive and false negative results is also a risk. The use of soil morphology is most helpful though in special cases such as recent alluvial deposits, sandy coastal aquifer systems, certain chemical conditions and in soils whose parent materials have insufficient Fe, sometimes these features are not well expressed. The presence of relict features can also complicate matters along with the disruption of the soil due to human activities. Hence IRIS tubes provide a useful opportunity to gain a time integrated direct measurement of reducing conditions occurring in the soil.

3. Description of study sites

3.1. Introduction

Three study sites were selected in the Kruger National Park based on their differing lithology, available literature and ease of access. These were the Malahlapanga Spring mire complex, the Nshawu Valley bottom wetland, and the Tshutshi Spruit (Figure 2). These three sites are situated in the northern region of the Kruger National Park. The thermal character of the Malahlapanga system was described and the plant species composition recorded by Grootjans *et al*. (2010). The Nshawu Valley bottom wetland is in one of the Kruger National Park study supersites, where research efforts are concentrated and is known as the “Northern basalts” site. The Tshutshi Spruit was selected as a site mainly due to its close proximity, approximately 1 km, from the Phalaborwa Gate. Each of these sites have differing hydrology and lithology, which provide a wide range of variables to test the IRIS tubes.

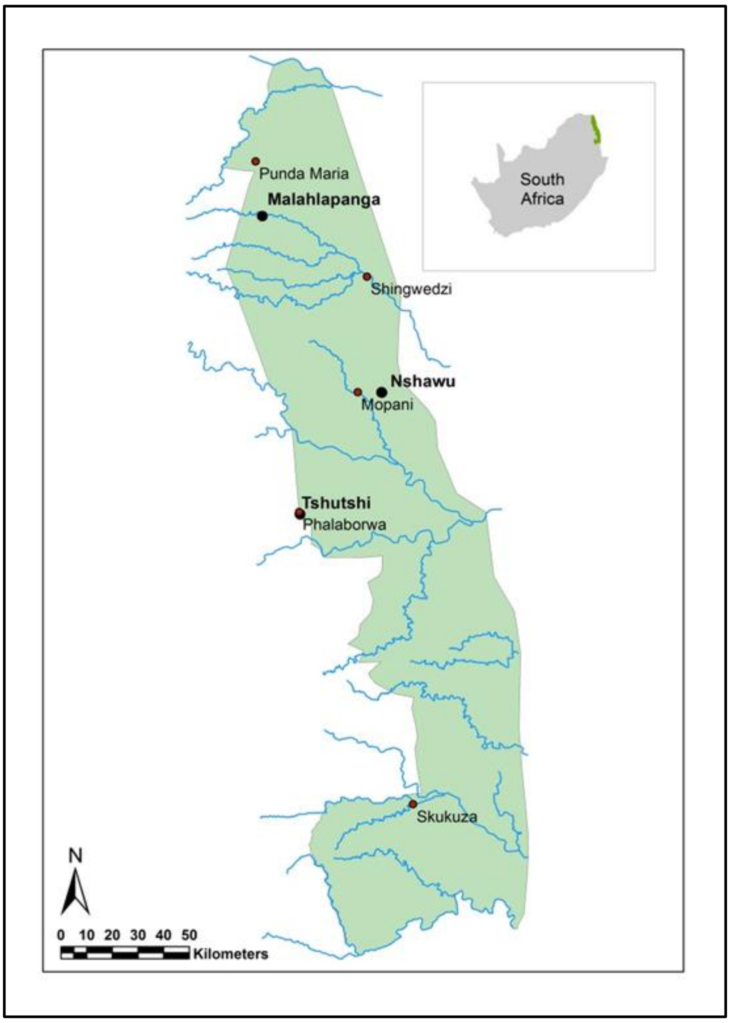

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Figure 2 Study sites in relation to rest camps and rivers in the Kruger National Park

3.2. Malahlapanga

3.2.1. Introduction

Over 90 thermal springs have been identified across South Africa, with the Limpopo Province having the greatest number (Olivier *et al.*, 2011). The name Malahlapanga is a Venda word which, loosely translated, means “to lose one’s panga” (L. Chauke, pers. comm. 2013). There are several thermal springs occurring in the Kruger National Park and while the name Malahlapanga does not describe the system particularly well in terms of the nature of the place, other than someone’s misfortune, the name of a similar spring in the region, Mati Yovila, does. Mati Yovila is a Tsonga word meaning “boiling water” (D. Mabaso, pers. comm. 2013). Malahlapanga is a peat-forming system. Less than 1% of the wetlands in the Kruger National Park have accumulation of peat greater than 300 mm (Grootjans *et al.*, 2010). This is because the process of peat formation and accumulation requires a permanent source of water, which is unusual with the erratic rainfall and high evaporation rates characteristic of the region.

3.2.2. Location

The Malahlapanga system is in the far north region of the Kruger National Park, near the Park’s western boundary, in the Shangoni section. It is situated close to a tributary stream on the southern bank of the Mphongolo river, at 22°53.243’S; 31°02.426’E (Figure 3). Malahlapanga is a 51 km drive from Shingwedzi rest camp, with a service road running past it, allowing access. It is used as a water source by game, and is heavily utilised in the dry winter months. It is the only permanent fresh water source for quite a distance and is thus frequented by large game, such as elephant, which is thought to be contributing significantly to the system’s erosion (Grootjans *et al.*, 2010).

3.2.3. Topography

Malahlapanga has a very gentle slope ranging from 1.3 to 2.7%. The elevation of the site does not range by more than about 4 m, averaging 369 m above sea level. The system (Figure 3) occupies a low-lying position in the landscape and has an area of about 4 to 6 ha (Grootjans *et al.*, 2010). Malahlapanga has 5 peat domes, in various stages of development, from which the thermal waters discharge and drain down a system of dynamic channels towards the Mphongolo River. The northern-most mire is presumed to be the oldest (it is the largest) and has been severely trampled by elephant. The southern-most feature is a thermal pool which is thought to be the start of a new mire, where vegetation has not yet established and, hence, is not yet forming peat. It is believed that when the weight of peat exceeds the pressure head of the thermal waters, the water will seek a new escape outlet and begin the formation of a new mire. An alternative theory is that there has been minor geological movement which has caused a shift in the water source (P-L. Grundling, pers. comm. 2012).

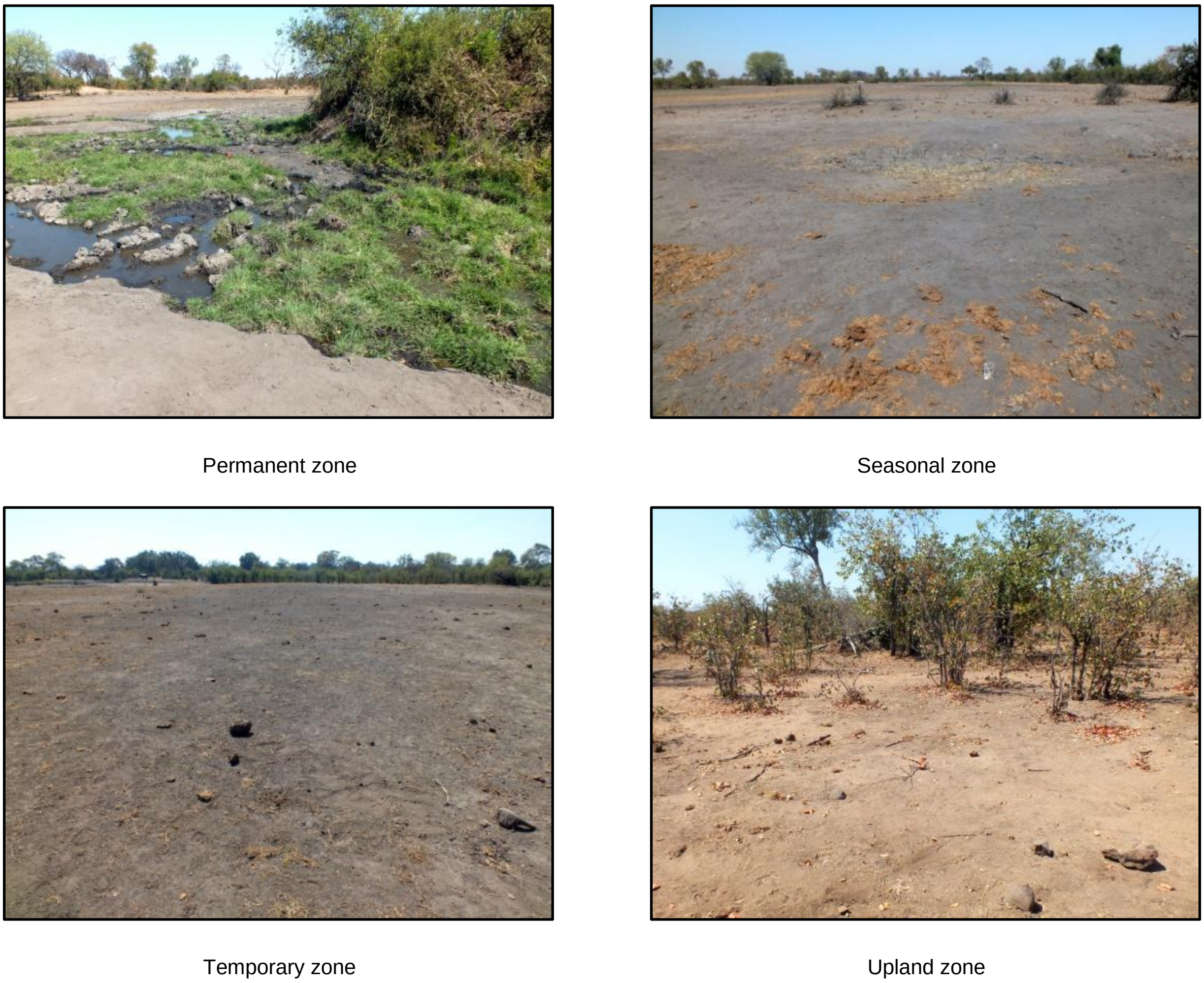

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Figure 3 Images of the Malahlapanga spring mire complex along the catena

3.2.4. Climate

The area receives between 450 to 500 mm of rainfall per annum (Schulze *et al.,* 1997; Zambatis, 2003). However, Gertenbach (1980) cited by Grootjans *et al.* (2010) states the annual precipitation as between 550 and 600 mm per annum. The mean annual temperature for Malahlapanga is 22°C (Schulze *et al.,* 1997). Schulze *et al.* (2008) report mean annual evaporation for the area (calculated using the A-pan method) between 2000-2200 mm (Table 3). The annual evaporation of the region exceeds the amount of rain thereby creating a strong soil water deficit (Venter & Gertenbach, 1986; Mucina and Rutherford, 2007; both as cited by Grootjans *et al.,* 2010).

Table 3 Potential evaporation values for northern Kruger calculated using two different methods (Schulze *at al.,* 2008)

Month	A-pan Equivalent (mm)	FAO Penman-Monteith Equivalent (mm)
January	220-240	160-180
February	180-200	140-160
March	180-200	140-150
April	140-150	100-110
May	120-130	90-100
June	100-110	70-80
July	120-130	80-90
August	150-160	100-110
September	180-200	130-140
October	200-220	140-160
November	220-240	160-180
December	220-240	160-180
Year	2030-2220	1470-1640

3.2.5. Geology

Much of the western area of the Kruger National Park consists of granite, gneiss, migmatite, amphibolite, schist, and undifferentiated metamorphic rock (Bristow & Venter, 1986). Malahlapanga lies within this band that runs longitudinally in a north-south direction. The site is underlain by Goudplaats gneiss (Brandl, 1981; Schutte, 1986), which was formed in the Swazian erathem (>3 090 million years BP) and is recognisable by alternating bands of light and dark material (Brandl, 1987). The Goudplaats gneiss consists mainly of tonalite, a plutonic rock with the composition of diorite but with more quartz, with a small portion consisting of granodiorite, a coarse grained plutonic rock that consists of quartz, oligoclase or andesine, and orthoclase with biotite, hornblende or pyroxene as mafic constituents (Brandl, 1987; Soil Classification Working Group, 1991). Much of the parent material appears to be alluvial in nature due to the low lying cumulative position of the site. There is a zone of faulting 10 km to the north of Malahlapanga, namely the Dzundwini and Nyunani Faults which run in an east-west direction. However, there is an offshoot of the Nyunani Fault that runs from north to south stopping 2 km short of Malahlapanga (Brandl, 1981 as cited by Grootjans *et al.,* 2010). It is this fault that is thought to be the source of the spring complex.

3.2.6. Vegetation

Malahlapanga is in the Tsende Mopaneveld region which falls under the Mopane Bioregion. This is under the umbrella of the Savanna Biome (Mucina *et al.,* 2005). Locally, at Malahlapanga, there is a sharp boundary between the surrounding veld, dominated by *Colophospermum mopane* and the system which is largely barren with a few patches of heavily grazed grass cover and small forbs. Protruding from this barren area are the peat domes, or mires, which are well vegetated due to the constant water supply. Grootjans *et al.* (2010) identified numerous species occurring at the bases of the mires, many of which were common hydrophytes such as *Phragmites australis* and *Miscanthus junceus.*

3.2.7. Soils

Malahlapanga is in the fersiallitic map unit of the Venter (1990) soil map. These soils are described as being coarse fersiallitic sands and loams that are mainly red in colour. The region is also associated with lithosols, described as being fine fersiallitic sands, arenaceous sediments and loams which are also red in colour.

3.3. Nshawu

3.3.1. Introduction

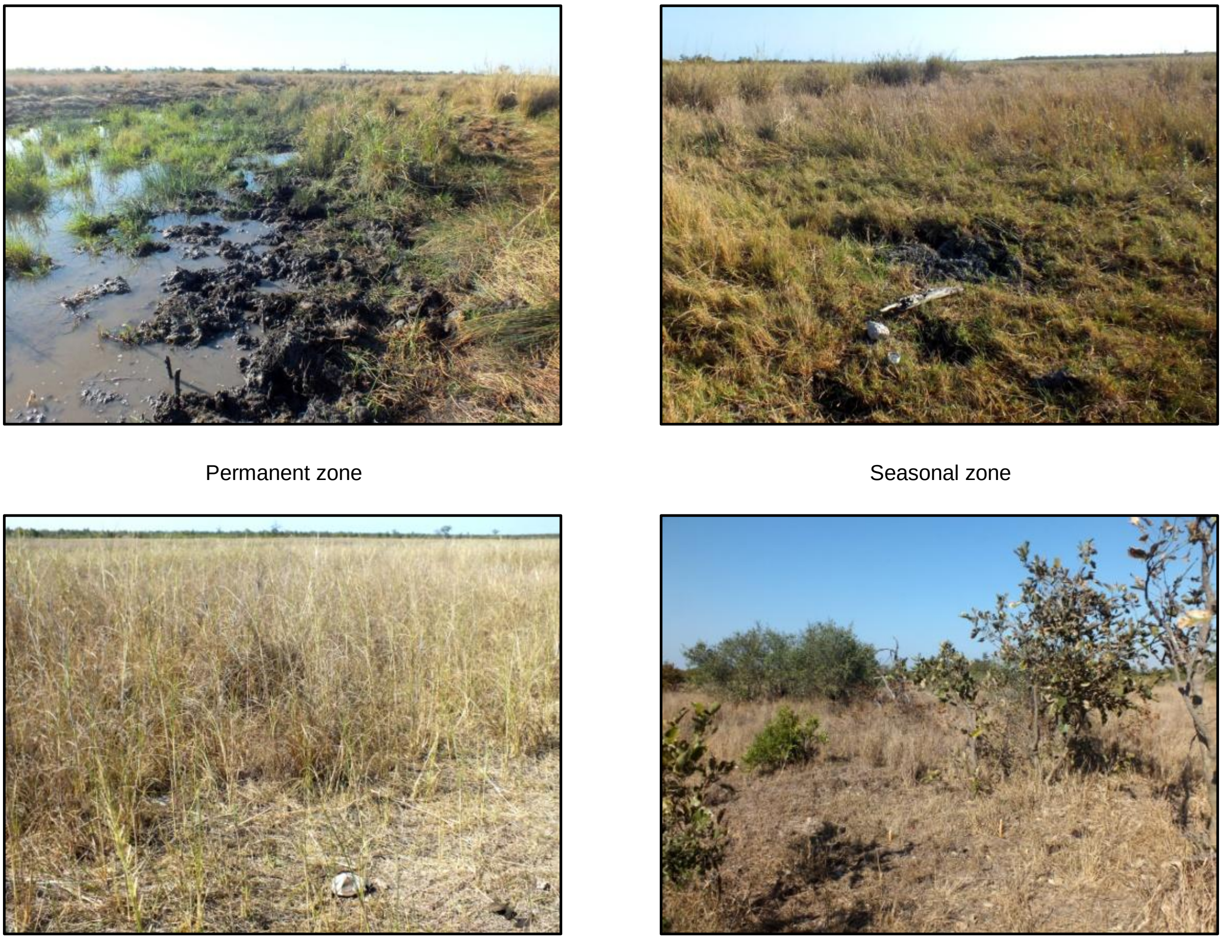
The Nshawu valley bottom wetland (Figure 4) is one of the largest wetland systems in the Kruger National Park, occupying an area of 570 ha (Grundling, 2010). The wetland was characterised and assessed by Grundling in 2010 because there were concerns relating to a breached dam wall that was influencing the hydrology of the system as well as an old tourist road that was built across the wetland. Nshawu was an attractive site for this study due to its basic igneous rock geology, in contrast to the other two sites which are underlain by acidic parent materials. Nshawu is also a Kruger National Park research supersite where a number of other research efforts are concentrated.

3.3.2. Location

Nshawu is in the northern region of the Kruger National Park approximately 23 km from the Mopani rest camp and in the Mooiplaas section. The wetland runs in a longitudinal direction (roughly NNE to SSW) and drains into the Tsendze River. Due to the size of the wetland it would be difficult to monitor the whole system. Only a section on the western bank was therefore selected due to there being clear vegetation wetland indicators showing the permanent, seasonal, temporary and terrestrial zones. There is also a tourist road that runs along the western edge of the system which aids access. The site selected is at 23°31.326’S; 31°29.165’E.

3.3.3. Topography

The western bank of the Nshawu wetland has an east facing aspect. The slope is approximately 1% and the elevation of the site is 321 m above sea level. Notable features of the site include the breached dam wall to the north and areas of channelisation within the wetland.



Permanent zone | Seasonal zone | Temporary zone | Upland zone

T Johnson

Figure 4 Images of Nshawu valley bottom wetland along the catena

3.3.4. Climate

Nshawu has a mean annual temperature of 22°C (Schulze *et al.,* 1997) and has a higher mean annual rainfall than Malahlapanga, ranging between 500 and 550 mm with an average of 525 mm (Schulze *et al.,* 1997; Zambatis 2003). Nshawu falls within the same mapping unit as Malahlapanga in terms of evaporation, and mean annual evaporation is in the region of 2000-2200 mm (Schulze *et al.,* 2008). Refer to Table 3 for monthly evaporation values.

3.3.5. Geology

Nshawu is underlain by basalt and falls within the map unit containing olivine rich basalt, subordinate alkali-basalt and shoshonite which are all part of the Karoo System (Bristow & Venter 1986). The wetland is located in a broad band of this olivine rich basalt though it is flanked by olivine poor basalt, granophyres and rhyolite which form the Lebombo mountain range to the east. Grundling (pers. comm. 2012) believes that there are alluvial fans that are originating in the Lebombo mountains and are influencing the channelisation of the Nshawu wetland.

3.3.6. Vegetation

According to Mucina *et al.* (2005) the wetland lies within the Mopane Basalt shrubland vegetation unit in the Mopane bioregion under the Savanna Biome. Nshawu also falls within the Mopane shrubveld ecozone (Mucina & Rutherford, 2007).

3.3.7. Soils

Venter (1990) characterised the soils of this region as being high in smectitic clays, describing them as calcareous, having a pedocutanic structure and being mainly brown or black in colour.

3.4. Tshutshi Spruit

3.4.1. Introduction

The Tshutshi spruit was selected as a study site due to its close proximity to the Phalaborwa gate. The Tshutshi spruit is of concern for the Kruger National Park management because it brings with it an abundance of litter and effluent from the upstream town and is also a continuous source of alien plant seeds. The river also runs past the Phalaborwa sewage works where overflow may enter the system.

3.4.2. Location

The Tshutshi spruit is a tributary of the Olifants River and rises outside the Kruger National Park's eastern boundary. It lies in the Phalaborwa section in the north region of the park, with an access road running past it (23°57.186'S; 31°10.089'E). The study site is on the northern bank of the river and therefore has a south facing aspect.

3.4.3. Topography

The average slope is roughly 1% and the average elevation is approximately 403 m above sea level. The barren area in Figure 5 was identified as a sodic site.

Permanent zone

Seasonal zone

Temporary zone

Upland zone

T Johnson

Figure 5 Images of the Tshutshi spruit along the catena

3.4.4. Climate

The mean annual temperature for the Tshutshi spruit area is 21°C, 1 degree cooler than both Malahlapanga and Nshawu (Schulze *et al.,* 1997). The mean annual rainfall for the area is between 500 and 550 mm, with an average of 525 mm (Schulze *et al*., 1997; Zambatis, 2003). The Tshutshi spruit falls within the same evaporation mapping unit as Malahlapanga and Nshawu (Schulze *et al*., 2008). Mean annual evaporation is between 2000-2200 mm and monthly evaporation values can be found in Table 3.

3.4.5. Geology

The site is underlain by Archean granite of the Swaziland system, consisting of granite, gneiss, migmatite, amphibolite, schist, and undifferentiated metamorphic rocks (Bristow & Venter, 1986). Schutte (1986) mapped the area as being underlain by the Orpen Gneiss.

3.4.6. Vegetation

The site is within the Mopane bushwillow woodlands ecozone (Mucina and Rutherford, 2007) and the vegetation unit is Phalaborwa and Timbavati mopane veld, also in the Mopane bioregion of the Savanna Biome (Mucina *et al.,* 2005). *Typha capensis* designates the permanently saturated zone while *Cyperus sexangularis* indicates the seasonally saturated zone.

3.4.7. Soils

Venter (1990) describes the soils occurring in this area as fersiallitic with coarse fersiallitic sands and loams which are mainly yellow and grey in colour and associated lithosols.

3.5. Conclusions

All three of the selected wetlands have a similar climate and vegetation although they each have unique hydrological and lithological conditions. This provided a good range of conditions in which the IRIS tube methodology could be tested and compared.

4. Materials and methods

4.1. Study layout

The zone boundaries were determined by observing changes in vegetation and soil morphological features in the top 0.5 m of the profile. Three transect replications were selected at each wetland site. A monitoring point was situated in each wetness zone of each transect, giving 12 monitoring points per wetland site. Water table monitoring wells and five IRIS tubes were installed at each monitoring point and profile pits were dug for soil characterisation. IRIS tubes were installed in a pentagon star configuration around each monitoring well, according to the protocol (Rabenhorst, 2008). Figure 6, Figure 7, and Figure 8 indicate the exact locations of each monitoring point in the different wetland sites.

[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U)]

Figure 6 Google earth image of the Malahlapanga wetland and the monitoring points (Google Earth, 2013).

[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U)]

Figure 7 Google earth image of the Nshawu wetland and the monitoring points (Google Earth, 2013)

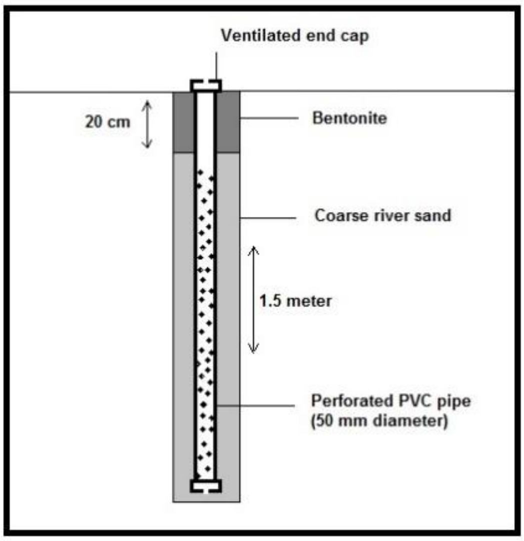
[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U)]

Figure 8 Google earth image of the Tshutshi spruit and the monitoring points (Google Earth, 2015)

4.2. Monitoring wells

4.2.1. Construction and instillation

The monitoring wells were constructed according to the procedure described by Sprecher (2008) and the WRP Technical Note (1993), by drilling holes, approximately 50 mm apart, along the length of a 1.5 m, 50 mm diameter PVC waste pipe. The Kruger National Park Scientific Services raised concern about vandalism or interference by animals (especially elephant) and therefore the wells were installed flush with the soil surface. In the initial stages of the study, the elephants were able to detect the fresh water in the wells and would dig the wells out. The wells were then sunk a further 50-100 mm and were covered with grass and dung to deter the elephants. This proved adequate to prevent further vandalism. It was also preferable not to have the well risers visible, which would be undesirable to tourists in the Park. The wells were excavated using a bucket auger. The wells were then placed in position and river sand was poured around it, with a layer of bentonite near the surface to prevent preferential flow of water along the sides of the well and sealed with waste pipe end caps (Figure 9). Wells were installed to a shallower depth where restricting layers impeded auguring.



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A

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B

Figure 9 Construction of wells (A) and photograph of a well section after elephant vandalism (B)

4.2.2. Water table measurement

The water table depth was measured from the soil surface, every 28 days using a tape measure. A small torch was used when poor light conditions made it difficult to see whether there was water present or not. When the wells were dry it was noted that the water table was not reached.

4.2.3. pH measurement

A water sample was taken from the well using a bailer, after the water level measurement had been recorded, and poured into a small clean glass beaker. The pH was then measured in the field with a portable pH/Eh meter (HANNA HI8314 instrument and a HI3230 pH electrode). The meter was calibrated with buffers of 4.00 and 7.00 at the beginning of each fieldwork trip. The reading was taken once the pH value had stabilised.

4.2.4. Eh measurement

An Eh measurement was taken in a similar manner in the field also using the HANNA instruments HI8314 instrument, but with a Pt electrode (HI3230) attached. The same water sample for the pH measurement was used and then the sample was discarded. The Eh electrode was calibrated at the beginning of each field trip against a 230 mV standard solution, because Eh is dependent on temperature.

4.2.5. Well removal

After the study, the wells at Phalaborwa and Nshawu were removed using a pipe extractor. The depths of the wells were recorded before their removal as some had to be shortened and others had filled with sand, reducing the initial depth of installation. At Malahlapanga there was a request by Working for Wetlands to leave the wells *in situ* because the Kruger National Park was beginning a rehabilitation program and would use these wells to monitor the success of the re-wetting of the wetland.

4.3. IRIS tubes

4.3.1. Paint synthesis

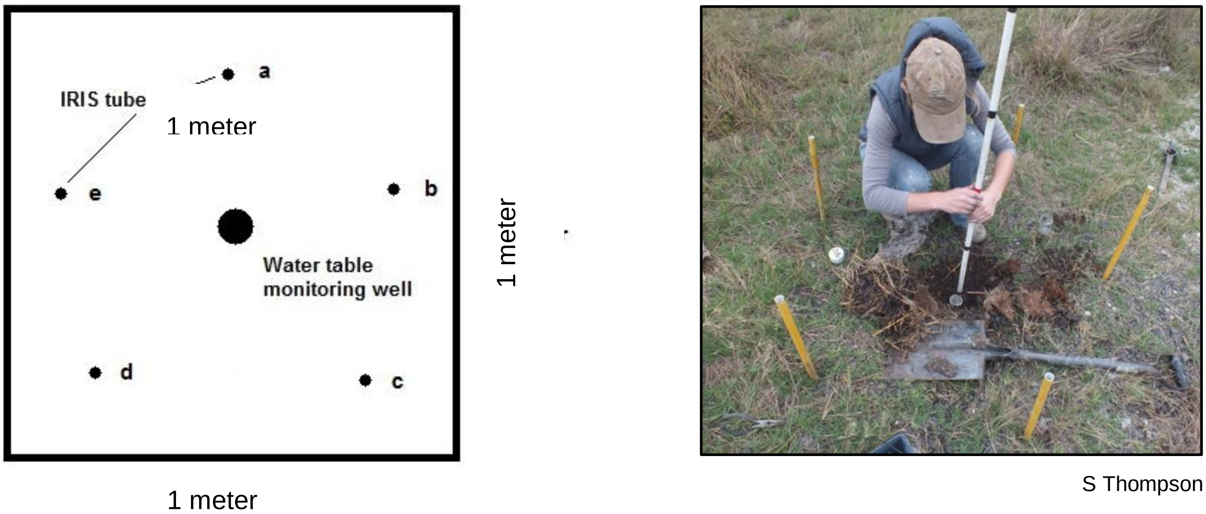
The paint was synthesised using Rabenhorst's (2006) "Quick (7-day) IRIS Tube Paint Recipe and Construction Procedure". An XRD analysis was performed on the paint, which can be referred to in Appendix D, and it was found that the main Fe-oxide constituent was goethite. The paint was refrigerated at approximately 5°C to delay mineralogical alteration.

4.3.2. Construction

The IRIS tubes were constructed by first cleaning 20 mm diameter PVC conduit piping with acetone to remove dirt, glue, and ink and then sanded to provide a suitable surface for the paint to adhere to. The prepared tubes were placed on a lathe-like device constructed using a battery powered hand-drill. A paintbrush was then used to apply two coats of goethite paint to the tube, allowing the paint to dry between coats. After the tubes were air dried they were placed in an oven overnight at 70°C to increase the paint's resistance to abrasion (this step was only required if the paint was easily rubbed off). Most of the tubes were 0.5 m in length, but were cut to 0.4 m in length where it was impossible to auger to 0.5 m in some of the upland rocky soils and some of the temporary sites. The tubes did not protrude from the soil as in the traditional method due to the risk of animals damaging them, being unsightly, more cost effective, and the risk of inquisitive people removing them not knowing what they were. Where tubes were not flush with the soil surface, they were bent and couldn't be scanned in the modified flatbed scanner. However, this made locating the tubes extremely difficult especially in areas with thick vegetation cover and during the growing season. It would be recommended to use small brightly coloured flags in such an area.

4.3.3. Installation and extraction

The IRIS tubes were installed using a 20 mm wood drill auger. Once the hole was augured the IRIS tubes were pushed down until they were flush with the soil surface, sometimes having to be gently tapped with a hammer, care being taken not to damage the tube. In the particularly rocky and calcareous soils it was impossible to auger a hole with such a small diameter and so an metal stake, with a diameter of 20 mm, was hammered into the ground and then removed using a vice grip. This then created the correct sized hole for the IRIS tubes to be installed. The tubes were installed in a pentagon-shaped pattern (Figure 10) around the central water monitoring well, all within 1 m², and in accordance to the protocol outlined by the NTCHS (2007). The IRIS tubes were replaced approximately every 28 days and each time into the same holes. Care was exercised when removing the tubes to prevent soil from falling back into the holes. Pouring a small amount of water around the tube before removing the IRIS tube also helped in preventing this. The tubes were extracted using a pair of narrow long nose pliers. Care was taken not to damage the tubes or scratch the paint. The tubes at each site were labelled in a clockwise direction (starting from the same point each time) a, b, c, d, e. Once removed the pipes were placed in plastic bags and taken to the laboratory to be carefully washed and dried.



A B

Figure 10 Diagram of IRIS tube installation (A) and a photograph showing the setup in the field and the collection of a water sample (B)

4.3.4. Quantification of paint removal

The cleaned IRIS tubes were lain out in their batches and a quick visual assessment was performed. Only the tubes which had paint removal were scanned. Using a permanent marker each tube was marked with a small dot at 100 mm intervals. The tubes were then scanned using a DPI of 70 on the greyscale setting, with 2 scans per tube to cover the top 300 mm. The bottom 200 mm was not scanned as this depth is not used in the NTCHS's or Rabenhorst's criteria (NTCHS, 2007). The images were then cropped to one revolution of the tube using the dots as guides. The images were then converted into black and white images on Photoshop using a threshold which was the most accurate when comparing the scanned image to the real tube. From here a percentage value was obtained and the area percentage paint removal from the top 300 mm was calculated. The IRIS tubes from Malahlapanga's permanent zone had to be treated differently as the organic matter from the peat stained the white PVC of the tubes. When looking at the scans it was impossible to differentiate the areas on the tubes that had not been reduced. This was because areas where there had been paint removal were stained the same grey tone that the scanner recorded the unreduced orange paint. When this was the case, an estimated value was given based on visual inspection of the tube.

4.4. Vegetation

The vegetation was assessed during the summer growing season. At each of the monitoring points, 25 random sampling points were selected within a 5 m radius from the monitoring well. At each of the 25 random sampling points, the nearest species were identified. Species which were not easily identifiable in the field were given a temporary name and detailed photographs were taken. All species were classified as either being ***present*** or ***dominant*** in terms of their abundance at the monitoring point. The species were also classified as being one of the following: dryland, opportunistic/dryland, obligate wetland, facultative wetland, and facultative negative or facultative positive plants. An obligate wetland plant is a plant that occurs for >99% of the time in a wetland or water saturated area. A facultative wetland plant is a plant that occurs 50% of the time in wetland or water saturated areas, a facultative positive wetland plant occurs between 67-99% of the time in a wetland or water saturated area, and a facultative negative plant occurs <25% of the time in a wetland or water saturated area (van Ginkel *et al.,* 2011).

4.5. Soil profile descriptions

A profile pit was dug in each wetness zone at each of the selected wetlands, giving 12 profiles for the study and described in detail (Turner, 1991). Photographs were also taken at each pit. The soils were classified according to both the South African classification (Soil Classification Working Group, 1991) and the World Reference Base for Soil Resources (IUSS Working Group WRB, 2014). Detailed profile descriptions are given in Appendix B.

4.6. Soil analyses

4.6.1. Sampling

Soil samples were taken at all 36 monitoring points. Composite soil samples were taken from the profile pit walls and by auger at the other monitoring points. Where auguring was not possible due to lime concretions, samples were taken from a small pit. Samples were collected at 15 depths: 0-50, 50-100, 100-150, 150-200, 200-250, 250-300, 300-400, 400-500, 500-600, 600-700, 700-800, 800-900, 900-1000, 1000-1100, 1100-1200 mm. Samples were bagged and labelled, and taken to the laboratory for analysis. There they were air dried and lightly ground using a porcelain mortar and wooden pestle (to prevent Fe contamination) to pass a 2 mm sieve. The coarse size fraction was determined as the percentage of fragments >2 mm in diameter. The soil was then stored in plastic containers ready for analysis. Peat samples were handled differently: half the sample was dried and sieved while the other half was kept in its moist state for certain analyses.

4.6.2. Analyses

All analyses were done according to the methods of the Non-Affiliated Soil Analysis Work Committee (1990), unless stated otherwise.

4.6.2.1. pH

The pH was measured in distilled water as well as a 1M KCl salt solution in a 1: 2.5 ratio (soil: distilled water/KCl) with a waiting period of 30 minutes.

4.6.2.2. Electrical resistance

The electrical resistance of saturated pastes was measured in ohms using a standard electrode cup and resistance bridge. The electrical resistance is inversely proportional to the salt concentration of a soil.

4.6.2.3. Cations

The soluble and exchangeable cations were determined using the 60% aqueous alcohol for the soluble and 1M NH_4OAc for the exchangeable cation extraction. After the exchangeable cations had been leached the samples were leached with Na-acetate, and the leachate was discarded. The sample was then leached with 60% alcohol. Finally the samples were leached with an NH_4OAc solution and the leachate was collected to determine the Na concentration by using an atomic absorption meter.

4.6.2.4. Nitrogen

Total nitrogen was measured using the Kjeldahl method whereby the nitrogen was first released via digestion, with boiling H_2SO_4 and a catalyst, and then distilled with NaOH. A boracic acid indicator was used and the samples were titrated with a H_2SO_4 solution. The total nitrogen was calculated using a blank value.

4.6.2.5. Organic Carbon

The organic carbon was measured using the Walkley Black method. Samples were oxidised using a Potassium dichromate solution. Care was taken when adding concentrated H_2SO_4 and concentrated ortho phosphoric acid. Due to the high organic carbon present in the peat samples at Malahlapanga, less soil was used to ensure an accurate titration with the 0.5 M Ferro ammonium sulphate solution. It is normally the case to use an alternative method for samples with >8% organic carbon (Soil Survey Staff, 2014), but in this study the Walkley Black method was used throughout for the sake of comparison and because only a relatively small number of samples had >8% organic carbon.

4.6.2.6. Phosphorous

Phosphorous was determined using the Bray 1 method. 2.5 g of soil was used and shaken with 50 cm^3 extraction solution ($NaHCO_3$ at a pH of 8.5). The extract was then diluted with distilled water and a colour reagent was added. The light adsorption was determined using a colorimeter set at a wave length of 882 nm. A standard graph was compiled using a standard stock phosphorous solution. Using this graph, the concentration of phosphorous in the soil was calculated.

4.6.2.7. Iron and Manganese

The total reducible Fe and Mn were extracted using the dithionate-citrate-bicarbonate method. 2 g of soil per sample was used and the relative ratios of reagents were maintained. The samples were placed in a water bath at 77°C.

4.6.2.8. Texture

Soil texture was determined in seven fractions (coarse sand, medium sand, fine sand, very fine sand, coarse silt, fine silt and clay) using the pipette and sieve method. All the samples were pre-treated with acidified NaOAc to remove carbonates and with H_2O_2 to remove organic matter. Samples were then dried and ground to pass a 2 mm sieve and stored in small plastic bags. The amount of soil required for each sample was weighed out and noted. The samples were dispersed with Calgon and the clay and silt fractions were separated from the sand. The sand fractions were determined via sieving while the silt and clay fractions were determined via pipetting. The seven different size fractions were calculated and a blank correction factor for the Calgon was incorporated. The cumulative value of the 7 size fractions was calculated. For the purpose of accuracy a 5% margin of error was allowed (i.e. Values between 95-105%) and any samples that fell outside of this range were re-analysed.

4.6.2.9. Derived values

Values were calculated from the above analyses. The ESP (exchangeable sodium percentage) was calculated as follows:

$$ESP = [Na] \times 100 / CEC \qquad (Equation\ 1)$$

The SAR (sodium adsorption ratio) was calculated using the following equation:

$$SAR = [Na] / (\{[Ca] + [Mg]\}/2)^{\wedge}0.5 \qquad (Equation\ 2)$$

The CEC clay was calculated using:

$$CEC_{clay} = CEC\ x\ 100 / clay\ (\%) \qquad (Equation\ 3)$$

The Base Saturation was calculated using:

$$Base\ Saturation = \{[Ca]+[Mg]+[K]+[Na]\} \times 100 / CEC \qquad (Equation\ 4)$$

Organic matter values were calculated as follows: by multiplying the organic carbon results by a factor of 1.12.

$$Organic\ Matter = Organic\ Carbon \times 1.12 \qquad (Equation\ 5)$$

4.7. Statistical analysis

The variables pH (KCl), Organic Carbon, Fe, Mn, Clay, Electrical Resistance (ER), Exchangeable Sodium Percentage (ESP), and CEC_{Clay} were analysed as follows: The dependent variables were analysed by fitting a mixed model, namely a so-called random effects model, in order to investigate various aspects of the data. The mixed model was fitted using the SAS software package (SAS, 2009).

The linear mixed model was fitted with the following effects: Fixed effects: wetland, zone, wetland*zone and Random effects: transect*wetland. From this mixed model, mean values for wetland, zone and wetland by zone combinations were calculated (note: mean values on the natural logarithmic scale where appropriate). Furthermore, from the mixed model, F-statistics and associated P-values for the fixed effects wetland, zone and wetland*zone were calculated. Generally the wetland*zone interaction term is statistically significant, which suggests that there are statistically significant differences between at least some pairs of wetland/zone combinations.

Side by side boxplots of the data are presented in order to visualize the differences between wetlands and zones. If residual plots suggested that the residual variance was approximately constant on the logarithmic scale (natural logarithm), the data were analysed on the logarithmic scale. If, however, residual plots suggested that the residual variance was approximately constant on the original scale, the data were analysed on the original (un-transformed) scale.

The data contained a small number of gross outliers which were handled as follows: The mixed model described above was fitted, and based on this initial fit individual measurements associated with an absolute value of the conditional studentized residual larger than 3 were identified. Thereafter, the mixed model was re-fitted after exclusion of those outliers from the data (Schall, 2015; SAS, 2009).

4.8. Characterizing the wetlands

The climate was described and the rain that fell over the study period was presented for each wetland. The geology was defined in order to provide background information for the discussions to follow regarding the influence of geology on wetland indicators. The topography of each wetness zone was defined using the terrain unit indicator along with the slope percent, aspect and type. The vegetation for the sites was presented and the dominant species identified. Plant species were further classified as wetland or dryland in order to determine which species are wetland indicators. The chemical and physical analytical data are presented to define the soils at each wetness zone within the three wetlands. Photographs of relevant soil wetness indictors and soil morphology observed are shown and explained. The geological, topographic, soil wetness and soil form data presented, refer to the first transect of each wetland derived from the profile descriptions in Appendix B. The soil analytical data (chemical and physical) and hydrological data describe all three transects at each wetland and can be referred to in Appendix B and Appendix C. Statistical analyses will compare the soil analytical data for each of the three wetlands. All the data are interpreted in order to comment on the physical, chemical, mineralogical and hydrological characteristics of the three wetlands.

4.9. Data handling

All data collected in the field (monthly pH and Eh values, water table data, and profile descriptions) and in the laboratory (soil analyses, IRIS tube results) was entered into a Microsoft Excel database which was backed up regularly along with photographs that were taken in the field. Profile description sheets and field books were stored safely.

5. Characterisation of the three wetland sites

5.1. Introduction

This chapter address the first objective, namely to characterise the physical, chemical, mineralogical, and hydrological properties of the three different wetland types, with differing lithologies (Basalt, Gneiss, and Granite), in the Kruger National Park.

5.2. Characterisation of Malahlapanga

5.2.1. Climate

In the January of 2013 the Shingwedzi region (within which Malahlapanga falls) was subject to extensive flooding (Figure 11; Figure 12). This resulted in several dams breaching and many access roads becoming impassable. For this reason it was not possible to reach Malahlapanga for several months after the floods while the roads were being repaired resulting in missing monthly data for January and February of 2013.

SANParks SANParks

Figure 11 Aerial photograph of the Shingwedzi River in flood and the submerged Shingwedzi rest camp

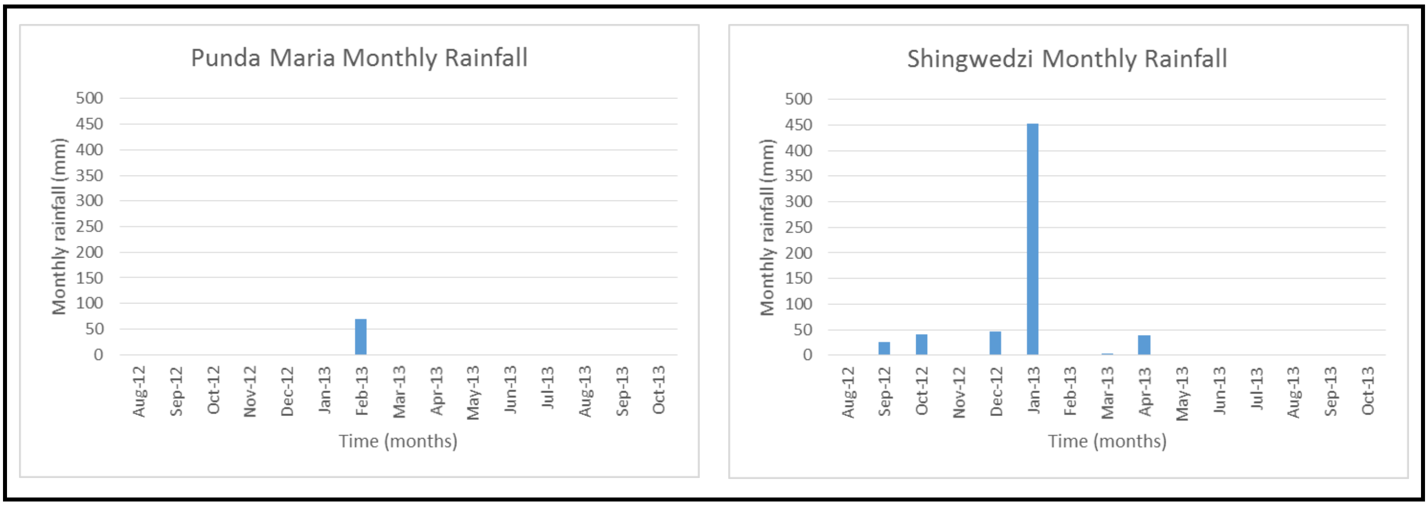


Figure 12 Monthly rainfall values for the closest rainfall stations to Malahlapanga

January 2013 was an extremely wet month with a total of 452.2 mm of rain. The rest of the year was relatively dry except for a few smaller rainfall events (<40 mm) occurring in September, October and December of 2012 as well as in April 2013.

5.2.2. Hydrology

The water table at the permanent zone was within the 0.5 m depth throughout the period of the study (Figure 13). The missing data for January and February 2013 is attributed to the Shingwedzi Flood where access to Malahlapanga was restricted. It can however, be presumed that there would have been a rise in water table levels over this period due to the magnitude of the flood that occurred. The water table levels fluctuated over the seasons but to a much lesser extent than the other two wetlands. It could be speculated that because the wetland is fed via ground water, there is a greater lag period, and that the effect of seasonal rainfall variation is buffered to some extent. In the case of repetition 2, the slight fall in water table level in the permanent zone is attributed to measurement error rather than a change in hydrology. The elephants were continuously damaging the well and so it had to be moved higher up on the peat mound to avoid being trampled, hence, the slightly lower values recorded.

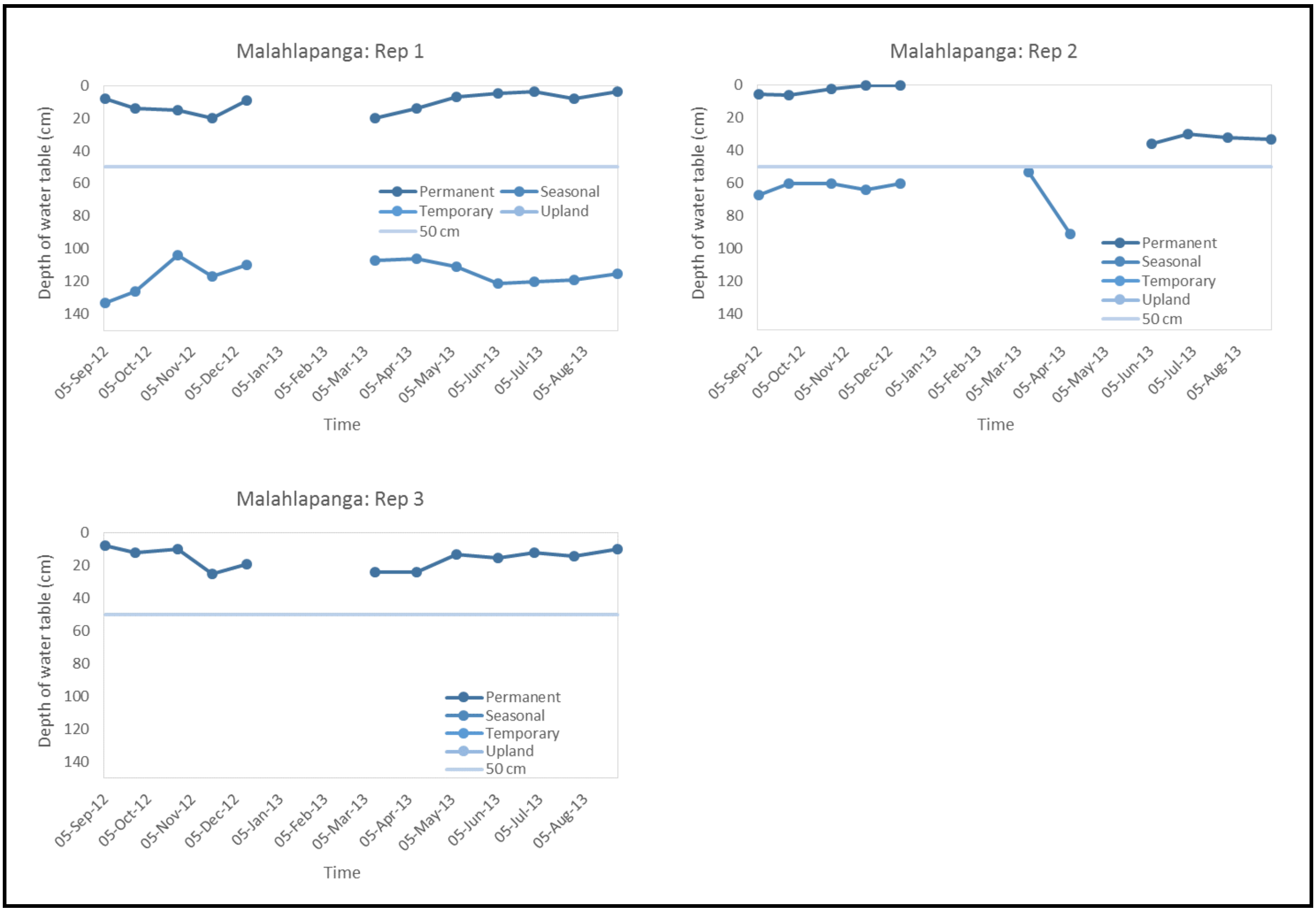


Figure 13 The hydrology of each wetness zone at Malahlapanga over the study period

5.2.3. Soil parent material

All the soils at the wetland are derived from the Goudplaats gneiss, a foliated metamorphic rock. The material at each of the zones has been ferruginised. In the permanent zone the parent material is of binary origin, namely alluvium and solid rock, and the degree of physical and chemical weathering is strong. In the seasonal zone the parent material is of a single origin, namely alluvium, the degree of physical weathering is advanced while chemical weathering is strong. In the temporary zone the parent material is of a binary nature consisting of transported alluvium as well as solid rock and has undergone weak physical and chemical weathering. The upland soil is of a single origin, being local colluvium, and has undergone advanced physical and weak chemical weathering.

5.2.4. Topography

The terrain unit indicator of 5, as defined by DWAF (2005) and MacVicar *et al*. (1977) is met, and wetland conditions could be expected at these positions (Table 4).

Table 4 Topography summary of Malahlapanga

Wetness zone	Terrain unit indicator	Slope %	Type	Aspect
Permanent	5-Valley bottom	0	Straight	North-facing
Seasonal	5-Valley bottom	0.5	Straight	North-facing
Temporary	5-Valley bottom	0.5	Straight	North-facing
Upland	4L-Lower footslope	2	Straight	Level

5.2.5. Vegetation

Due to the trampling from the animals, the vegetation had been significantly disturbed, which allowed the establishment of numerous small opportunistic/dryland species (Table 5). True wetland vegetation indicator species were hence scarce, however, the obligate wetland species *Phragmites mauritianus* was noted both in the permanent and seasonal zones (Table 6). The photographs in Table 6 are repeated from Figure 3 for convenience. The sharp boundary between the barren area and the *Colophosperum mopane* served as a positive boundary between the upland and the temporary wetland zone and could be used to delineate the wetland using aerial imagery.

Table 5 Plant species composition of the Malahlapanga wetland

Botanical name	Wetland / Dryland species	Assumed Wetness Zone											
		Permanent			Seasonal			Temporary			Upland		
		1	2	3	1	2	3	1	2	3	1	2	3
Woody species (p=present, d=dominant)													
Acacia robusta subsp clavigera	Dryland							p					
Capparis tomentosa	Opportunistic / Dryland	d											
Colophosperum mopane	Dryland										d	d	p
Lannea schweinfurthii	Dryland	p											
Grass species (p=present, d=dominant)													
Chloris virgata	Opportunistic / Dryland							p	p				
cf Dactyloctenium aegyptium	Opportunistic / Dryland			d									
Eragrostis sp.	Dryland									p			p
Enneapogon cenchroides	Dryland											p	
Leptochloa fusca	Obligate	p		d									
Panicum duestum	Dryland										p	p	p
Panicum maximum	Dryland	p											
Phragmites mauritianus	Obligate	d	d	d	p								
Tragus berteronias	Dryland							p			p	d	p
Forb species (p=present, d=dominant)													
**Alternanthera pungens*	Opportinistic / Dryland							p	p				
cf Campanulacea	Facultative negative		p										
cf Sesuvium hydaspicum	Opportunistic / Dryland												p
cf Zaleya pentandra	Opportunistic / Dryland							p			p		
Hibiscus cannabinus	Opportunistic / Dryland		p										
Portulaca oleraceae	Opportunistic / Dryland							p					
**Sesbania bispinosa*	Opportunistic / Dryland	p	d	p									
Trianthema salsoloides	Opportunistic / Dryland							p	p	p	p	p	p
Tribulas terrestris	Opportunistic / Dryland							p	p		p		p
Sedge and rush species (p=present, d=dominant)													
Fimbristylis dichotoma	Obligate			p									
Pycreus sp.	Obligate	d	p	d									

** Alien invasive species*

Table 6 Photographs of each zone showing differences in vegetation and corresponding descriptions at Malahlapanga

Permanent zone:

Leptochloa fusca and *Phragmites mauritianus* were noted as being dominant obligate grass species. The facultative negative forb *cf Campanulacea* was present. The obligate species *Fimbristylis dichotoma* (present) and *Pycreaus sp* (dominant) were also observed. The alien opportunistic species of **Sesbania bispinosa* was recorded in this zone. The presence of free standing water is evident in the photo as well as the lush vegetation associated with the peat domes.

Seasonal zone:

It is apparent that this zone is largely barren. Attributed to the trampling from large herds of buffalo attracted by the water eminating from the springs. The only species recorded in this zone is the obligate wetland species *Phragmites mauritianus*.

Temporary zone:

Also barren, this zone did not have any domiant species which made the boundary determination between the seasonal and temporary zones challenging. One Acacia robusta tree was observed. Opportunistic/ dryland grasses *Chloris virgata* and *Tragus berteronias* were present. Several opportunistic/dryland forbs were noted namely: the alien **Alternanthera pungens*, *cf Zaleya pentandra*, *Portulaca oleraceae*, *Trianthena salsoloides*, *Tribulas terrestris*.

Upland zone:

The boundary between the barren area and the mopane-veld is distinct. The upland zone is dominated by the dryland *Colophosperum mopane* and numerous dryland grasses were present: *Eragrostis sp, Enneapogon cenchroides, Panicum deustum and Tragus berteronias (dominant)*. Several opportunistic/dryland forb species were present namely: *cf Sesuvium hydaspicum, cf Zaleya pentandra, Trianthena salsoloides, Tribulas terrestris.*

5.2.6. Soils

5.2.6.1. Soil form

The soil form indicator was met for the permanent, seasonal and temporary zones (Table 7). A Glenrosa soil form can be a seasonal or temporary zone soil if there are signs of wetness encountered at a family level, however, this was not the case at Malahlapanga. The soil form indicator was able to distinguish between the different zones, however, it implied that the temporary zone was wetter than observed over the study period. This could mean that the Katspruit soil form is not restricted to the permanently saturated zones as the DWAF (2005) guidelines imply, or there may be relict features within this zone which may have been much wetter in the past. The soils at Malahlapanga have a high organic matter content resulting in a relatively low bulk density. The soil surface is covered in a loose organic powder which is easily blown by wind. White salt accumulations form on the surface of the soil where water evaporates. Fe and Mn mottles can also be observed in both the seasonally and temporarily saturated zones. The permanently saturated zone is peat forming, reaching heights of around 1-2 m above the immediate surrounds.

Table 7 Soil classifications related to the soil form indicator (DWAF, 2005) for Malahlapanga

Wetness zone	South African Soil Classification	World Reference Base Classification	DWAF 2005 Soil form indicator
Permanent	**Champagne 1200** (Organic O / unspecified. Fibrous organic material dominant, underlying material not consolidated)	Gleysol (Hyperhumic, Salic)	**Yes**, Champagne soils always occur in the permanent zone
Seasonal	**Kroonstad 1000** (Orthic A / E horizon / G horizon. Colour of E horizon “grey” when moist)	Epigleyic Fluvisol (Siltic, Eutric)	**Yes**, signs of wetness are incorporated at the form level
Temporary	**Katspruit 1000** (Orthic A / G horizon. Non-calcareous G horizon)	Mollic Gleyic Fluvisol (Endoruptic)	**Yes**, Katspruit soils usually occur in the permanent zone
Upland	**Glenrosa 1111** (Orthic A / Lithocutanic B. A horizon not beached, B1 horizon not hard, no signs of wetness in B1 horizon, non-calcareous B horizon)	Hyposodic Cambisol (Endoskeletic)	**No**, signs of wetness were not found at a family level

5.2.6.2. Laboratory results

The pH values, measured in water, at Malahlapanga ranged from 5.06 to 7.81, while the values measured in KCl ranged from 5.16 to 8.08. Generally there was an increase in pH with depth, which is likely attributed to the acidifying effect of the organic material at the soil surface. The upland zone had the highest pH values followed by the temporary, permanent and seasonal zones (Figure 14 A and B). While it would be expected that the KCl results would be more acidic than those measured in distilled water, this was not the case for some of the samples at Malahlapanga and Nshawu. This anomaly could not be explained, though van Raij and Peech (1972) found that in the highly weathered soils of the sub tropics, subsurface horizons with low permanent charge silicate clays and low organic carbon displayed this phenomenon. Upon the addition of KCl, the Cl^- would displace the OH^- ions resulting in an increase in measured pH.

The coarse size fraction values are recorded in Figure 16 B, which shows that there was generally an increase in coarse size particles with depth and that the percentage coarse size fragments were generally under 15%. The upland zone had the greatest coarse size fraction at depth due to the underlying weathering rock.

The organic carbon percent in the permanent zone was markedly higher than of the seasonal, temporary and upland zones due to the peat mires. Average organic carbon values in the permanent zone ranged from 5.80-23.12%, while values in the seasonal, temporary and upland zones were less than 5% as illustrated in Figure 14 C. There was a definite decrease in organic carbon with increased distance from the permanently saturated zone.

The seasonal, temporary and upland zones had CEC values below 25 $cmol_c$/kg (Figure 14 D). The upland zone had slightly lower CEC values due the fact that there has been less weathering and formation of clays. This is also corroborated by the coarse size fraction data in (Figure 16 B) which shows a coarse size fraction of 36.3% in the upland zone at 550 mm depth, indicative of a shallower and younger soil. The CEC is not given for the permanent zone due to the challenges involved in accurately measuring the cation exchange capacity of peat soils.

The upland zone had the highest electrical resistance with a maximum value of 805 ohms suggesting that the wetter zones have a higher salt content. The surface horizon of the seasonal zone had the lowest resistance of 42.83 ohms, thus the artesian water is thought to contain salts (Figure 14 E).

The most nitrogen was recorded in the seasonal zone followed by the temporary zone (Figure 15 A). The upland zone had the least nitrogen, which can be explained due to the low organic carbon recorded in this zone. The permanent zone had low nitrogen values which are attributed to nitrate reduction, nitrates are reduced first in the reduction reaction sequence (Verpraskas & Faulkner, 2001). Recorded nitrogen values for Malahlapanga ranged from 0-5500 mg/kg.

The amount of reducible Fe in the profile was directly related to the wetness of the zones. The permanent zone had the least amount of Fe while the upland zone had the most. This tallies with the observed Munsell colours recorded in the profile descriptions. The Fe values increased in even increments as one moves towards the drier zones, showing a trend between soil wetness and the reduction of Fe. Fe values recorded at Malahlapanga ranged from around 520-9750 mg/kg (Figure 15 C).

Less than 125 mg/kg of Mn was recorded in the permanent and seasonal zones and the upland zone had the highest Mn with a maximum value of 501 mg/kg with an increase in Mn with depth (Figure 15 D). This suggests that Mn has been reduced in the permanent and seasonal and temporary zones.

All the soluble cation values for Malahlapanga fell below 10 $cmol_c$/kg. In the upland zone there was an increase in soluble cations with depth, while in the temporary zone there was an increase and then decrease, in the seasonal zone there was a decrease in soluble cations. The seasonal zone had the most soluble cations at the soil surface and the least at depth when compared to the other zones. This suggests that there is an accumulation of soluble salts at the surface due to evaporation and a net removal of salts at depth due to a semi-permanent water source which can remove them (Figure 15 F).

The CEC clay for Malahlapanga ranged from 25-125 $cmol_c$/kg with the exception of a layer at 400 mm depth in the temporary zone with a CEC clay of 300 $cmol_c$/kg (Figure 16 A). This coincides with the ash layer that was classified as an E horizon.

Due to the high organic carbon content of the peat soils of the permanently saturated zone at Malahlapanga, it was not possible to perform a texture analysis on the samples collected. Figure 16 C, D, and E show the sand, silt and clay contents of the seasonally saturated, temporarily saturated and upland zones. In the seasonal zone there was an increase in sand with depth and a decrease in silt and clay with depth. Sand values ranged from 20-55%. In the temporary zone sand increased with depth while silt decreased with depth. Sand values in this zone ranged from 40% to 55%. In the upland zone sand decreased with depth while silt increased. Sand values ranged from 50-65% in this zone. Generally the seasonal zone was much clayeyer than the other zones and the upland zone much sandier than the other zones.

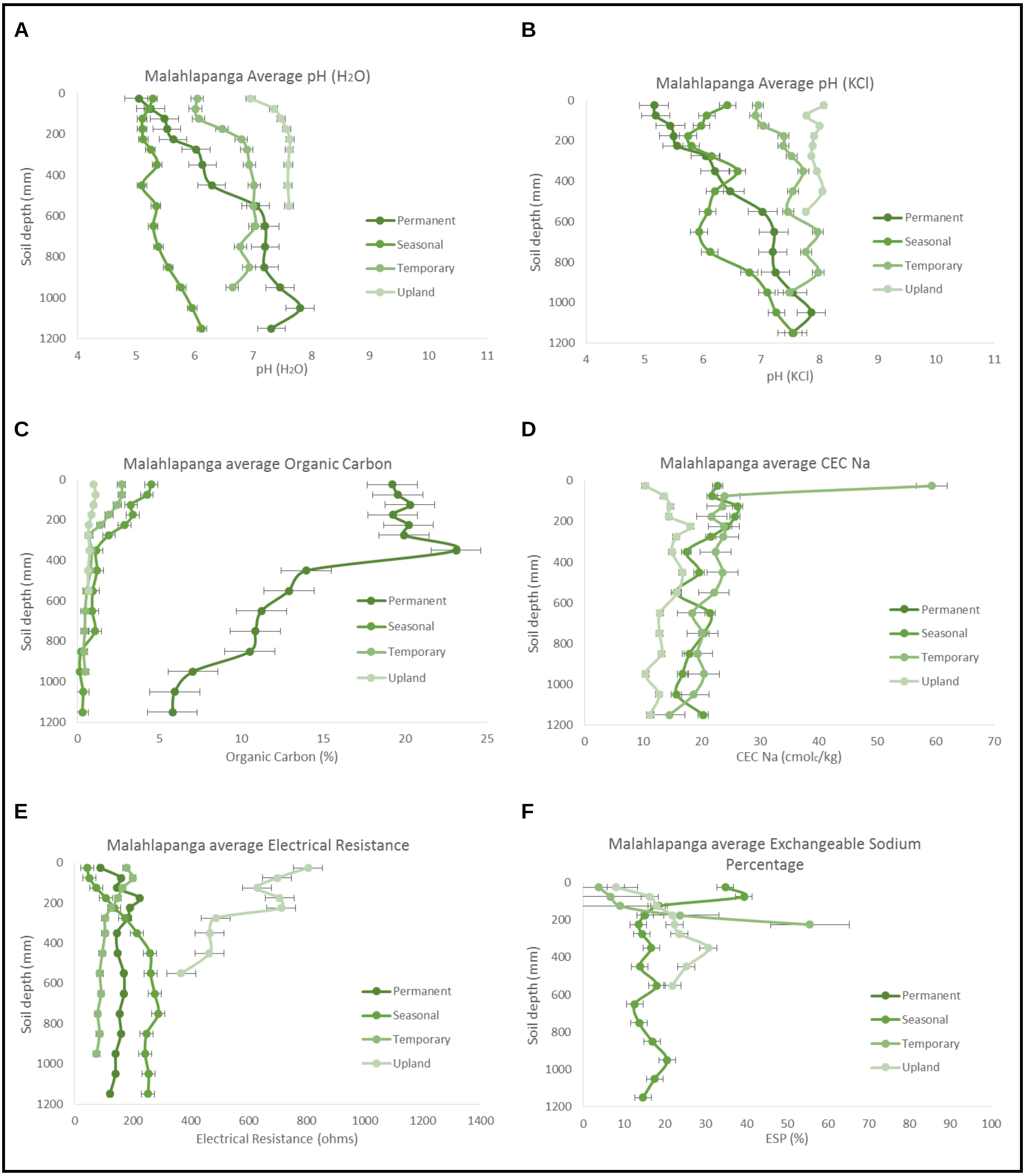


Figure 14 Laboratory analyses for the soils of Malahlapanga (pH measured in H_2O and KCl, organic carbon, CEC Na, electrical resistance and exchangeable sodium percentage)

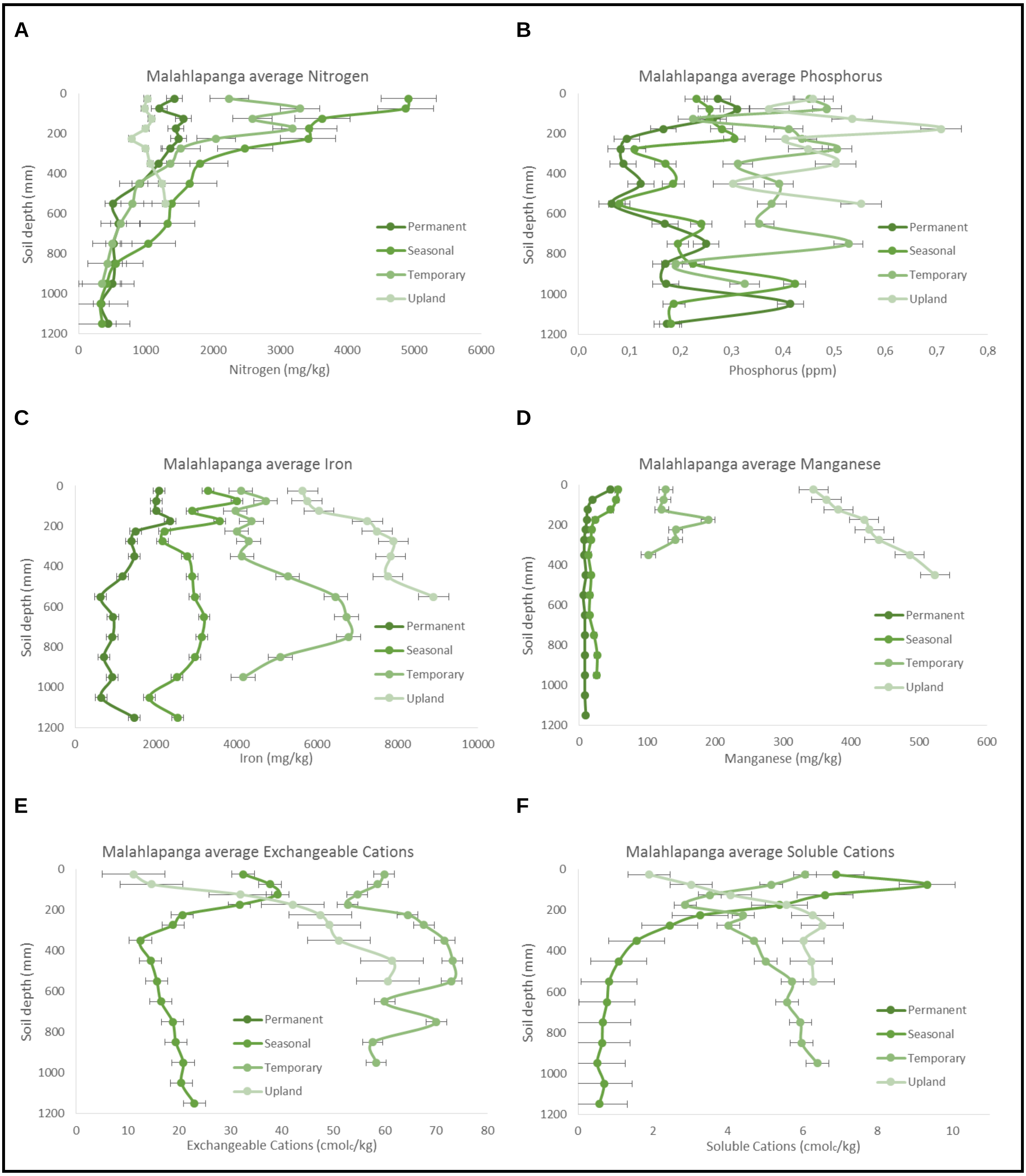


Figure 15 Laboratory analyses for the soils of Malahlapanga (nitrogen, phosphorus, iron, manganese, exchangeable cations and soluble cations)

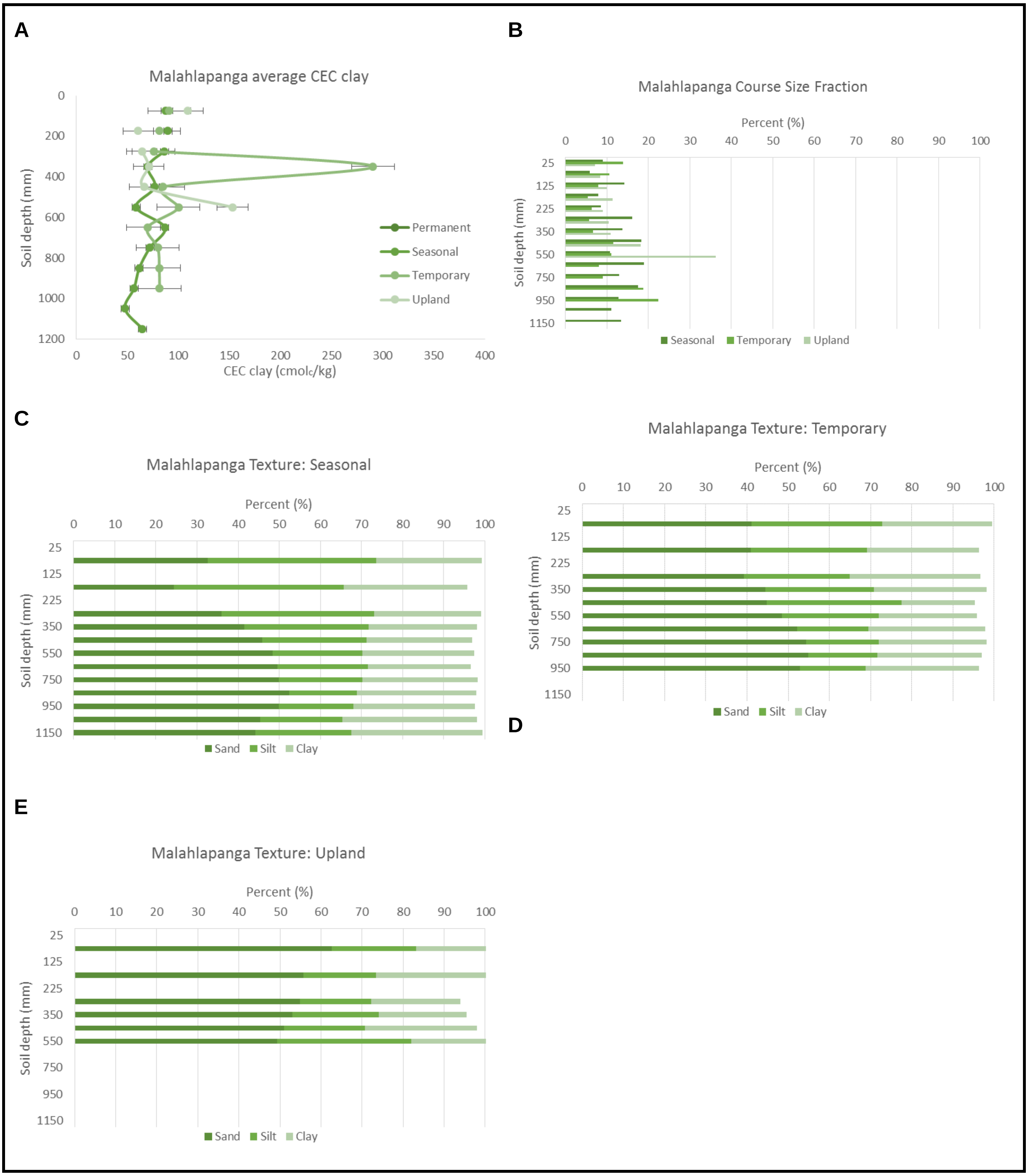


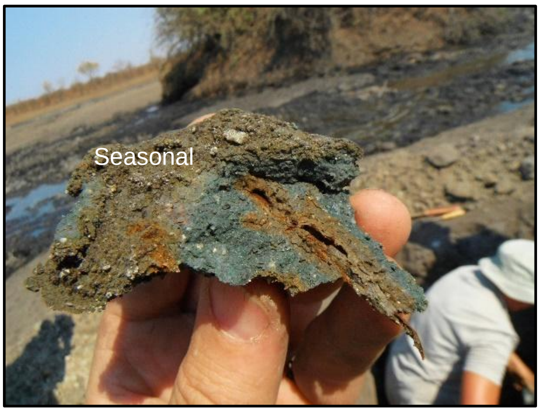
Figure 16 Laboratory analyses for the soils of Malahlapanga (CEC clay; coarse size fraction; and textures) for the seasonal, temporary and upland zones

5.2.6.3. Soil wetness

The soil wetness indicator accurately distinguished between the different zones. The presence of an organic horizon in the permanently saturated zone is indicative of the very wet conditions that were recorded over the study period. In the seasonal and temporary zones an E horizon was encountered, however, it is thought that this E is not formed via reducing processes but rather is an ash layer that formed during a peat fire. A gleyed horizon was still encountered within 0.5 m in both the seasonal and temporary zones (Table 8).

Table 8 Photographs of soil wetness indicators at Malahlapanga and corresponding descriptions

M Fuchs and E Micheli



CW Van Huyssteen

Permanent zone:

An Organic O horizon (0-1000mm) was identified containing a few (<2%) faint, medium (5-15 mm) sized mottles that were grey in colour (attributed to reduced iron oxides). The presence of an Organic O horizon has sufficient organic carbon to ensure an average content of at least 10% throughout a vertical distance of 200 mm. This can be confidently described as a permanently saturated zone.

Seasonal zone:

No signs of wetness were detected in the A1 horizon (0-50 mm), but a few (<2%), fine, distinct white mottles were observed in the A2 (50-300 mm) which was attributed to the reduction of iron-oxides. In the E horizon (300-450 mm) fine, prominent mottles became common (2-20%) and were yellow, brown and red in colour. In the G1 horizon (450-850 mm) there were common (2-20%) fine, prominent red mottles as well as a few (<2%) fine, faint yellow mottles attributed to oxidised iron-oxides. These morphological features are ascribed to a fluctuating water table and the presence of redox depletions so close to the soil surface (starting at 50 mm) is indicative of a seasonally saturated soil. The presence of an E horizon is thought to be an ash layer rather than a bleaching of the soil horizon through water movement. It is speculated that at some stage the peat domes may have burnt, creating this buried pale horizon which was often encountered adjacent to the peat mires.

CW Van Huyssteen

Temporary zone:

The following master horizons were identified A1 (0-100 mm), A2 (100-300 mm), E (300-400 mm), G1 (400-800 mm) and G2 (800-1100 mm). A few (<2%), fine (<5 mm), faint red oxidised iron oxide mottles were identified in the A1 horizon. A few, fine, faint red oxidised iron oxide mottles were identified in the A2 horizon with a few fine grey secondary mottles. A few, fine, distinct yellow oxidised iron oxides were present in the E horizon. Common (2-20%), medium (5-15 mm), prominent, grey and yellow reduced iron oxide mottles were noted in the G1 horizon with a few, fine, faint, red oxidised iron oxide mottles. The G2 horizon contained many (>20%), medium, prominent, red oxidised iron oxide with many, coarse (>15 mm), prominent, black magnetite secondary mottles. The presence of mottling in the A horizons suggests that the water table does fluctuate high within the profile. The E horizon present is also presumed to be an ash layer formed via burning peat which has now been buried.

M Fuchs and E Micheli

Upland zone:

At the **upland site** white mottles were noted in both the A and B horizons. From 0-400 mm few (<2%) fine (<5 mm) faint mottles were noted. From 400-600 mm common (2-20%) medium (5-15 mm) prominent mottles were observed. All these mottles were however, not attributed to a fluctuating water table or lime but rather the growth of fungi in the soil.

5.2.7. Discussion

The physical properties of Malahlapanga are the key drivers for the system, namely, the fractured Goudplaats Gneiss of the Soutpansberg Group. This geological phenomenon provides the permanent artesian waters that deliver the necessary hydrological conditions for the formation of peat and carries with it the salts which influence the mineralogy of the soils at Malahlapanga. During this study it was found that the water table only rose to within 0.5 m of the soil surface in the permanently saturated zone. However, it was not possible to determine how high the water levels rose during the 2013 floods. The soil chemistry of the wetland is mainly influenced by the accumulation of organic material. The Fe analyses at Malahlapanga, showed that there was reduction with respects to Fe due to the relative absence of Fe in the wetter zones. Due to the wetland being fed by groundwater and not runoff it meant that in the dry months animals concentrated around this water point which then had an influence on the surrounding vegetation. The seasonal zone was largely barren due to trampling from animals and lacked the vegetation indicators that otherwise would have been expected. This unique system is driven by groundwater and any restoration attempts should therefore address the flow of water at the outlet and be monitored over time. Currently it is thought that the high elephant activity is the cause of the peat degradation, but to definitively prove this one must have a clear understanding of the hydrological nature of the system.

5.3. Characterisation of Nshawu

5.3.1. Climate

The Nshawu catchment received very little rain during the course of the study, with the exception of the January 2013 Floods where the Shingwedzi rainfall station received 450 mm (Figure 17).

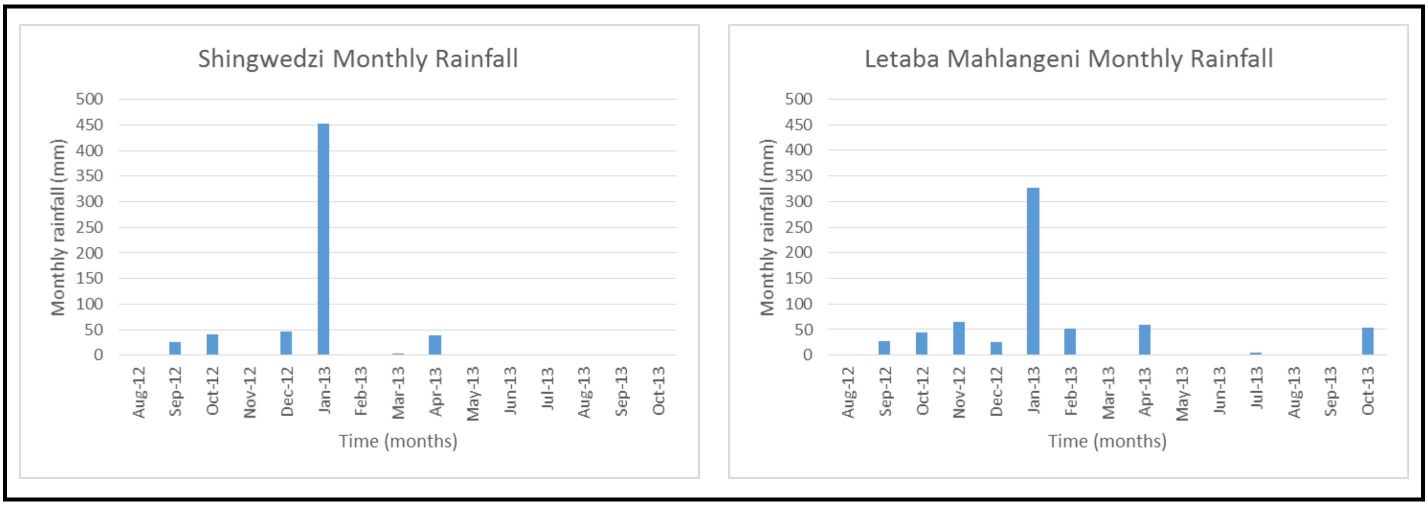


Figure 17 Monthly rainfall values for the closest rainfall stations to Nshawu

5.3.2. Hydrology

The permanently saturated zone had a water table that rose within 0.5 m during the length of the study period. The seasonally saturated zone came within 0.5 m only after the January 2013 floods, and the missing data for the month of January is attributed to the floods. The temporary zone rose within 0.5 m a month after the flooding occurred. While the zone boundaries were determined based on vegetation, there was a strong agreement in terms of the length of saturation that was recorded over the study period and the vegetation indicators noted.

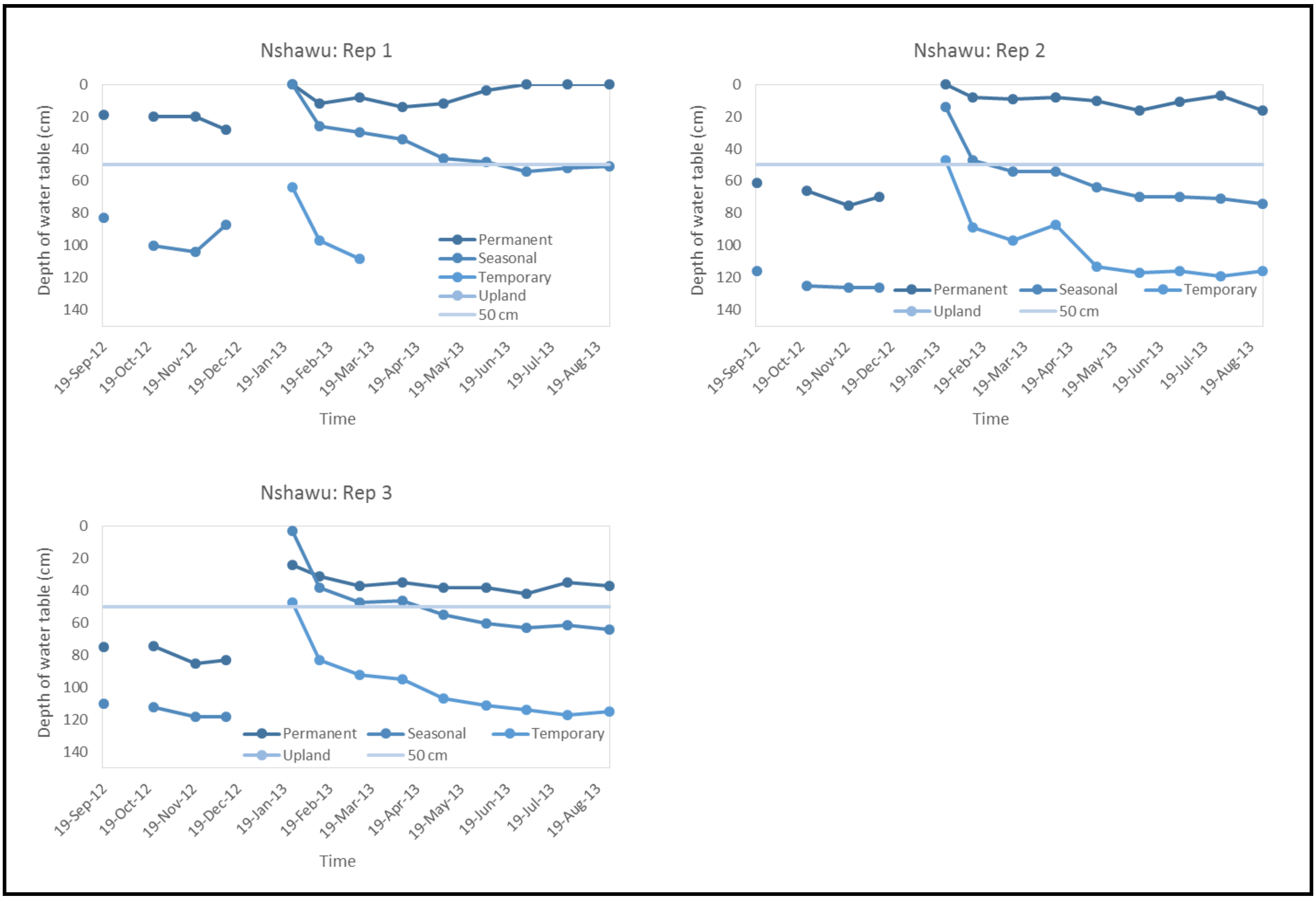


Figure 18 The hydrology of each wetness zone at Nshawu over the study period

5.3.3. Soil parent material

The parent material for the permanent, seasonal and temporary zones is of a single origin, namely alluvium derived from basalt, a basic igneous rock. There is advanced physical weathering and strong chemical weathering and the soil has become calcified. The upland parent material is the same as the other zones, however, there is moderate chemical and physical weathering, and the material has been ferruginised and calcified.

5.3.4. Topography

Wetland conditions can be expected at the permanent, seasonal and temporary zones according to the terrain unit indicator (Table 9) defined by DWAF (2005).

Table 9 Topography summary of Nshawu

Assumed Wetness zone	Terrain unit indicator	Slope %	Type	Aspect
Permanent	5-Valley bottom	1	Concave	East-facing
Seasonal	5-Valley bottom	1	Concave	East-facing
Temporary	4L-Lower footslope	3	Straight	East-facing
Upland	3U-Upper midslope	3	Convex	East-facing

5.3.5. Vegetation

The vegetation indicators were much clearer for Nshawu than Malahlapanga and there were more species recorded (Table 10). This could be attributed to the size of the wetland (less pressure from animals and hence less trampling) as well as the more fertile parent material (Basalt having more bases than Gneiss). There were two clear vegetation indicator species that were present in the permanent, seasonal and temporary zones namely, *Sporobolus pyramidalis* and *Cyperus sexangularis* which are both facultative positive wetland species. Each zone also had wetland species which were unique to the specific zone. In the permanent zone, *Leptochloa fusca* was exclusively found, while in the seasonal zone the alien species of **Juncus effusus* was soley found, and in the temporary zone *cf Sporobolus ioclados* and *Cyperus obtusiflorus* were unique. The dryland zone consisted only of dryland species with the exception of *Abultilon rehmanni* an opportunistic species. The zones showed a gradual change in species composition and there was no disturbance in the vegetation which aided in accurate vegetation delineation (Table 11). The photographs in Table 11 are repeated from Figure 4 for convenience.

Table 10 Species composition of Nshawu

Botanical name	Wetland / Dryland species	Wetness Zone											
		Permanent			Seasonal			Temporary			Upland		
		1	2	3	1	2	3	1	2	3	1	2	3
Woody species (p=present, d=dominant)													
Acacia nigrescens	Dryland							p					
Albizia forbesii	Dryland											p	P
Colophosperum mopane	Dryland										d	p	p
Dichrostachys cinerea	Dryland										p	p	p
Euclea divinorum	Dryland										p		
Gymnosporia senegalensis	Dryland										p		
Philenoptera violacea	Dryland										d		
Grass species (p=present, d=dominant)													
Andropogon gayanus	Opportunistic / Dryland					p		p					
Cenchrus ciliaris	Dryland							p			d	p	
Chloris gayana	Dryland		p	p	d	d	d		p				
Cynodon dactylon	Dryland				d			p					
Eragrostis capensis	Dryland							p					
Enneapgon cenchroides	Dryland							p			p	p	p
Leptochloa fusca	Obligate	p											
Panicum duestum	Dryland												p
cf Panicum infestum	Facultative negative		p	p	p								
Panicum maximum	Dryland							p			p		p
Phragmites mauritianus	Obligate	p	p	p	p		p						
Shmidtia pappophoroides	Dryland										p	p	
cf Sporobolus ioclados	Facultative negative							p	p	d			
Sporobolus pyramidalis	Facultative positive	p	p				d	d	d	d			
Urochloa mosambicensis	Dryland										p	p	p
Tragus berteronias	Dryland										p		p
Forb species (p=present, d=dominant)													
Abutilon rehmanni	Opportunistic / Dryland										p		
Acanthaceae	Dryland												p
Asparagus sp.	Dryland											p	
cf Boscia foetida	Dryland										p		
Heliotropium sp.	Dryland											p	p
Hermbstaedtia odorata	Dryland							p			p	p	p
Hybiscus micranthus	Dryland										p		
cf Neuracanthus africanus	Dryland							p			p		
Pechuel-Loeschea leubnitziae	Dryland							p				p	p
cf Sesbania sesban	Opportunistic / Dryland		p							p			
Tragia durbanensis	Dryland											p	
Sedge and rush species (p=present, d=dominant)													
Cyperus laevigatus	Obligate	d			d	p							
Cyperus obtusiflorus	Opportunistic / Dryland							p					
Cyperus sexangularis	Facultative positive	d	d	p	d	p	p		p	p			
**Juncus effusus*	Obligate				p	p							

** Alien invasive species*

Table 11 Photographs of each zone showing differences in vegetation and corresponding descriptions at Nshawu

Permanent zone:

The following obligate species were present in the permanent zones: *Leptochloa fusca, Phragmites mauritianus and Cyperus laevigatus.* The facultative positive species of *Sporobolus pyramidalis* and *Cyperus sexangularis* were present. *Cf Panicum infestum* (facultative negative) was recorded in two repetitions and the opportunistic species *cf Sesbania sesban* was present at one repetition. It is clear to see the standing water and the greener vegetation.

Seasonal zone:

The obligate species present in this zone were: *Phragmites mauritianus, Cyperus laevigatas* and **Juncus effusus* (alien). The facultative positive species *Sporobolus pyramidalis* and *Cyperus sexangularis* were recorded. The opportunistic *Andropogon gayanus* and the facultative negative *cf Panicum infestum* were only present at one repetition each.

Temporary zone:

The facultative positive species *Sporobolus pyramidalis* (dominant) and *Cyperus sexangularis* were recorded. *Cf Sporobolus ioclados* (facultative negative) was present at two of the repetitions and dominant at one. The following opportunistic species were noted: *Andropogon gayanus, cf Sesbania sesban*, and *Cyperus obtusiflorus.* It is clear to see from the photograph that there is a distinct change in the colour of the vegetation as well as the species composition.

Upland zone:

Only dryland species were recorded in this zone with the exception of one opportunistic species: *Abutilon rehmanni.* From the photograph it is clear to see that there are small dryland woody species which are not present in the temporary, seasonal or permanent zones.

5.3.6. Soils

5.3.6.1. Soil form

The soil form indicator accurately described the hydrological conditions occurring at the wetland. The permanent, seasonal and temporary zones all displayed soil forms which are identified in the DWAF (2005) guidelines as being wetland soils (Table 12). The soils occurring in the temporary zone and in the terrestrial zone have an abundance of calcium concretions, which can be observed on the surface of the soil, making augering a challenge. The seasonal and permanent zones lack these concretions as they have well developed gleyed characteristics typical of the Katspruit soil form (Soil Classification Working Group, 1991) or a Gleysol (IUSS Working Group WRB, 2014).

Table 12 Soil classifications related to the soil form indicator (DWAF, 2005) for Nshawu

Wetness zone	South African Soil Classification	World Reference Base Classification	DWAF 2005 Soil form indicator
Permanent	**Katspruit 2000** (Orthic A / G horizon. Calcareous G horizon)	Calcic Gleysol (Eutric, Vertic)	**Yes**, Katspruit soils occur in the permanent zone
Seasonal	**Katspruit 2000** (Orthic A / G horizon. Calcareous G horizon)	Calcic Mollic Gleysol (Eutric, Vertic)	**Yes**, Katspruit soils usually occur in the permanent zone
Temporary	**Steendal 2000** (Melanic A / Soft Carbonate B)	Bathypetric Endogleyic Hypercalcic Calcisol (Endoruptic)	**No**
Upland	**Milkwood 2000** (Melanic A / Hard rock)	Eutric, Skeletic Leptosol (Arenic, Ochric)	**No**

5.3.6.2. Laboratory results

The pH water ranged from 7.88-10.27, with the upland zone having the lowest pH. The upland and temporary zones had an increase in pH with depth while the seasonal and permanent zones had a decrease in pH. The decrease in pH could be attributed to the influence of reduction occurring within these zones. The pH KCl ranged from 7.73-9.57 and the permanent, seasonal and temporary zones were slightly lower than the H_2O values while the upland zone remained similar suggesting less exchangeable acidity. The basic pH can be attributed to the basalt parent material which yielded large amounts of sodium and calcium carbonate (Figure 19 A and B).

The coarse particle size fraction at Nshawu was much higher than the other two wetlands because of the carbonate nodules associated with the basic parent material. The temporary zone had the highest content of carbonate concretions falling just under 75% (Figure 21 B).

The average organic carbon percentage fell below 3% for all four of the sites and the temporary zone had the lowest organic carbon with a minimum value of 0.04%. The upland zone had the highest organic carbon content (4.13%) of all the zones (Figure 19 C).

The CEC was highly variable, the values initially decreased but then increased with depth. Values ranged from 13.37-84.78 $cmol_c$/kg. It was speculated that the process of ferrolysis could occur at the seasonal zone at Nshawu, however the data did not show extremely low CEC values when comparing them to the other two wetlands (Figure 19 D).

In the permanent and upland zones there is an increase in electrical resistance with depth, but in the temporary zone there is a decrease in electrical resistance with depth. The upland zone is thought to have the least amount of salts while the temporary zone, with a low resistance, is thought to be high in salts and carbonates. The electrical resistance values ranged from 68-1140 ohms (Figure 19 E).

The upland zone had no exchangeable sodium, with a minimum value of 0.47%. The temporary zone had the highest exchangeable sodium percentage which increased dramatically with depth while the exchangeable sodium percentage of the permanent and seasonal zones decreased with depth (Figure 19 F).

The wetter the soil, the more nitrogen is expected in the soil. There was a link between organic carbon and nitrogen in all the zones except in the upland zone where carbon content far exceeded the amount of nitrogen expected. The nitrogen values all decreased with depth. The minimum value recorded was 70 mg/kg and the highest was 15 150 mg/kg (Figure 20 A).

The upland zone has distinctly more Fe than the other three zones which decreases with depth. The permanent, seasonal and temporary zones have <2600 mg/kg while the upland zone has >2600 mg/kg. This suggests that the Fe has been reduced and removal has occurred within the wetter zones (Figure 20 C).

The upland and temporary zones had the most amount of Mn, suggesting that Mn has been reduced in the permanent and seasonal zones. Mn values ranged from 16.25-556.25 mg/kg (Figure 20 D).

In general the Nshawu had less soluble cations than the other two wetlands but had more exchangeable cations overall. This could be attributed to the basic parent material and lack of soluble salts in the water (Figure 20 E, F).

The averaged CEC clay showed that the process of ferrolysis could be occurring. Values ranged from 45.5-161.7 $cmol_c$/kg of clay. In the permanent and seasonal zones there was a marked change in CEC clay from 500 mm. This can be attributed to a change in clay mineralogy from 2:1 clays to 1:1 clays as described by (Brinkman, 1970; Brinkman 1977). Furthermore when consulting the texture data, there was an increase in sand and decrease in clay within the seasonal zone, suggesting that there is a destruction of clays occurring and secondary accumulation of quartz. However, in order to definitively prove that the ferrolysis is occurring at

Nshawu, the influence of organic matter needs to be subtracted from the CEC clay values (Figure 21 A).

The permanent zone had <30% sand and had an increase of clay with depth, the clay content ranged from 40-65%. In the seasonal zone, there was a decrease and then increase in sand content while the clay content increased and then decreased. The temporary zone had significantly more sand (40%) than the permanent and seasonal zones, with less clay and more silt. The upland zone also had higher sand and clay contents but less silt (Figure 21 C, D, E, and F).

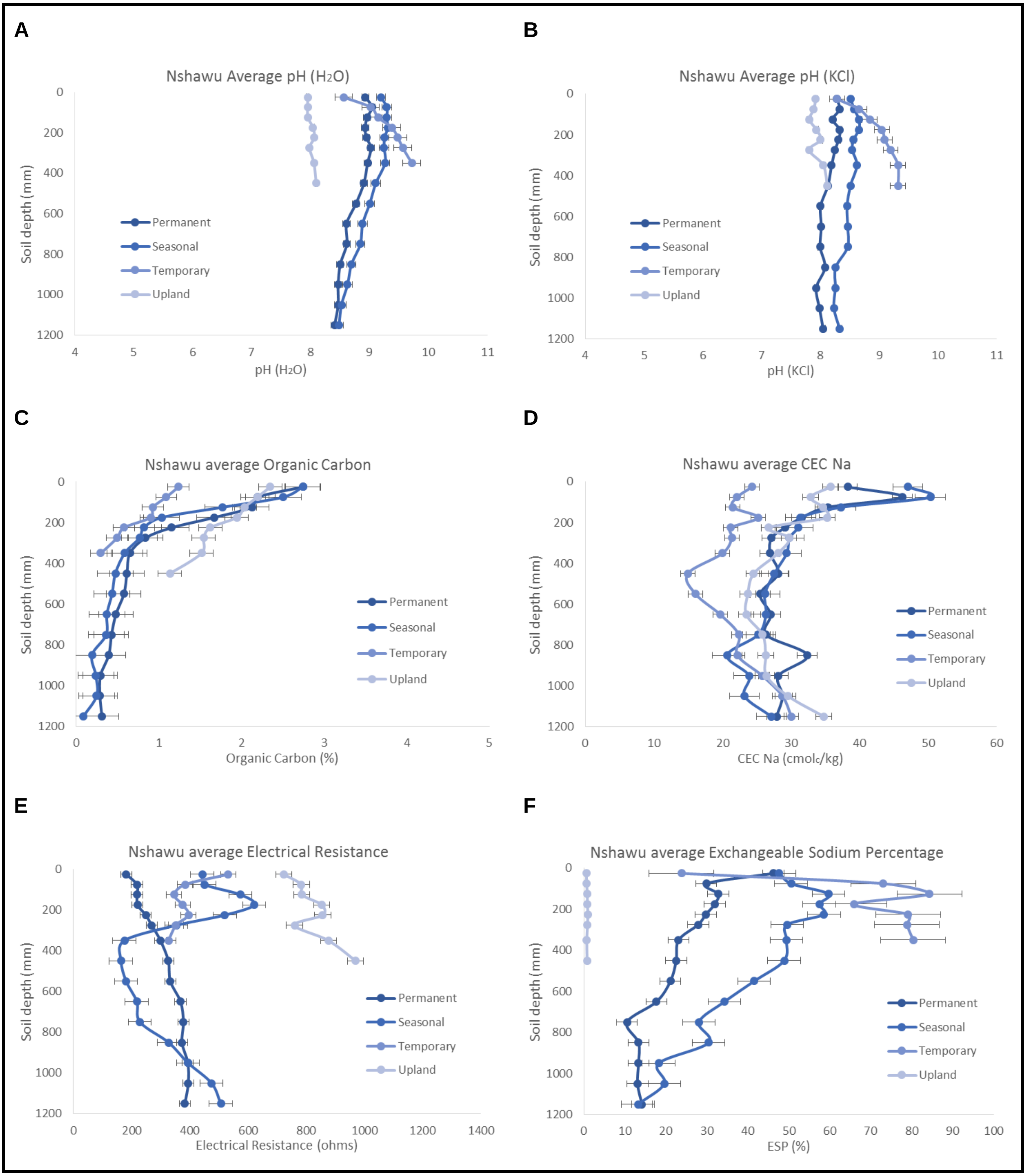


Figure 19 Laboratory analyses for the soils of Nshawu (pH measured in H_2O and KCl, organic carbon, CEC Na, electrical resistance and exchangeable sodium percentage)

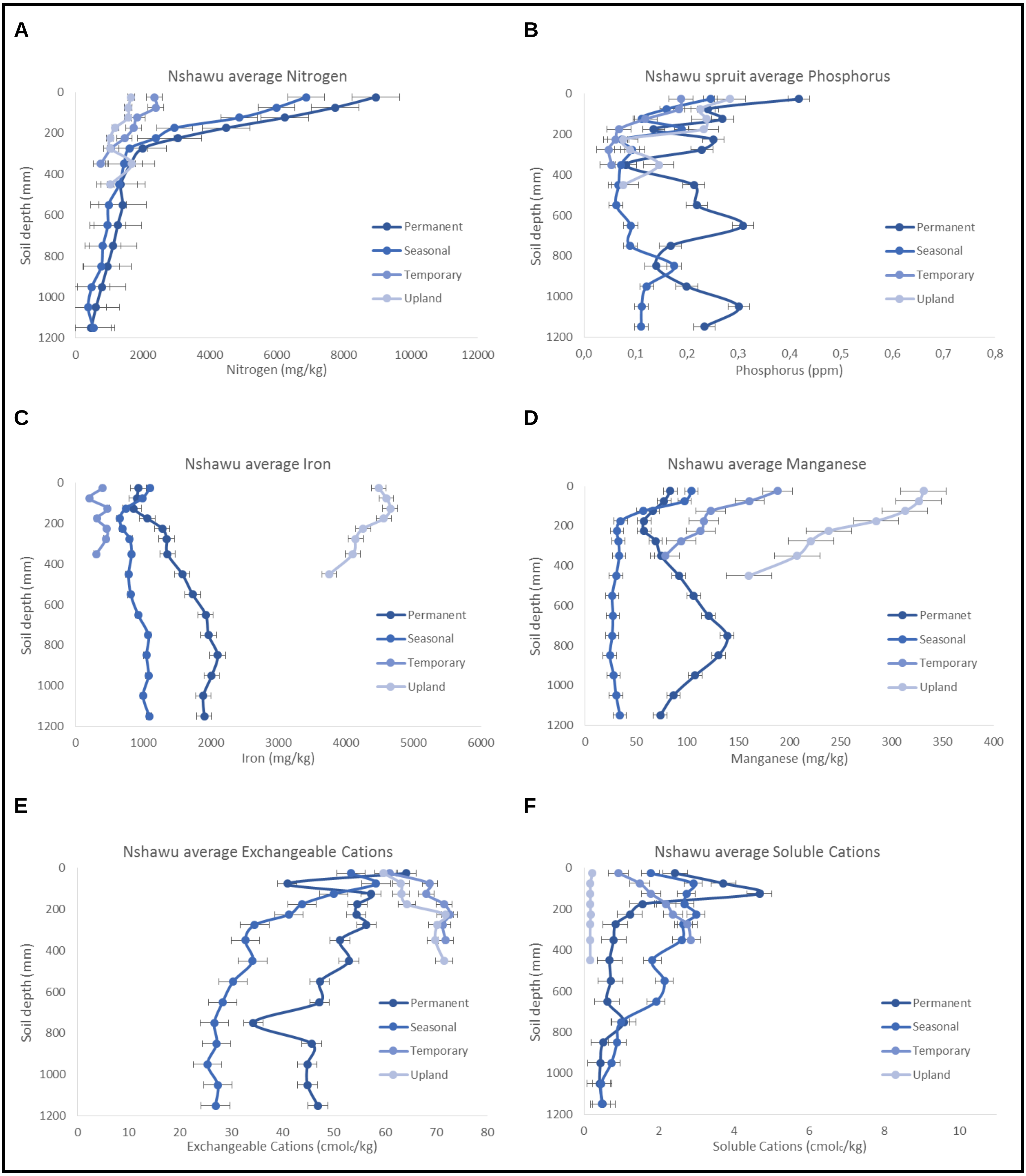


Figure 20 Laboratory analyses for the soils of Nshawu (nitrogen, phosphorus, iron, manganese, exchangeable cations and soluble cations)

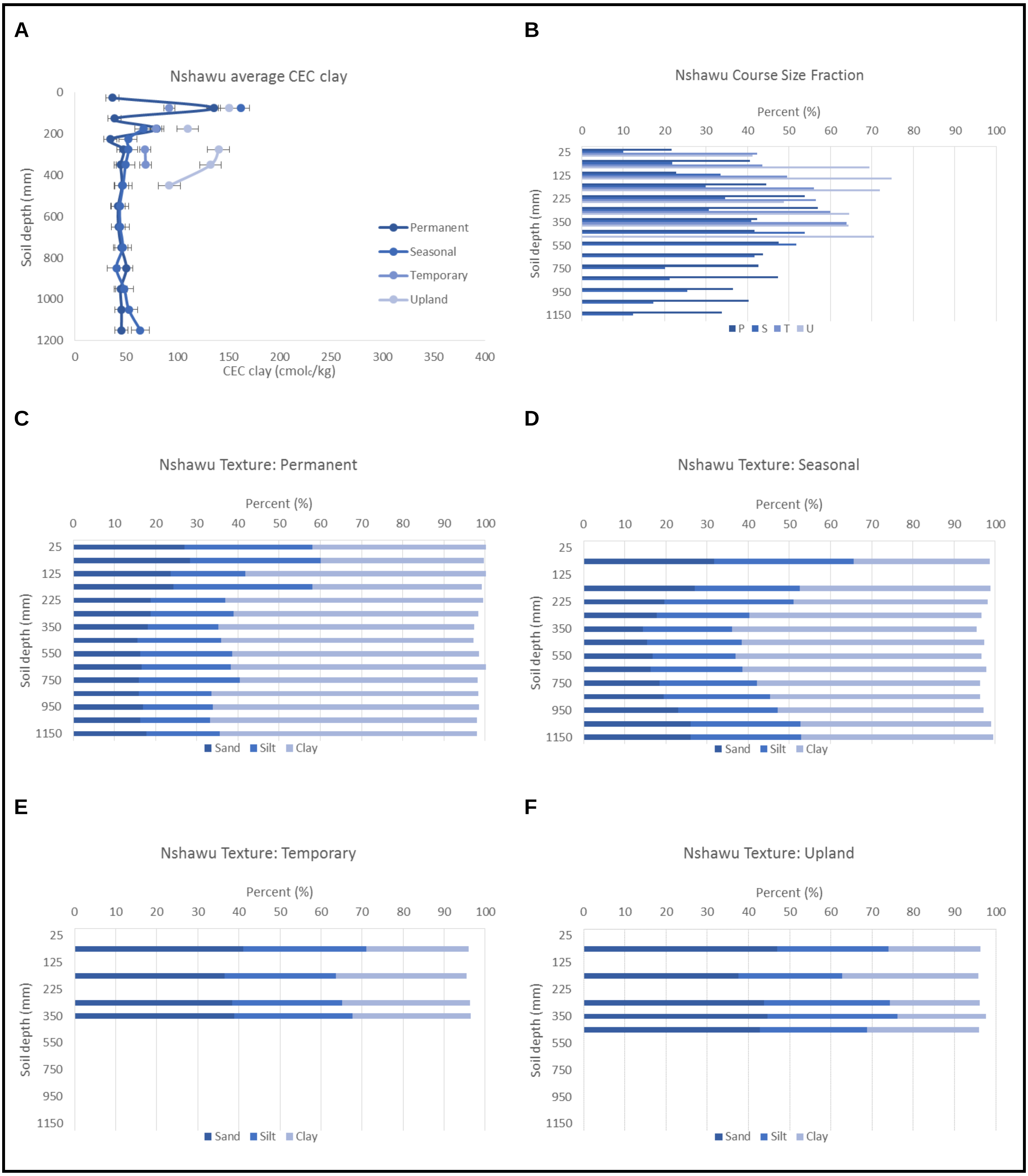


Figure 21 Laboratory analyses for the soils of Nshawu (CEC clay; coarse size fraction; and textures) for the permanent, seasonal, temporary and upland zones

5.3.6.3. Soil wetness

The soil wetness indicator was met for the permanent and seasonal zones, however the temporary zone did not display signs of wetness within the top 0.5 m of the soil profile, only deeper. The temporary zone did however, display a distinct change in morphology with the occurrence of calcium carbonate nodules (Table 13).

Table 13 Photographs of soil wetness indicators at Nshawu and corresponding descriptions

CW Van Huyssteen

Permanent zone:

The following horizons were identified: A1 (0-200 mm), G1 (200-1100 mm) and G2 (1100-1400 mm). Common (2-20%), fine (<5%), distinct, white lime mottles were noted in the A and G1 horizons. Few (<2%), fine, faint red and yellow oxidised iron oxide secondary mottles were noted in the G1. Common, medium (5-15 mm), distinct, blue and green reduced and oxidised iron oxide was noted in the G2 with few, fine, faint, white lime secondary mottles. The G horizons are indicative of a permanently saturated zone.

Seasonal zone:

The following horizons were identified: A (0-250 mm), B (250-600 mm) and C (600-1200 mm). Common (2-20 mm), fine (<5 mm), prominent, white lime mottles were noted in the B horizon. Common, medium, faint, black and brown mottles were noted in the G horizon.

M Fuchs and E Micheli

Temporary zone:

Four horizons were identified: the A1 (0-150 mm), the C1 (150-400 mm), C2 (400-1100 mm) and the C3 (1100-1400 mm). Common (2-20%), coarse (>15 mm), distinct yellow, olive and brown mottles were noted in the C3 attributed to oxidised and reduced iron oxides as well as manganese and magnetite. Carbonate concretions dominated the profile and this resulted in a high percentage of coarse sized fragments.

Upland zone:

Three horizons were identified, namely: A (0-100 mm), B (100-240 mm), C (240-500 mm). Many (>20%), medium (5-15 mm), prominent, white lime mottles were noted throughout the profile.

5.3.7. Discussion

The basic parent material at Nshawu determines the mineralogy and chemistry of the wetland. The basalt parent material is high in calcium and combined with the seasonal hydrological fluctuations, produces an abundance of calcium carbonate nodules. It was found that the wetland zones which were mapped based on vegetation were in strong agreement with the hydrological data. The permanent and seasonal zones were saturated within 0.5 m and after the January 2013 floods the water table rose within 0.5 m of the temporarily saturated zone. There was a lag in the water table after the floods suggesting that the wetland is fed by infiltrated water and not just surface runoff. The high pH recorded is attributed to the basic nature of the parent material and carbonates. In terms of the chemistry of the wetland, there is some evidence to suggest that the process of ferrolysis could be occurring, however, this would need further evidence to confirm and the organic matter would have to be corrected for. The data suggests that the conditions are favourable for both the reduction of Mn and Fe and that they are being depleted in the wetter zones of the wetland. The vegetation at Nshawu was much more diverse than at the other two wetlands. A possible reason for this is the higher nutrient status and fertility, and that the wetland is under much less pressure from animals, in comparison to Malahlapanga. Further, because of the sheer size of the wetland, the animal concentration and its resultant utilization therefore does not result in the degradation observed at Malahlapanga.

5.4. Characterisation of the Tshutshi spruit

5.4.1. Climate

The Tshutshi spruit received the least amount of rain during the January 2013 Floods, however, it can still be noted in Figure 22. The rain mainly fell during the summer months.

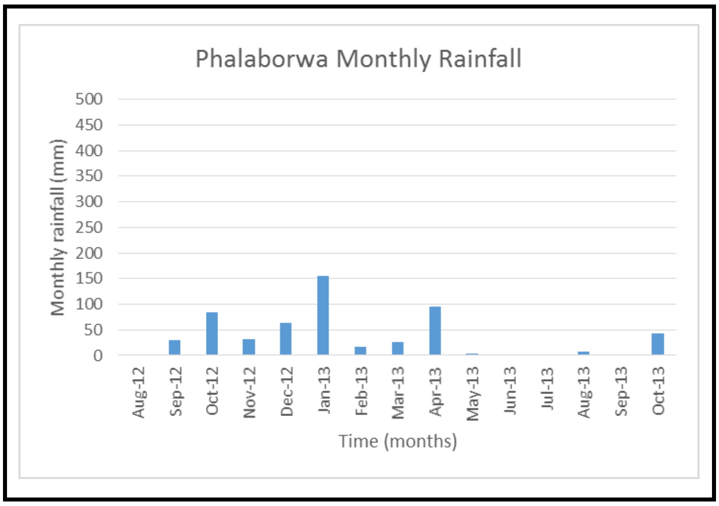


Figure 22 The monthly rainfall for the closest rainfall station to the Tshutshi spruit

5.4.2. Hydrology

For all the wetness zones, the water table did not rise within the 0.5 m depth except for the month of January 2013 where the permanent, seasonal and temporary zones rose substantially due to the floods (Table 18). This can be attributed to the nature or type of system being a channelled valley bottom wetland. The water table was typically around a depth of 800 mm for the permanent and seasonal zones for all three repetitions and it fluctuated slightly from month to month. It could be speculated that because these zones were sandy being comprised of stratified alluvial sediment that the response to a hydrological event would be rapid while the drop in water table after the event would also be relatively quick due to the large pore size distribution of these sandy soils.

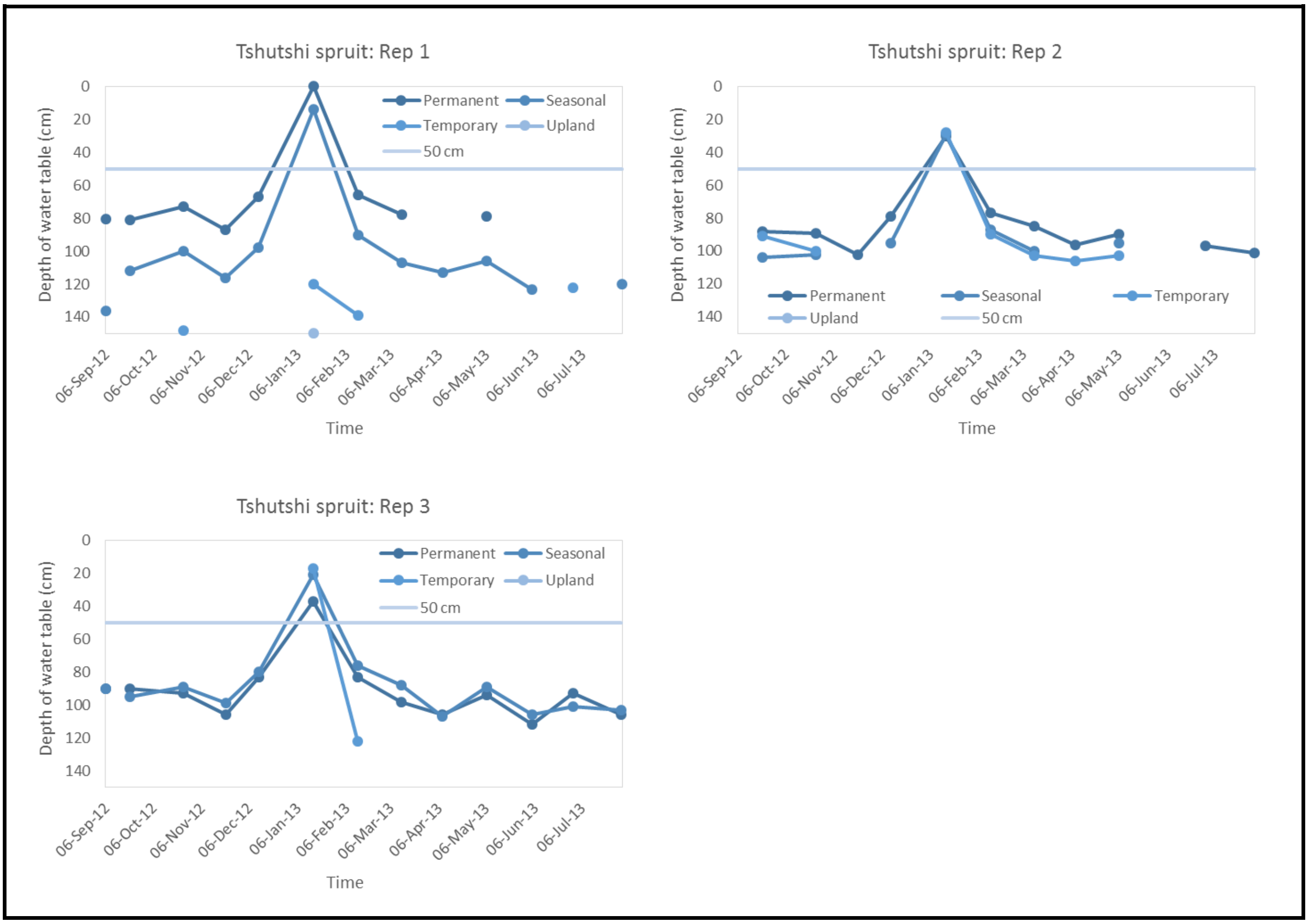


Figure 23 The hydrology of each wetness zone at the Tshutshi spruit over the study period

5.4.3. Soil parent material

The material in the permanent zone is of binary origin being made of alluvium as well as unconsolidated mineral sediments. This material is derived from granite, an igneous coarse or intrusive acidic rock, or gneiss which has undergone advanced physical weathering. The soils of the seasonal zone are of a similar origin to those in the permanent zone, but have undergone advanced physical and strong chemical weathering and are ferruginised. The soils of the temporary zone are also of a similar origin with advanced physical weathering and calcification. The upland soils are also of a binary nature and there is advanced physical and strong chemical weathering with calcification.

5.4.4. Topography

It would be expected to find wetland conditions at the permanent, seasonal and temporary zones. While DWAF (2005) only defines position 5 as being suitable for the occurrence of wetlands the 4L or lower foot slope was included due to the manner in which the micro-topography was described in the field.

Table 14 Topography summary of the Tshutshi spruit

Assumed Wetness zone	Terrain unit indicator	Slope %	Type	Aspect
Permanent	5 - Valley bottom	0	Straight	South-facing
Seasonal	4L - Lower footslope	1	Straight	South-facing
Temporary	4L/U - Middle footslope	1	Straight	South-facing
Upland	4U - Upper footslope	1-2	Straight	South-facing

5.4.5. Vegetation

The only wetland indicator species (Table 15; Table 16) that was common between the temporary, seasonal and permanent zones was the alien **Tagetes minuta*. Photographs from Table 16 are repeated from Figure 5 for convenience. The species unique to the temporary zone were: *Hibicus cannabinus*, **Schkuhria pinnata* (alien) and *Solanum sp*. The permanent zone was characterised by the presence of *Cyperus sexangularis* and *Typha capensis.* Numerous alien species were recorded. The Tshutshi spruit had the greatest number of alien species when compared to the other two wetlands.

Table 15 Species composition of the Tshutshi spruit

Botanical name	Wetland / Dryland species	Wetness Zone											
		Permanent			Seasonal			Temporary			Upland		
		1	2	3	1	2	3	1	2	3	1	2	3
Woody species (p=present, d=dominant)													
Colophosperum mopane	Dryland				p	p		d	d		d	d	p
Combretum hereroense	Dryland	p											
Euclea divinorum	Dryland			p			d		p				
Gymnosporia senegalensis	Dryland	p	p	p		d	p						
Philenoptera violacea	Dryland					d							
Grass species (p=present, d=dominant)													
Aristida adscensionis	Dryland							p	p		p		
Aristida congesta	Dryland												p
Chloris virgata	Opportunistic / Dryland							p	p		p	p	
Cynodon dactylon	Dryland	p	d	d	p		d			d			
Cynodon nlemfuensis	Opportunistic / Dryland	d	d	d			p						
Eragrostis rigidor	Dryland							p					
Panicum maximum	Dryland	d	p	d	p	d	d	p	p	p	p		
Sporobolus ioclados	Facultative negative				d			d	d		d	d	d
Tragus berteronianus	Dryland												p
Urochloa mosambicensis	Dryland	p	p		p	p	p		p				
Forb species (p=present, d=dominant)													
**Bidens bipinnata*	Opportunistic / Dryland							p	d		p		
Commelina sp.	Opportunistic / Dryland					p				p		p	
Hibiscus cannabinus	Opportunistic / Dryland									p			
Ipomoea sp.	Dryland					p				p			
Justica flava	Dryland				p								d
**Schkuhria pinnata*	Opportunistic / Dryland							p					
**Sesbania bispinosa*	Opportunistic/ Dryland	p											
Sesuvium hydaspicum	Opportunistic/ Dryland								p		d	p	
Sida cordifolia	Opportunistic / Dryland	p											
Solanum sp.	Opportunistic / Dryland									p			
**Tagetes minuta*	Opportunistic / Dryland	p		p		p				d			
Sedge and Rush species (p=present, d=dominant)													
Cyperus sexangularis	Facultative positive	p	p										
Typha capensis	Obligate	p	p	p									

** Alien invasive species*

Table 16 Photographs of each zone showing differences in vegetation and corresponding descriptions

Permanent zone:

The only obligate species recorded was *Typha capensis* which was present at all three repetitions. The facultative positive *Cyperus sexangularis* was present at two repetitions. The following opportunistic species were recorded: *Cynodon nlemfuensis, *Sesbania bispinosa* (alien), *Sida cordifolia,* and **Tages minuta* (alien).

Seasonal zone:

Only one facultative negative species was recorded, namely, *Sporobolus ioclados*. Three opportunistic species were noted: *Cynodon nlemfuensis, Commelina sp., *Tagetes minuta* (alien).

Temporary zone:

Only one facultative negative species was noted: Sporobolus ioclados. Numerous opportunistic species were recorded: *Chloris virgate, *Bidens bipinnata* (alien), *Commelina sp., Hibiscus cannabinus, *Schkuhria pinnata* (alien), *Sesuvium hydaspicum, Solanum sp., *Tagetes minuta* (alien).

Upland zone:

Sporobolus ioclados (facultative negative) was recorded. The following opportunistic species were noted: *Chloris virgate, *Bidens bipinnata* (alien), *Commelina sp.,* and *Sesuvium hydaspicum.*

5.4.6. Soils

5.4.6.1. Soil form

The soil form indicator was misleading for the Tshutshi spruit as the seasonal and temporary zones did not meet the DWAF (2005) criteria, while the upland soil, which is presumed to be the driest, met the criteria of a wetland soil (Table 17). There was agreement in the permanent zone with the expected hydrology and soil form observed. The soils at the study site (mainly in the upland and temporary zones) are sodic showing strong coarse columnar structure near the surface of the soil profile. The seasonally saturated and permanently saturated soils have alluvial stratification due to the close proximity to the river.

Table 17 Soil classification related to the soil form indicator (DWAF, 2005) for the Tshutshi spruit

Wetness zone	South African Soil Classification	World Reference Base Classification	DWAF 2005 Soil form indicator
Permanent	**Dundee 1220** (Orthic A / Stratified alluvium, Non-red stratified alluvium, signs of wetness present, calcareous within 1500 mm of the soil surface)	Epigleyic Fluvisol (Eutric)	**Yes**, signs of wetness incorporated at family level, usually found in seasonal or temporary zone
Seasonal	**Sterkspruit 2100** (Orthic A / Prismacutanic B, A horizon bleached, non-red B horizon)	Epigleic Fluvisol (Sodic)	**No**, the Sterkspruit is not a wetland soil
Temporary	**Sterkspruit 2100** ((Orthic A / Prismacutanic B, A horizon bleached, non-red B horizon)	Calcic Endogleyic Solonetz (Novic, Endofluvic)	**No**, the Sterkspruit is not a wetland soil
Upland	**Brandvlei 2000** (Orthic A / Soft carbonate horizon, signs of wetness in carbonate horizon)	Calcic Endogleyic Fluvisol (Sodic, Eutric)	**Yes**, signs of wetness at family level, usually found at seasonal or temporary zones

5.4.6.2. Laboratory results

pH H_2O ranged from 7.13 to 11.36 while pH KCl ranged from 6.42 to 10.41. The wetter zones had values closer to neutrality than the drier zones. These soils are highly basic due to the fact the area is a sodic side with high exchangeable sodium content (Figure 24 A and B).

There was an increase in the coarse size fraction with depth. The upland zone had the highest component of coarse fragments. All the zones had <40% coarse material (Figure 26B).

The organic carbon contents decreased with depth for all of the four wetness zones. The seasonal zone had the highest organic carbon content with the upland zone having the lowest. Organic carbon values ranged from 0.05-5.48% (Figure 24 C).

The CEC Na at the permanent zone was highly variable and the CEC was high within the surface of the profile. The upland and temporary zones had higher CEC values than the permanent and seasonal zones in general (Figure 24 D).

The electrical resistance values clearly showed that the drier soils had lower electrical resistance values and hence there were more salts in the drier zones. The salt content of the soils also increased with soil depth. The electrical resistance values ranged from 29-2010 ohms (Figure 24 E).

The exchangeable sodium percentage was found to be above 15% for all of the zones with the exception of the permanently saturated zone. This coupled with the pH values exceeding 8.5, confirms the sodic nature of this system (Figure 24).

The wetter zones had more nitrogen than the drier zones and there was a good correlation between nitrogen and organic carbon. The nitrogen decreased with depth and ranged from 3-6410 mg/kg (Figure 25 A).

Phosphorus values were erratic but there was a general trend whereby there was more phosphorus in the wetter zones than the drier zones. Phosphorus values ranged from 0.03-1.77ppm (Figure 25 B).

The Fe content at the Tshutshui spruit was fairly low when compared to the other two wetlands. The permanent zone at the Tshutshi had the most Fe followed by the upland and seasonal zones, with the upland zone having the least Fe. Values ranged from 655.2-4682.6 mg/kg. This suggests that Fe is not being reduced and removed in the wetter zones (Figure 25 C).

There was generally more Mn in the seasonal and permanent zones than the upland and temporary zones. This suggests that perhaps the wetland is not wet enough to reduce and leach Mn or that there was more reduction occurring in the “drier” sodic zones that experienced puddling from the dispersion of clays (Figure 25 D).

The upland and temporary zones had the most soluble cations compared to the seasonal and permanent zone. The temporary zone had the most exchangeable cations compared to the other zones (Figure 25 E).

The CEC clay values were highly variable and showed that there were predominantly 2:1 clays present (Figure 26 A).

The soils at the Tshutshi spruit were generally very sandy. The permanent zone contained >70% sand. It was found that the clay content increased as one moved further upslope. This can be attributed to the sand that was deposited on the banks of the Tshutshi, which was also noted in the soil morphology (depositional stratification; Figure 26 C, D, E, and F).

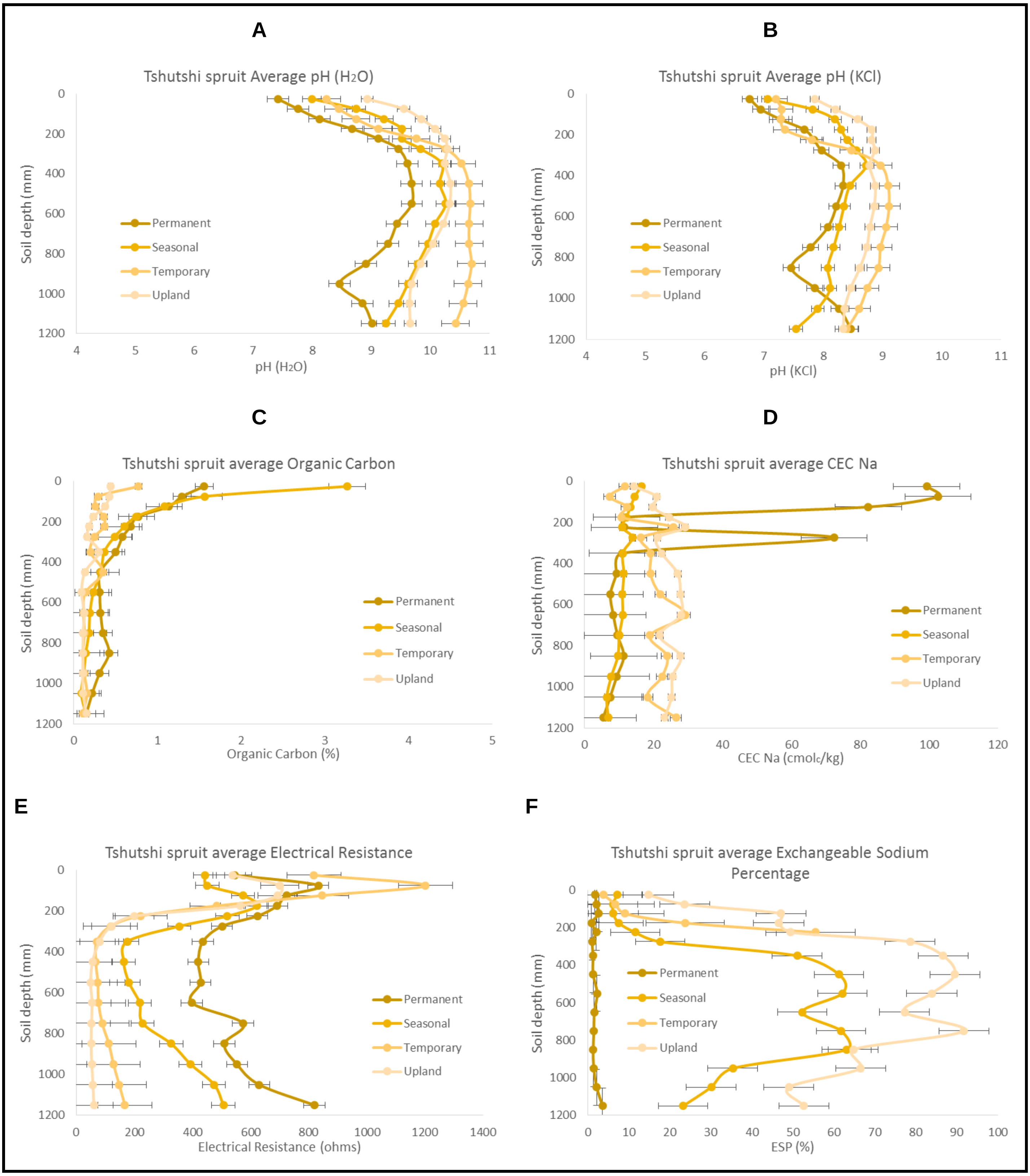


Figure 24 Laboratory analyses for the soils of the Tshutshi spruit (pH measured in H_2O and KCl, organic carbon, CEC Na, electrical resistance and exchangeable sodium percentage)

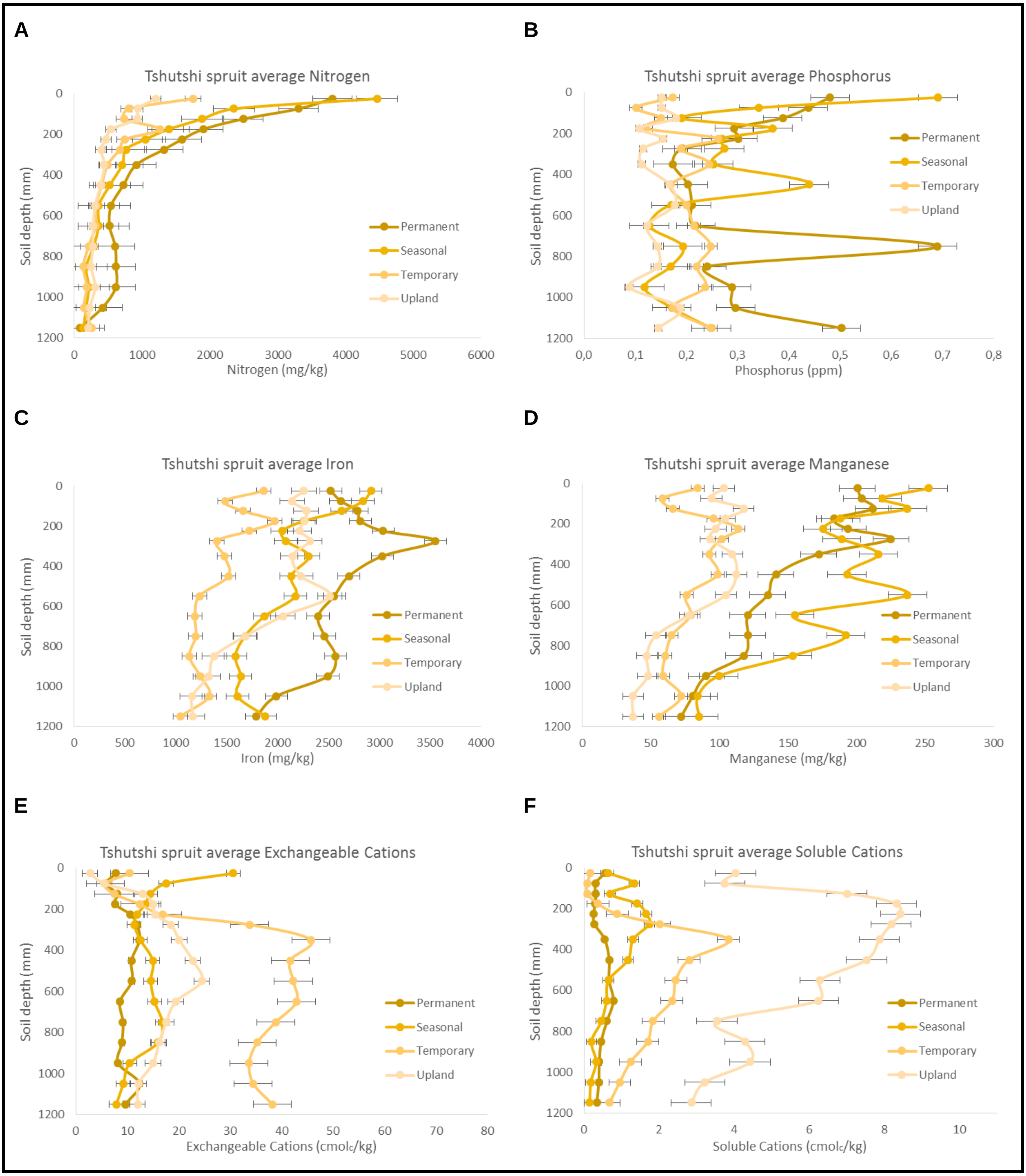


Figure 25 Laboratory results for the soils of the Tshutshi spruit (nitrogen, phosphorus, iron, manganese, exchangeable cations and soluble cations)

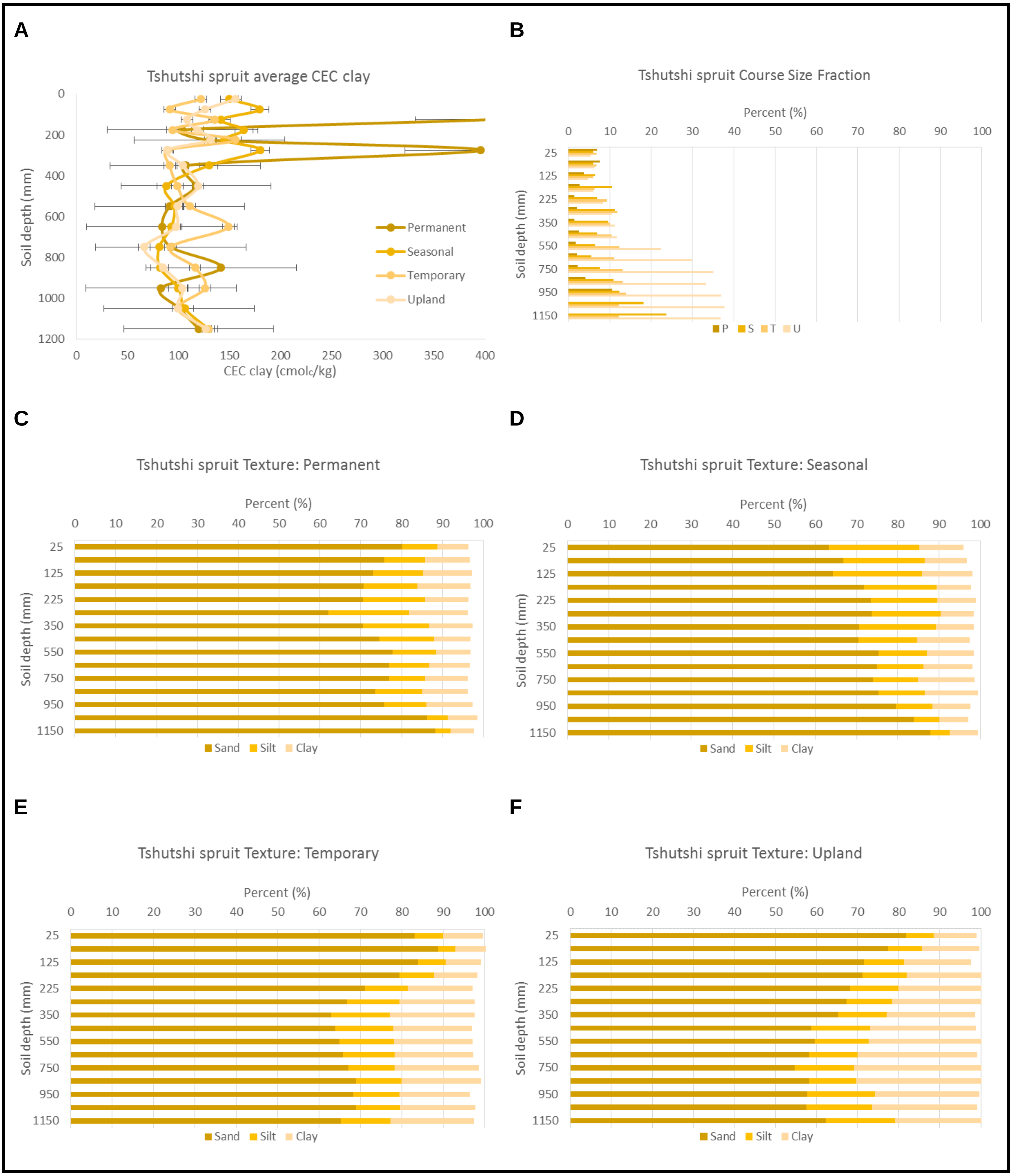


Figure 26 Laboratory results for the soils of the Tshutshi spruit (CEC clay; coarse size fraction; and textures for the permanent, seasonal, temporary and upland zones)

5.4.6.3. Soil wetness

The soil wetness indicator was met for all four of the zones. This is unexpected as one would assume that the upland zone, presumed to be the driest, should not meet the criteria indicative of wetland soil morphology (Table 18).

Table 18 Photographs of soil wetness indicators for the Tshutshi spruit and corresponding descriptions

M Fuchs and E Micheli

Permanent zone:

The following horizons were identified: A (0-100 mm), C1 (100-550 mm), C2 (550-800 mm), C3 (800-1000 mm). Many, medium, distinct, grey and yellow reduced iron oxide mottles were noted in the C1 horizon with common, fine, yellow, olive and brown secondary mottles attributed to oxidised iron oxide. Many, medium, distinct, red and yellow oxidised iron mottles were found in the C2 horizon. Few fine, distinct, yellow oxidised iron oxide mottles were found in the C3 horizon. Alluvial stratification was observed in the C1 horizon.

M Fuchs and E Micheli

Seasonal zone:

The following horizons were identified: A (0-20 mm), B1 (20-100 mm), B2 (100-180 mm), B3 (180-700 mm), B4 (700-1000 mm) and B5 (1000 mm onwards). Common (2-20%), coarse (>15 mm), faint, red oxidised iron oxide mottles were noted in the B3 horizon with many (>20%), coarse, prominent, black manganese, magnetite secondary mottles. Common, coarse, faint, grey, yellow and olive oxidised iron oxides were noted in the B4. Common, medium (5-15 mm), distinct, yellow, brown and red oxidised iron oxide mottles in the B5 horizon with common, medium, distinct grey and white reduced iron oxide secondary mottles.

M Fuchs and E Micheli

Temporary zone:

The following horizon were identified: A (0-160 mm), B1 (160-300 mm), B2 (300-550 mm), B3 (550-800), B4 (800-1180 mm), B5 (1180 mm- onwards). Few (<2%), fine (<5 mm), faint, red, oxidised iron oxide mottles in the B1. Common (2-20%), medium (5-15 mm), white lime mottles in the B2 with few, fine, faint, grey, yellow and olive oxidised iron oxide secondary mottles. Few, medium, distinct, white lime mottles with common, medium, prominent, red and yellow oxidised iron oxide secondary mottles in the B3. Common, medium, distinct, red and yellow oxidised iron oxide in the B4 with secondary mottles: common, medium, distinct, black and brown illuvial iron and humus. Few, medium, faint, red mottles in the B5 attributed to oxidised iron oxide.

	Upland zone: The following horizons were identified: A (0-180 mm), B1 (180-450 mm), B2 (450-850 mm), B3 (850-1300 mm). Many (>20%), fine (<5 mm), prominent, white lime mottles were observed in the A with few (<2%), fine, faint, red secondary oxidised iron oxide mottles. Many, medium (5-15 mm), prominent, grey, yellow and olive mottles were noted in the B1 horizon with common, medium, faint, red, oxidised iron oxide secondary mottles. Many, coarse (>15 mm), prominent, grey, yellow and olive mottles were noted in the B2 with common, medium, distinct red oxidised iron oxide secondary mottles. Many, coarse, prominent, grey, yellow and olive mottles were noted in the B3 with many, coarse, prominent, red oxidised iron oxide secondary mottles. Columnar structure was noted and manganese was precipitated along the ped faces, creating a "honey comb pattern" when viewed from above.

5.4.7. Discussion

The mineralogical and chemical characteristics of this system are determined by the parent material coupled with the hydrological regime, which acts more like a riparian area than a valley bottom wetland. This was evident by the depositional stratification on the banks of the Tshutshi spruit. The water table only rose to within the top 500 mm during the January 2013 floods. The parent material caused the area to be very high in sodium, resulting in an extremely basic pH and large amounts of exchangeable sodium. It was found that there were more salts in the drier zones. Because the Tshutshi drains through and from the Phalaborwa town, it brings with it alien plant seeds and is an area of concern for the Kruger National Park. The Tshutshi spruit therefore had the highest number of alien species compared to the other two wetlands.

5.5. Conclusion

The three wetlands that were selected were very distinct from each other in terms of their physical, chemical, mineralogical, and hydrological properties. Malahlapanga is a unique thermal hot spring fed predominantly by groundwater, resulting in the accumulation of peat, which played a major role in the mineralogy of the system. Nshawu is unique in terms of its basic parent material and sheer size. The accumulation of carbonate nodules was a notable wetland indicator for the temporary zone and affected the chemistry of the system. The Tshutshi spruit is sodic, extremely basic, and influenced more by runoff rather than groundwater and base flow. Salts were the major factors influencing the chemistry of the system.

6. Statistical comparison of the wetlands

6.1. Introduction

This chapter addresses the third objective, namely to determine the influence of lithology on soil wetness indicators.

The laboratory data was analysed statistically and the results are presented to provide insight into the wetland indicators that were found at the three wetlands with differing lithology. The ancillary laboratory data will be explored and the possible elements that could be used as wetland indicators, which are not influenced by lithology, will be identified.

6.2. Statistical analyses comparing the three wetlands

The wetter zones were generally more acidic than the drier zones, when comparing the three wetlands, with the only exception being the upland zone of the Basalt wetland, Nshawu (Figure 27). The majority of the zones were basic (with the exception of the wetter zones at Malahlapanga because of the acidifying effects of the organic material) the reason for this being because of the potassium feldspar in the Granite at the Tshuthsi spruit, the calcium carbonate from the olivine rich Basalt at Nshawu and because of the salts from the water at Malahlapanga. In general the wetter zones had the most organic carbon again with the exception of the upland zone of the Basalt wetland, Nshawu (Figure 28). This could possibly be due to measurement error or organic residues in the samples. At the Gneiss wetland, Malahlapanga, and Basalt wetland there was less Fe in the wetter zones than in the drier zones, however, at the Granite wetland, Tshutshi spruit, there was more Fe in the wetter zones than in the drier zones (Figure 29; Table 19; Table 20). A potential hypothesis for this is that material is continuously being deposited during flood events which might enrich these zones with Fe. The same trend was observed when comparing Mn data between the three different lithology's (Figure 30). The exchangeable sodium tended to increase as the zones got drier, the only exception again being the upland zone at the Basalt wetland which had extremely low exchangeable sodium values (Figure 31).

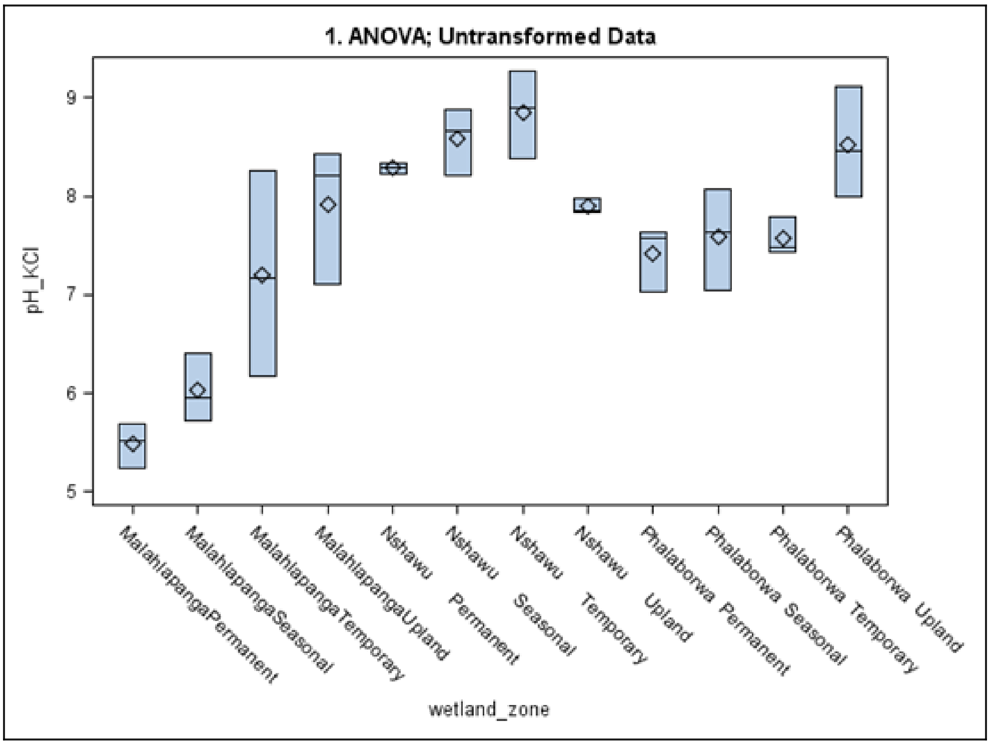


Figure 27 pH (KCl) ANOVA of untransformed data

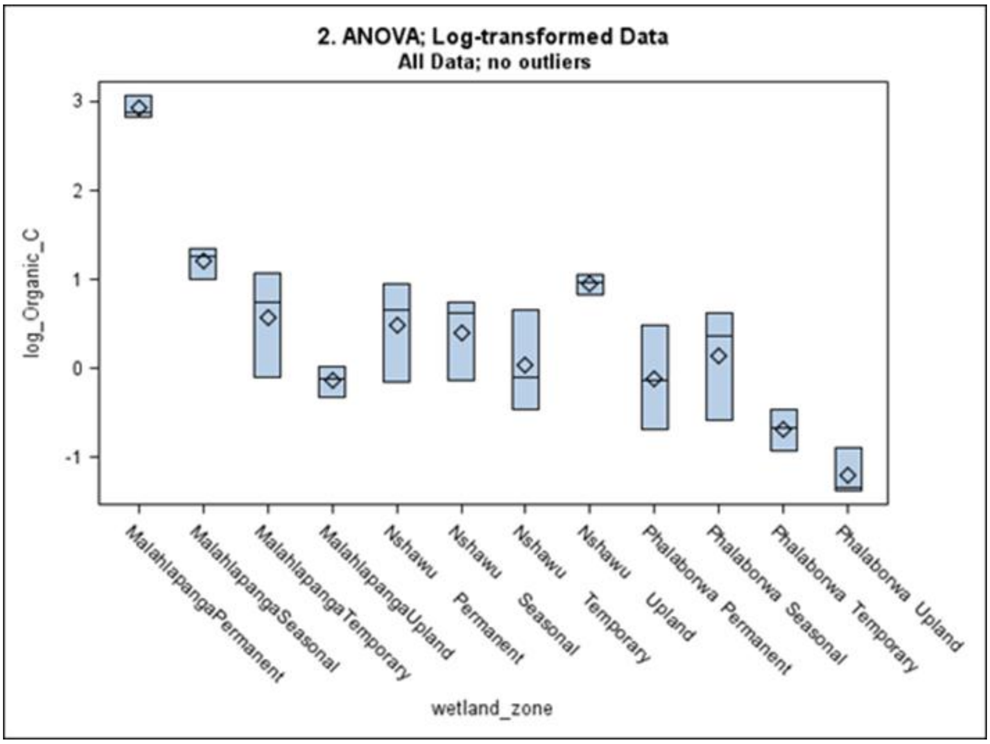


Figure 28 Organic carbon ANOVA of log-transformed data

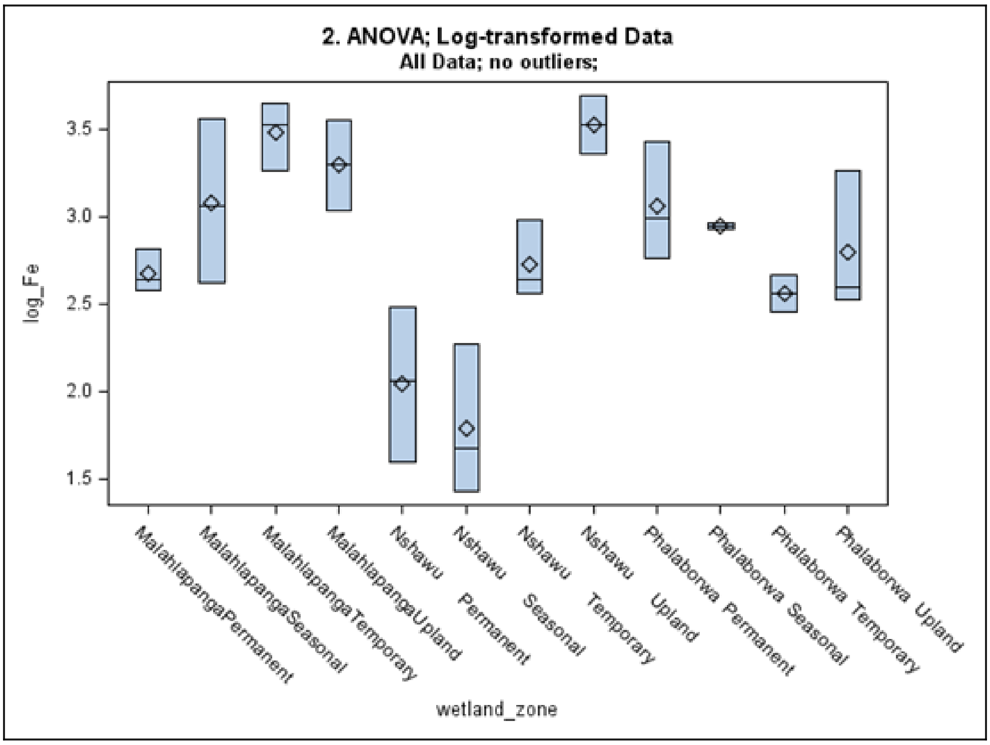


Figure 29 Iron ANOVA of log-transformed data

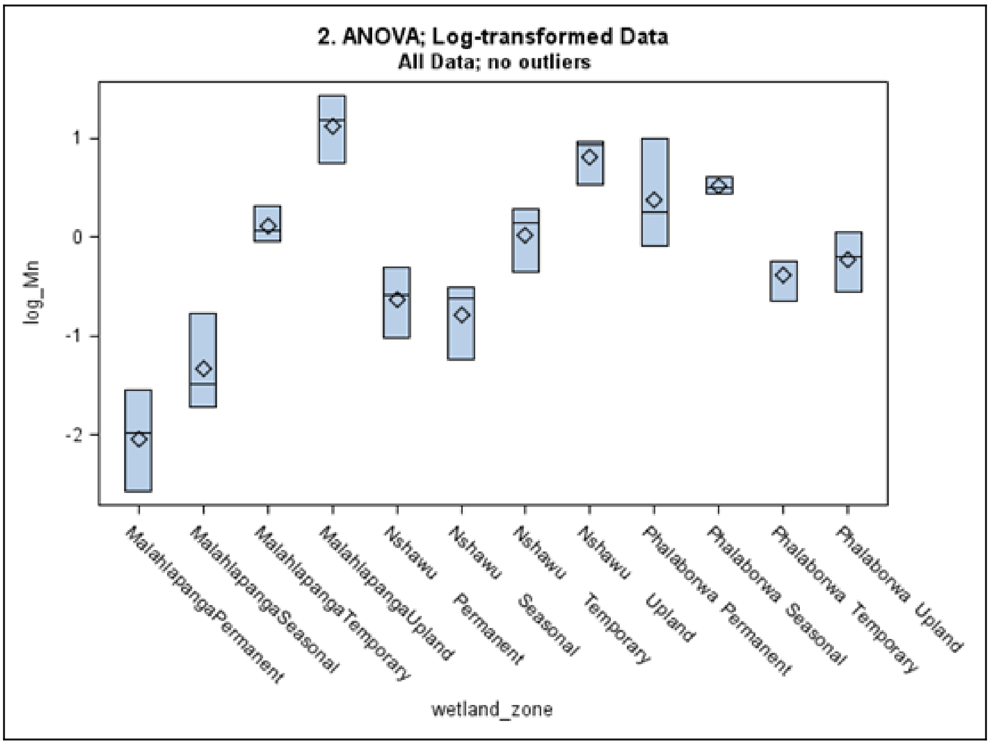


Figure 30 Manganese ANOVA of log-transformed data

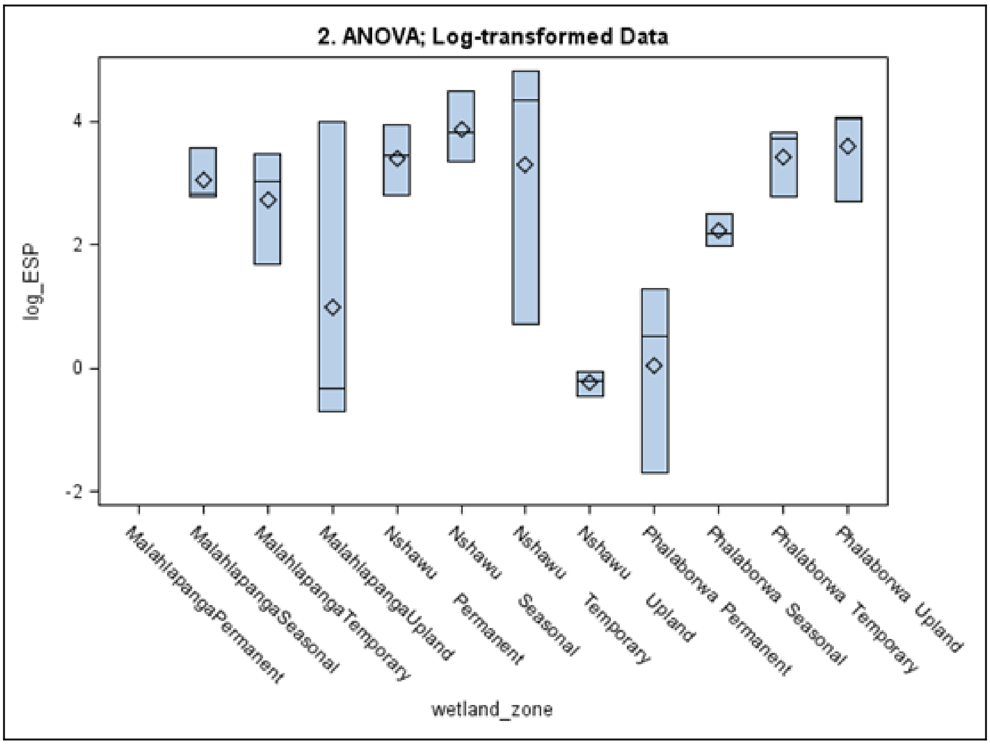


Figure 31 Exchangeable sodium percentage (ESP) ANOVA log-transformed data

The data used for the interpretations in Table 19 is given in chapter 5.

Table 19 The DWAF (2005) indicators for each lithology

Wetland	Lithology	Terrain unit	Soil form	Soil wetness	Vegetation
Malahlapanga	**Gneiss**	This was a good indicator for all four of the zones.	The indicator managed to differentiate between the zones, however, the temporary zone was classified as a Katspruit which is only meant to be associated with permanently saturated zones.	The soil wetness indicators at Malahlapanga were strong, though there were very few indicators to distinguish the seasonal and temporary zones based on soil wetness.	The vegetation indicators were strong for the permanent and upland zones but it was challenging to distinguish the seasonal and temporary zones based solely on vegetation.
Nshawu	**Basalt**	The temporarily saturated zone was classified as a lower footslope and would be excluded by DWAF (2005) as a wetland, but it definitely was a temporary wetland zone.	This indicator accurately distinguished the different zones and there was a good agreement between the guidelines and the hydrological conditions observed.	There was very little difference between the seasonal and permanent zones, however, there was a distinct change in the temporary zone and the carbonate nodules where indicative of a change in hydrological regime.	There were very distinct changes in the vegetation community for each zone at this wetland and there was a strong agreement between the vegetation data and the hydrological data.
Tshutshi	**Granite**	The seasonal and temporary zones were classified as lower footslopes but they did display other wetland indicators and perhaps the lower footslope should be included as a position in the landscape where wetlands are likely to occur.	Soil form was not a good indicator for this wetland. The seasonal and temporary zones had Sterkspruit soils which the DWAF guidelines do not identify as wetland soils while the upland had a Brandvlei soil which the DWAF guidelines do identify as wetland.	Mottling was identified in all zones, even the upland indicating that these soils do in fact become wet at some point in the season.	While there were changes in the vegetation composition within the zones, there were many species that overlapped zones and there were few indicators unique to each zone.

Table 20 The ancillary indicators for each lithology

Wetland	**Lithology**	**pH (KCl)**	**Organic carbon**	**Fe**	**Mn**	**Exchangeable Na**
Malahlapanga	**Gneiss**	The wetter the zone the lower the pH.	The wetter the zone the higher organic carbon content.	Less Fe in the wetter zones.	Less Mn in the wetter zones.	The drier the zone the more exchangeable sodium.
Nshawu	**Basalt**	The wetter the zone the lower the pH, with the exception of the upland zone which was the most acidic.	The wetter the zone the higher the organic carbon content with the exception of the upland zone with the highest organic carbon.	Less Fe in the wetter zones.	Less Mn in the wetter zones.	The drier the zone the more exchangeable sodium with the exception of the upland zone with the lowest exchangeable sodium.
Tshutshi	**Granite**	The wetter the zone the lower the pH.	The wetter the zone the higher organic carbon content.	More Fe in the wetter zones.	More Mn in the wetter zones.	The drier the zone the more exchangeable sodium.

6.3. Discussion

At the Gneiss wetland the terrain unit indicator was accurate, the soil form, soil wetness and vegetation indicators were met; however, they were not able to definitively differentiate between the seasonal and temporary zones. The ancillary data showed that there were definite trends. The drier zones had more exchangeable sodium, Fe and Mn than the wetter zones. The wetter the zone the more organic carbon occurred and the lower the pH.

The Basalt wetland showed similar trends to the Gneiss wetland when looking at the ancillary data for Fe and Mn, however, the upland zone was always an exception for the organic carbon, nitrogen and pH values. The soil form, soil wetness and vegetation indicators were all in agreement, and there was a strong link between the vegetation data and the water table data. While it is difficult to explain why the upland zone at the Basalt wetland did not show the anticipated trends that were observed at the Gneiss wetland, an explanation could be because this zone lacked the high amounts of carbonates that were present in the wetter zones. While carbonates were not measured, the upland zone was noticeably devoid of carbonate nodules in comparison to the temporary zone and even the seasonal and permanent zones. The water likely carries calcium carbonate and is evaporating from the wetter zones and depositing calcium carbonate. The Basalt wetland was the only wetland with a basic parent material and the only wetland that showed this phenomenon.

The Granite wetland followed the same trends as the Gneiss wetland with the exception of the Fe and Mn contents which were found to be higher in the wetter zones than the drier zones. This implies that there is a net removal of Fe and Mn in the upland and temporary zones and an accumulation in the seasonal and permanent zones. Possible reasons for this include the stagnation of water for long periods of time in the sodic site due to the dispersal of clays and blocking of soil pores. This would mean that Fe and Mn could be reduced and removed over time. Another theory could be that at the Granitic wetland there is continuously new material being deposited during flood events, containing Fe and Mn, which was deduced from the depositional stratification observed within the profiles along the stream bank.

6.4. Conclusion

In general the terrain unit was a good wetland indicator, however, many of the areas that were classified as lower foot slope (4L), were in fact wetlands and thus the 4L position should be considered to be included by the DWAF (2005) guidelines as a possible landscape position for the occurrence of wetlands. The soil form indicator accurately distinguished between zones and worked very well at the Basalt wetland. At the Granite wetland the soil forms found in the wetter zones did not agree with the DWAF (2005) guidelines, while the soil form found in the “driest” zone is only meant to occur in wet zones according to the guidelines. The soil wetness indicator was useful, however, at the Gneiss wetland it was difficult to distinguish between the seasonal and temporary zones. Perhaps these classifications of permanent, seasonal, temporary and upland are arbitrary for this system. At the Basalt wetland it was difficult to distinguish between the permanent and seasonal zones based solely on the soil wetness indicator, but there was a strong change in soil morphology between the seasonal and temporary zones and so this indicator was accurate in distinguishing the wetland boundary. At the Granite wetland the soil wetness indicators were found in all the zones even the upland zone, and could possibly be attributed to the dispersive nature of the soil and puddling of water. The vegetation indicator was a good indicator, however, at the Gneiss wetland, while it was possible to accurately define the permanent and upland zones it was more challenging to distinguish the seasonal and temporary zones due to external pressures such as the trampling by animals. At the Basalt wetland the vegetation indicator related well to the hydrological data and at the Granite wetland the changes in species abundance and vegetation composition reflected changes in soil and hydrology rather than individual species for each zone. When consulting the ancillary data, the pH, organic carbon and the exchangeable sodium, showed similarities between the wetlands regardless of lithology.

Generally the pH decreased with increased wetness, while the organic carbon content increased with wetness, and the exchangeable sodium percentage increased with a decrease in wetness. However, the upland zone at the Basalt wetland was an exception to the following trends, while this cannot be easily explained it is thought that the lack of carbonates, in comparison to the other zones, could be contributing to this anomaly. Fe and Mn were good wetland indicators for the Gneiss and Basalt wetlands. There was more Fe and Mn found in the drier zones because of reduction and removal in the wetter zones. At the Granite wetland the opposite was found, as there were higher amounts of Fe and Mn in the wetter zones.

7. Evaluation of the IRIS tubes

7.1. Introduction

The chapter addresses the second objective to evaluate the use of IRIS tubes as a technical standard for wetland delineation in South Africa.

As such the chapter relates the current methods being used in South Africa for wetland delineation to the IRIS tube data collected during the study. The influence of growing season is investigated to determine when best to install the IRIS tubes. The conditions required for reduction are explored to assess whether there were sufficient nutrients, organic material and water saturation for the onset of reduction. Lastly the limitations encountered are discussed and the pros and cons of the IRIS tubes stated. Finally the IRIS tubes are evaluated for their use in wetland delineation in South Africa.

7.2. Comparing the IRIS method to the traditional DWAF (2005) method

Table 21 and Table 22 compare the DWAF (2005) wetland indicators with the IRIS tube data collected. Table 21 shows the raw data while Table 22 is a summary indicating whether each particular indicator was met. The terrain unit was based on MacVicar *et al*. (1977) and if units of 5 or 4L were noted the indicator was assumed to be met. Soil forms were identified (Soil Classification Working Group, 1991) to determine whether the soil form was classified as a wetland soil according to the DWAF (2005) guidelines. The soil morphology was described in the top 0.3 m (one would usually look at the top 0.5 m but because the bottom 0.2 m of the IRIS tubes are disregarded the table only shows the top 0.3 m for comparative purposes). The wetland vegetation species are listed and if the plants were classified as obligate, facultative positive or facultative negative it was assumed that the vegetation indicator was met. The duration (months) of saturation were calculated but assumptions were made due to the water table only being recorded monthly and thus the figures listed can only be used as estimated duration of saturation. When the water table came within the top 0.3 m of the soil profile the rH (potential redox) was calculated using the following formula:

$$rH = \quad 2 \times Eh \;/59 \; + (2 \times pH) \qquad (\textit{Equation 6})$$

The values shown in Table 21 are the average rH figures over the months of saturation. The percentage paint removal values presented in the tables below were calculated averages from the months when saturation occurred for each IRIS tube position (i.e. a, b, c, d, and e). These five averaged values were then averaged to a single value. The last column shows the overall average percentage of paint removed over the months of saturation.

Table 21 Wetland indicator data and IRIS tube results for Malahlapanga, Nshawu and the Tshutshi spruit

Wetland	Rep	Zone	Terrain unit	Soil form	Soil wetness within 30 cm	Vegetation	Water table within top 30 cm of profile (months of saturation)	Average rH during saturation within top 30 cm of profile	IRIS paint removal (%)					
									a	b	c	d	e	Avg.
Malahlapanga	1	Permanent				Leptochoa fusca (obligate), Phragmites mauritianus (obligate), Pycreus sp. (obligate)	13	16,65	48,77	46,36	47,42	45,50	48,36	47,18
	2	Permanent	5	Champagne 1200	Few, coarse, faint, grey mottles; Organic O horizon	Phragmites mauritianus (obligate), Pycreus sp. (obligate)	7	7,76	51,43	69,33	53,43	39,06	48,33	52,32
	3	Permanent				Leptochoa fusca (obligate), Phragmites mauritianus (obligate), Fimbristylis dichotoma (obligate), Pycreus sp. (obligate)	13	17	65,50	66,40	53,07	51,60	61,85	59,35
Malahlapanga	1	Seasonal	5	Kroonstad 1000	Few, fine, distinct, white reduced iron oxide mottles; Alluvial depositional stratification	Phragmites mauritianus (obligate)	0							
	2	Seasonal					0							
	3	Seasonal					0							
Malahlapanga	1	Temporary	5	Katspruit 1000	Few, fine, faint red oxidised iron oxide mottles 0-100 mm; Few, fine, faint red oxidised iron oxide mottles and few, fine, faint grey mottles 100-300 mm; Alluvial depositional stratification		0							
	2	Temporary					0							
	3	Temporary					0							
Malahlapanga	1	Upland	4L	Glenrosa 1112	No redox morphology		0							
	2	Upland					0							
	3	Upland					0							
Nshawu	1	Permanent	5	Katspruit 2000	Common, fine, distinct white lime mottles present; Few, fine, faint red and yellow oxidized iron oxide mottles; G horizon encountered	Leptochloa fusca (obligate), Phragmites mauritianus (obligate), Sporobolus pyramidalis (facultative positive), Cyperus laevigatus (obligate), Cyperus sexangularis (facultative positive)	13	12,15	17,60	20,46	24,49	19,54	14,84	19,39
	2	Permanent				cf Panicum infestum (facultative negative), Phragmites mauritianus (obligate), Sporobolus pyramidalis (facultative positve), Cyperus sexangularis (facultative	9	18,15	25,10	23,87	21,33	25,52	22,37	23,73
	3	Permanent				cf Panicum infestum (facultative negative), Phragmites mauritianus (obligate), Cyperus sexangularis (facultative positive)	1	15,91	19,09	20,78	16,11	63,53	22,94	28,49
Nshawu	1	Seasonal	5	Katspruit 2000	Common, fine, prominent white lime mottles present; G horizon encountered	cf Panicum infestum (facultative negative), Phragmites mauritianus (obligate), Cyperus laevigatus (obligate), Cyperus sexangularis (facultative positive), *Juncus effusus (obligate)	3	11,47	15,94	32,90	19,50	19,01	37,17	24,90
	2	Seasonal				Cyperus laevigatus (obligate), Cyperus sexangularis (facultative positive), *Juncus effusus (obligate)	1	17,94	23,87	5,26	17,58	0,00	21,85	13,71
	3	Seasonal				Phragmites mauritianus (obligate), Sporobolus pyramidalis (facultative positive), Cyperus sexangularis (facultative positive)	1	20,2	15,48	18,48	3,07	7,44	17,20	12,33
Nshawu	1	Temporary	4L	Brandvlei 2000	No redox morphology	cf Sporobolus ioclados (facultative negative), Sporobolus pyramidalis (facultative positive)	0							
	2	Temporary				cf Sporobolus ioclados (facultative negative), Sporobolus pyramidalis (facultative positive), Cyperus sexangularis (facultative positive)	0							
	3	Temporary				cf Sporobolus ioclados (facultative negative), Sporobolus pyramidalis (facultative positive), Cyperus sexangularis (facultative positive)	0							
Nshawu	1	Upland			Many, medium, prominent, white lime mottles		0							
	2	Upland	3U	Mispah 1200			0							
	3	Upland					0							
Tshutshi	1	Permanent	5	Dundee 1210	Many, medium, distinct, grey and yellow reduced iron oxide; Common, fine, distinct, yellow, olive and brown oxidized iron oxide; Alluvial depositional stratification	Cyperus sexangilaris (facultative positive)	1	20,67	11,70	9,15	11,96	19,30	12,31	12,88
	2	Permanent				Cyperus sexangilaris (facultative positive)	1	20,29	0,00	0,00	0,00	0,00	0,00	0,00
	3	Permanent					0							
Tshutshi	1	Seasonal	4L	Sterkspruit 2100	Common, coarse, faint, red, oxidized iron oxidemottles; Many, coarse, prominent, black, manganese, magnetite mottles	Sporobolus ioclados (facultative negative)	1	21,48	9,54	11,97	10,34	0,00	0,00	6,37
	2	Seasonal					1	20,77	0,00	0,00	0,00	0,00	0,00	0,00
	3	Seasonal					1	12,16	5,18	0,00	0,00	0,00	0,00	1,04
Tshutshi	1	Temporary	4L/U	Sterkspruit 2100	Few, fine, faint, red, oxidized iron oxide	Sporobolus ioclados (facultative negative)	0							
	2	Temporary				Sporobolus ioclados (facultative negative)	1	16,49	6,57	4,84	6,08	33,97	4,95	11,28
	3	Temporary					1	12,34	0,00	0,00	0,00	0,00	0,00	0,00
Tshutshi	1	Upland	4U	Brandvlei 2000	Many, fine, prominent white lime mottles; Many, medium, prominent, grey, yellow and olive lime mottles; Few, fine, faint red oxidized iron oxide mottles; Common, medium, faint, red oxidized iron oxide mottles.	Sporobolus ioclados (facultative negative)	0							
	2	Upland				Sporobolus ioclados (facultative negative)	0							
	3	Upland				Sporobolus ioclados (facultative negative)	0							

Table 22 Summary of wetland indicator data and IRIS tube results for Malahlapanga, Nshawu and the Tshutshi spruit

Rep	Zone	Terrain unit	Soil form	Soil wetness within 30 cm	Vegetation	Water table within top 30 cm of profile	Average rH <20 during saturation within top 30 cm of profile	IRIS paint removal (%) >15%					
								a	b	c	d	e	Avg.
1	Permanent				Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Permanent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Permanent				Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1	Seasonal	Yes	Yes	Yes	Yes	No							
2	Seasonal				No	No							
3	Seasonal				No	No							
1	Temporary	Yes	Yes	Yes	No	No							
2	Temporary				No	No							
3	Temporary				No	No							
1	Upland	Yes	No	No	No	No							
2	Upland				No	No							
3	Upland				No	No							
1	Permanent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
2	Permanent				Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Permanent				Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1	Seasonal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Seasonal				Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
3	Seasonal				Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
1	Temporary	Yes	Yes	No	Yes	No							
2	Temporary				Yes	No							
3	Temporary				Yes	No							
1	Upland				No	No							
2	Upland	No	No	Yes	No	No							
3	Upland				No	No							
1	Permanent	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No	No
2	Permanent				Yes	Yes	Yes	No	No	No	No	No	No
3	Permanent				No	No							
1	Seasonal	Yes	No	Yes	No	Yes	No	No	No	No	No	No	No
2	Seasonal				No	Yes	No	No	No	No	No	No	No
3	Seasonal				No	Yes	Yes	No	No	No	No	No	No
1	Temporary	Yes	No	Yes	No	No							
2	Temporary				No	Yes	Yes	No	No	No	No	No	No
3	Temporary				No	Yes	Yes	No	No	No	No	No	No
1	Upland	No	Yes	Yes	No	No							
2	Upland				No	No							
3	Upland				No	No							

7.2.1. Malahlapanga

There was a strong agreement (100%) between the DWAF (2005) indicators and the IRIS data within the assumed permanently saturated zone for Malahlapanga (Table 21). The terrain unit, soil form indicator, soil wetness indicator, vegetation indicator, as well as the hydrology and rH of the water confirm that the zone is indeed permanently saturated. Figure 32 below shows an example of a typical IRIS tube that was installed within this zone. It is clear to see the paint stripped entirely from the tube. However, a grey staining from the organic matter can also be noted. This had implications when analysing the tubes using the flatbed scanner in greyscale. While it is very obvious where there was paint removal when looking at the tube by eye, it was a challenge for the scanner to distinguish between the grey tone of the orange paint and the grey staining on the tube from the organic material. These tubes were treated differently from the rest of the IRIS tubes during the analysis phase as a higher degree of accuracy was achieved via visual estimation of paint removal. In all the other zones a higher degree of accuracy was achieved by converting the greyscale image in Photoshop to black and white and obtaining a percentage of white and black pixels to get an accurate value. Due to differing light conditions and the varying colours of the tubes, a threshold value had to be set for each individual tube which was as close to the actual tube as possible.

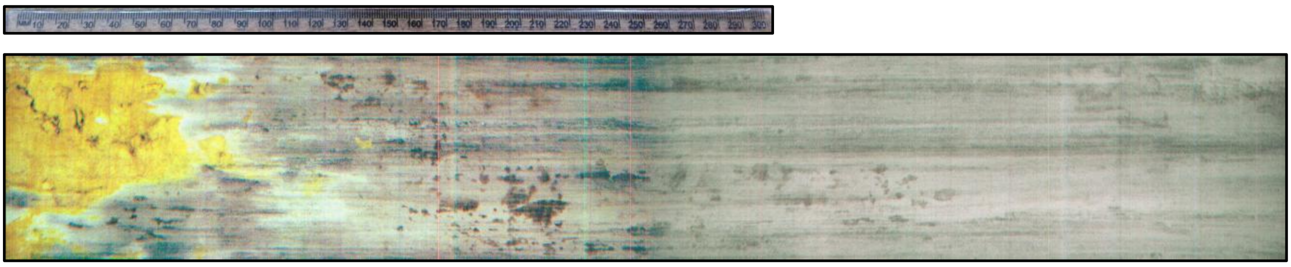


Figure 32 Colour scan of IRIS tube from permanently saturated zone at Malahlapanga showing removal of paint and staining from the peat (top of tube on the left, 0.5 m section)

There was no paint removal from the tubes in the seasonal and temporary zones (Table 21), because the water did not rise within the top 0.5 m of the soil profile during the study period. The terrain unit, soil form indicator and soil wetness indicators did, however, indicate that wetland conditions had occurred within these zones. The soil indicators could have been relict, or the year of the study may not have been wet enough. However, even with the occurrence of the January 2013 floods, no reduction was recorded within these zones. The vegetation was misleading due to the severe trampling from animals which prevented the establishment of certain plant species.

In the upland zone there was a lack of wetland indicators as well as no paint removal recorded from the IRIS tubes, implying that there was also a strong agreement between the methods at the dry end of this transect.

7.2.2. Nshawu

There was a strong agreement between the IRIS data and the DWAF (2005) indicators in the permanent and seasonal zones with less paint removal occurring in the seasonal zone (Table 21). While the terrain unit, soil form, soil wetness and vegetation indicators were met for the zones, along with the presence of the water table and reducing rH, there was a decrease in paint removal in the seasonal zone. Only one of the three repetitions would classify as a wetland while the other two repetitions would not have met the criteria of both Castenson and Rabenhorst (2006) or the NTCHS (2007).

In the temporary zone, no paint removal was recorded via reduction only via scratching from the carbonate nodules. The coarse size fraction consisting of carbonate nodules and stones was as high as 70%. Because of the high percentage of coarse fragments in this zone, abrasion and scratching was responsible for removing the IRIS tube paint. In the temporary zone only the terrain unit, soil form and vegetation wetland indicators were met. This means that in this zone the soil wetness indicator and IRIS tubes were in agreement as the water table did not reach the 0.5 m depth for a long enough period during the study for reduction to occur.

In the upland zone there was a lack of wetland indicators as well as no paint removal recorded from the IRIS tubes, implying that there was also a strong agreement between the methods at the dry end of the transect.

Interestingly, reduction from the IRIS tubes was also recorded in months where there was not 100% saturation documented. While the purpose of this study was not to relate the degree of saturation to the onset of reduction, this is an interesting result which corroborates the work done by Smith and Van Huyssteen (2011; 2013). They found that the onset of reduction typically occurs at 70% saturation but can be influenced by factors such as temperature, bulk density and organic carbon content. Further explanation for this is that the soils, being derived from a basic parent material are higher in clays which have a greater bulk density and higher capillary fringe than sandy soils. The clay content for the soils in the permanently and seasonally saturated zones were in the region of 60% (Figure 21).

The patterns in which the paint was removed from the tubes at Nshawu were also notable (Figure 33). Removal often followed root channels where the microbes utilized the organic material in their respiration process. Currently, carbonate nodules are not a wetness indicator, as the focus is primarily on Fe, Mn and organic carbon. However, in this study the carbonates did indicate a change in hydrology and wetland conditions, which should be investigated further.

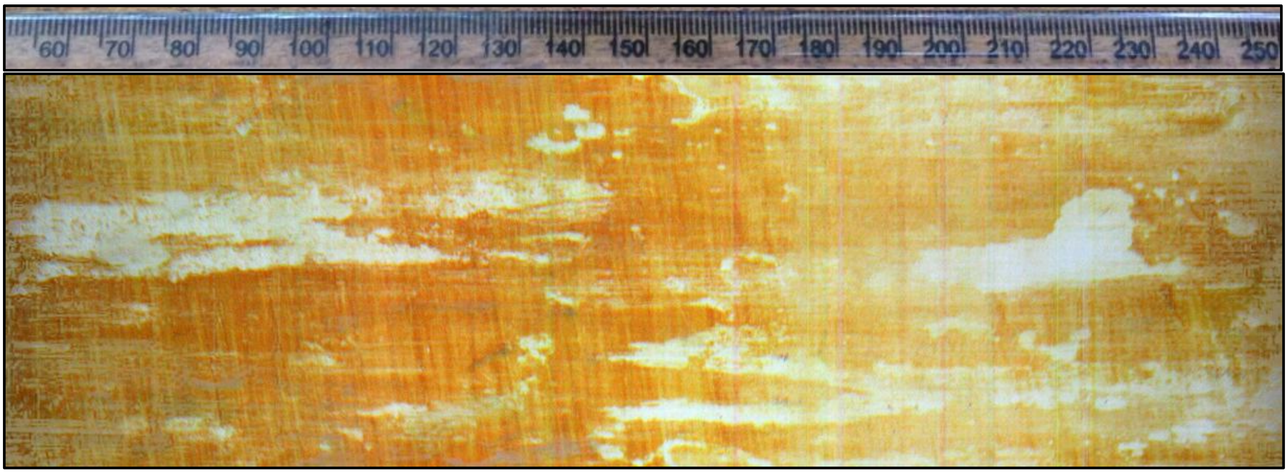


Figure 33 Colour scan of IRIS tube from the permanently saturated zone at Nshawu showing typical patterns of paint removal (top of tube on left, 200 mm section from 50-250 mm)

7.2.3. Tshutshi spruit

No reduction was recorded at any of the wetness zones at the Tshutshi spruit, despite the presence of wetland indicators and the inundation that occurred during the January 2013 flood. The terrain unit, soil wetness indicator and hydrological criteria were met for all the zones, while the vegetation and soil form indicators were also met in the permanent zone. This suggests that perhaps the chemistry of the system was not favourable for the reduction of Fe. This wetland is associated with a sodic site and the measured pH water was extremely high (the maximum value recorded was 11.36 in the seasonally saturated zone). The implication of this is that the area would have to be inundated with water for a very long period of time in order for the onset of the reduction of Fe. Because the system is not reducing in terms of Fe, one should therefore look to use other elements which are higher up in the reduction reaction sequence such as Mn and look at the use of MIRIS tubes in the future (Manganese Indicators of Reduction In Soils) (Stiles *et al.,* 2010).

The soils of Tshutshi spruit are very sandy which led to paint being easily scratched off the IRIS tubes during installation and extraction (Figure 26). Paint removal through abrasion was therefore problematic and the paint mineralogy could possibly have been refined by determining the optimum goethite content for the paint to resist abrasion, but still be easily reduced. A more sensitive XRD analysis is required, because the one that was undertaken only detected goethite and no other Fe oxide minerals (Appendix D, Figure 53, Table 42, Table 43).

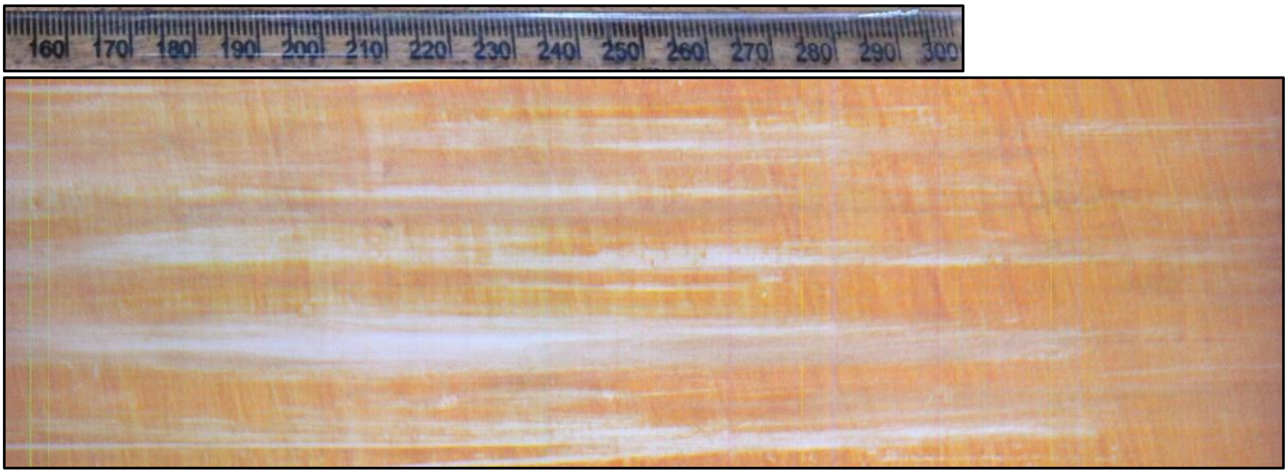
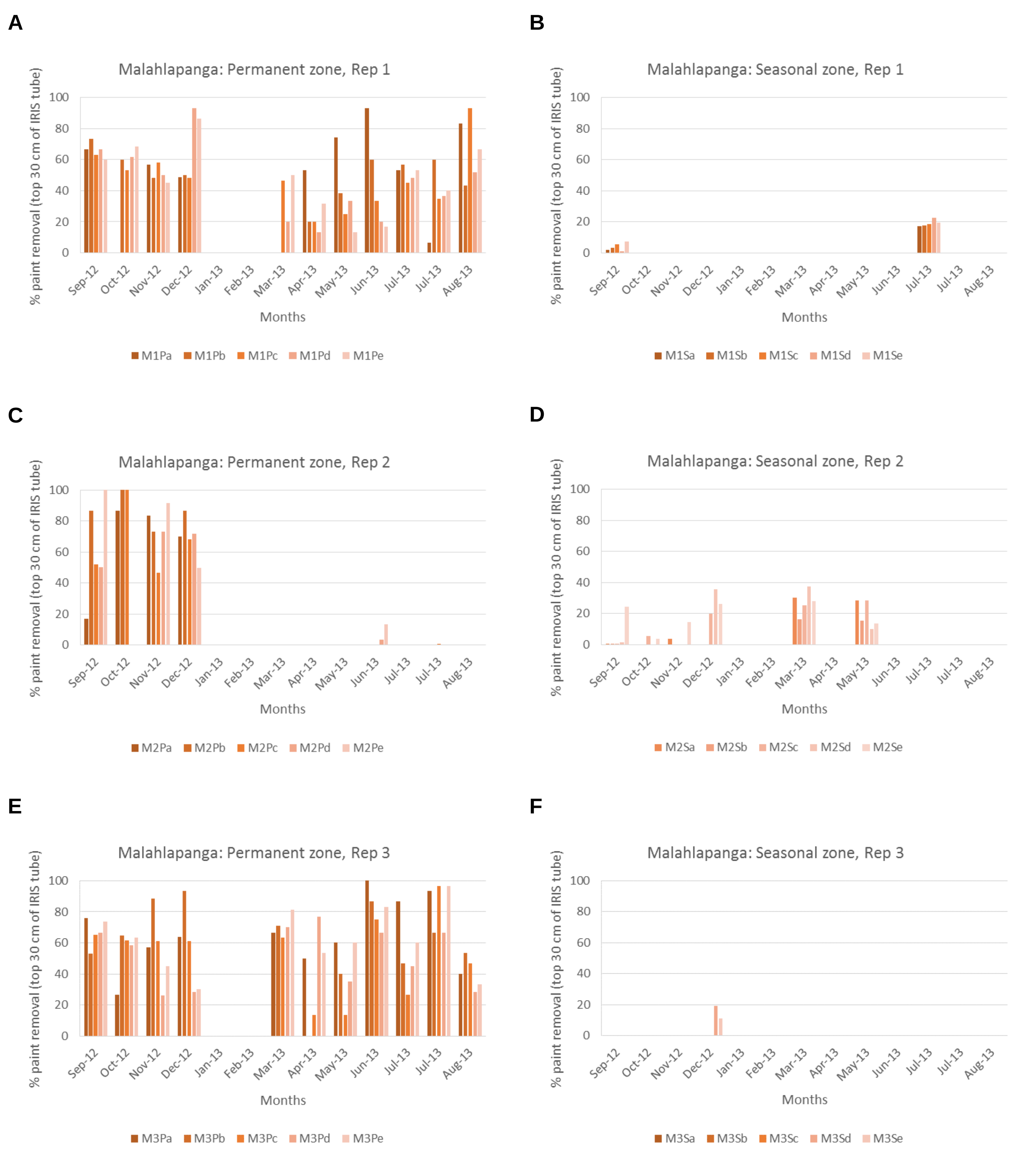


Figure 34 Colour scan of IRIS tube from the permanently saturated zone at the Tshutshi spruit showing scratching of paint (top of tube on left, 200 mm section from 150-350 mm)

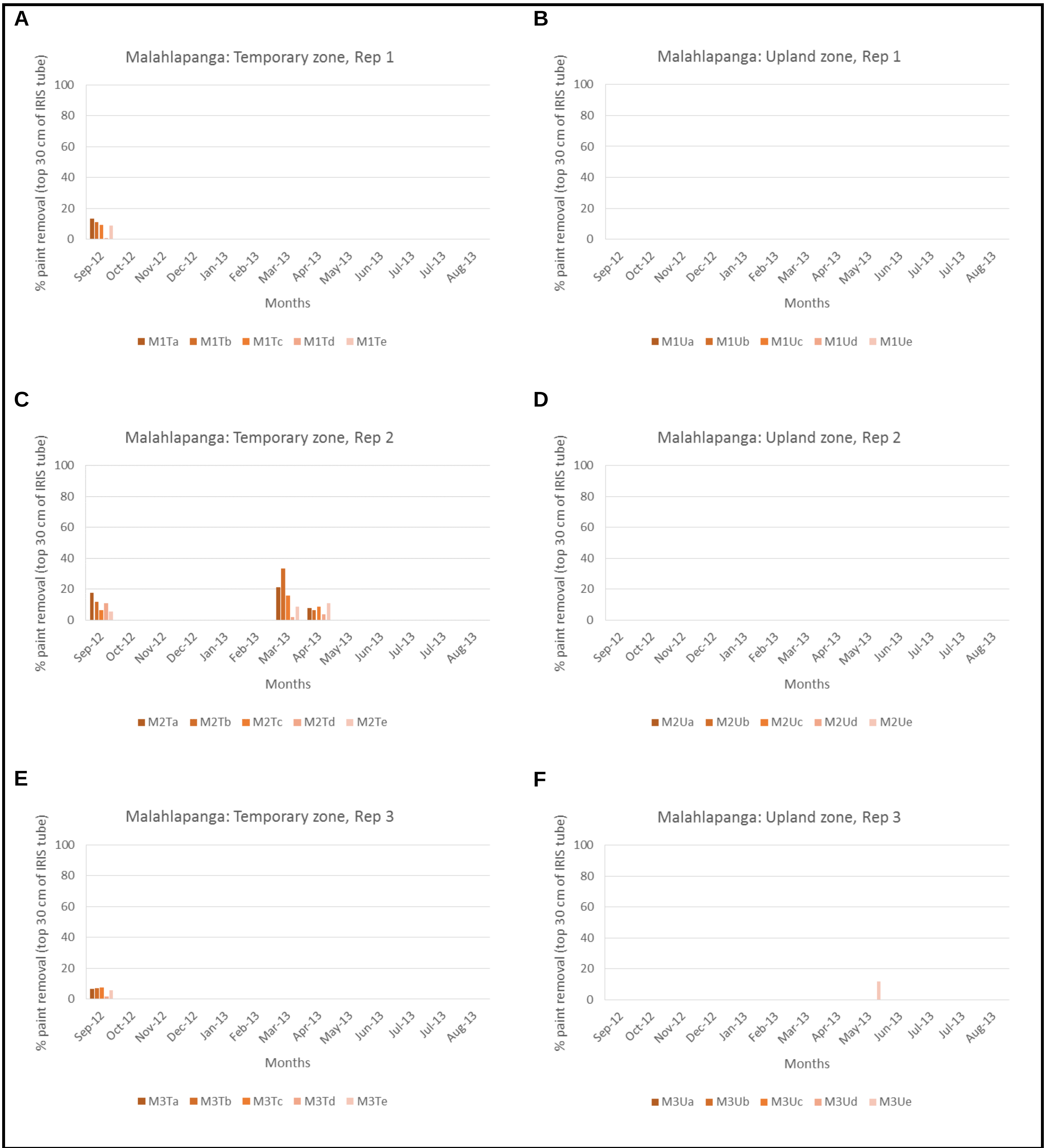
7.3. Influence of season on IRIS data

Graphs were plotted for each repetition in each of the wetness zones to show how the amount of paint removed for each tube changed with the season (Figure 35; Figure 36; Figure 37; Figure 38; Figure 39; Figure 40). Only the total amount of paint removed from the top 300 mm of each tube was plotted (because the bottom 200 mm is disregarded). The gap in data for Jan and Feb is attributed to not being able to access Malahlapanga for 2 months due to the damage caused by the floods to the access roads. In all other months at each wetland any 0 values are attributed to no reduction rather than missing data. The complete dataset is given in Appendix D.



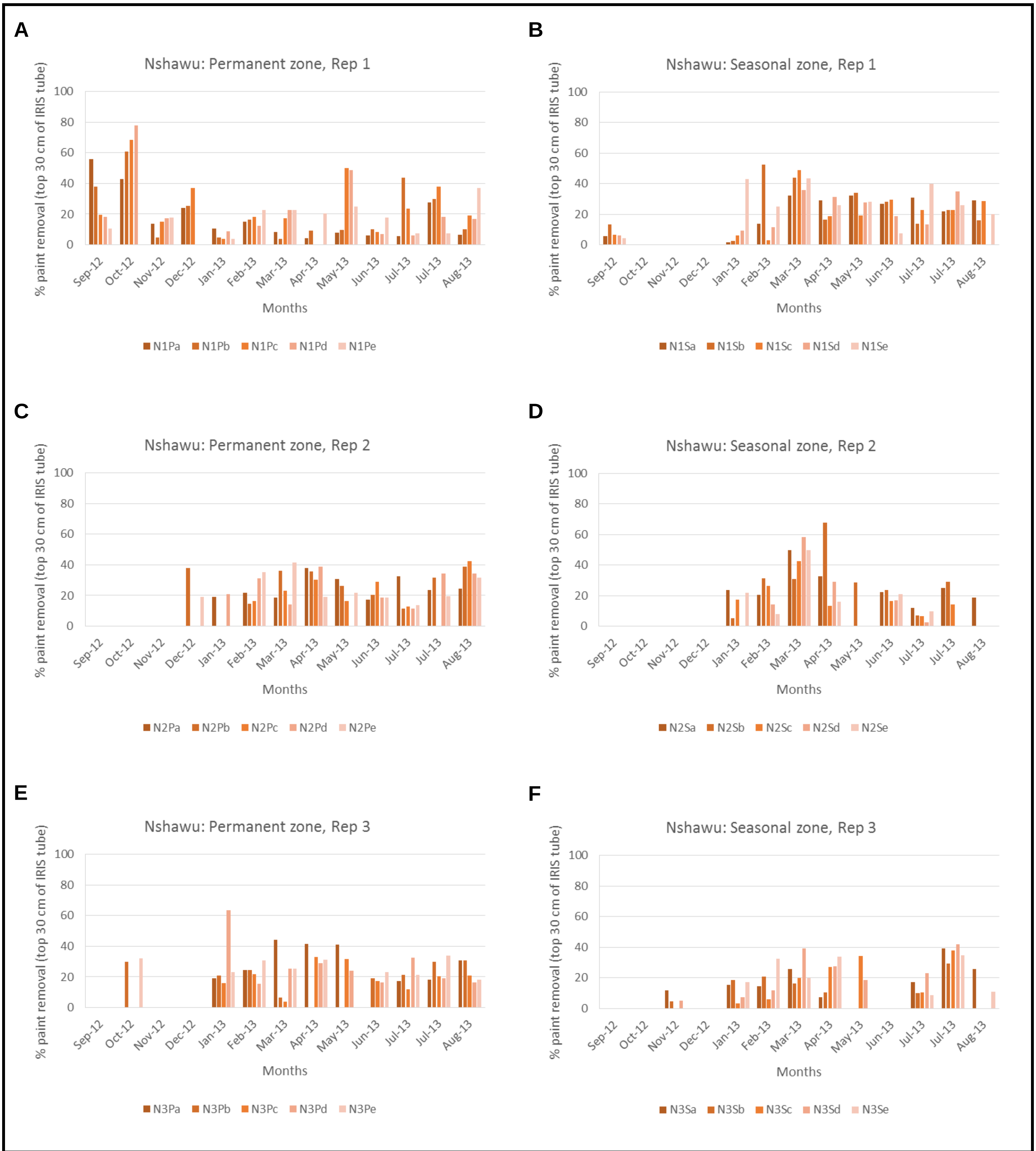
[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U) , then the tube No.]

Figure 35 Paint removal for the permanent and seasonal sites at Malahlapanga over the study period



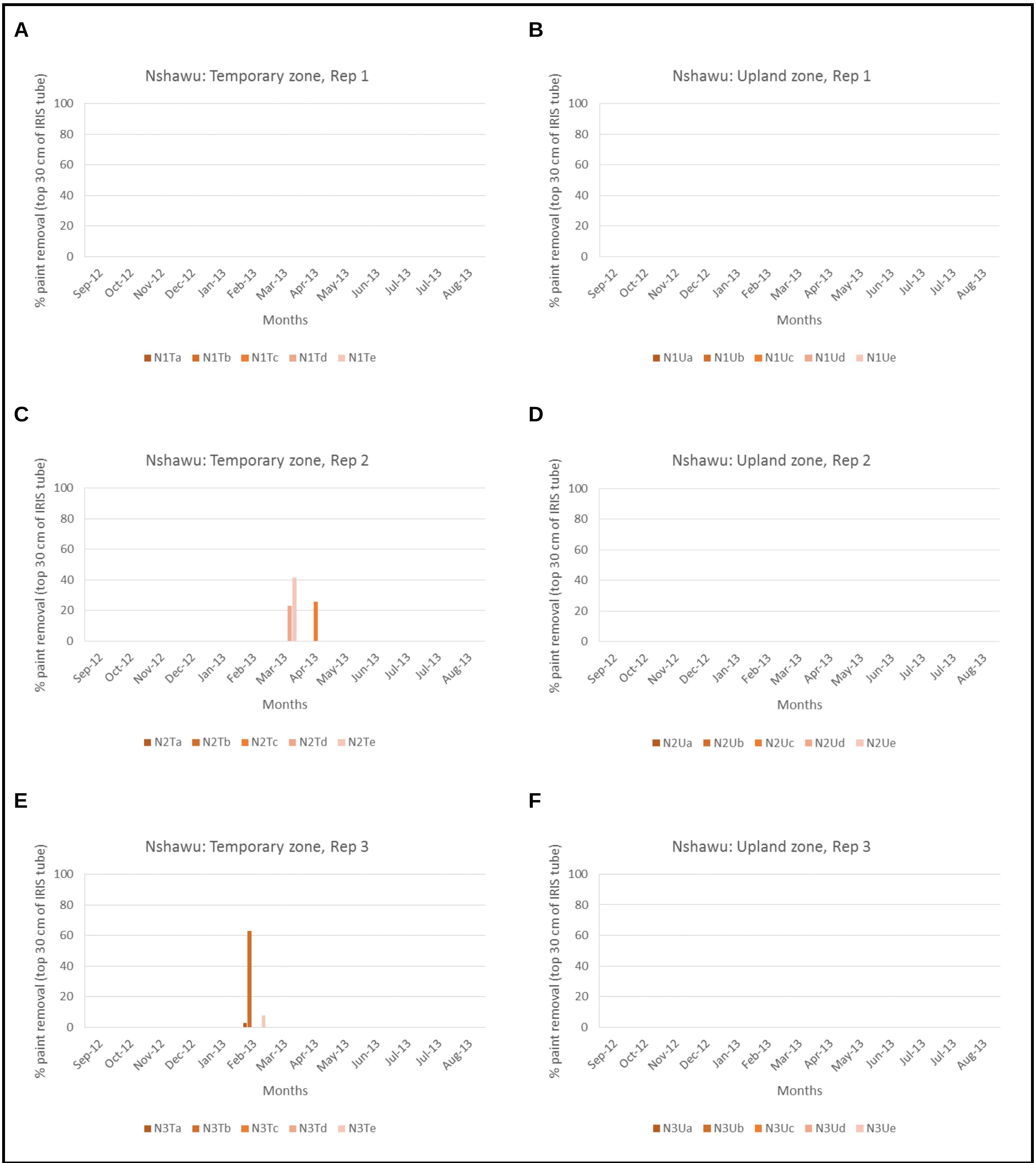
[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U) , then the tube No.]

Figure 36 Paint removal for the temporary and upland sites at Malahlapanga over the study period



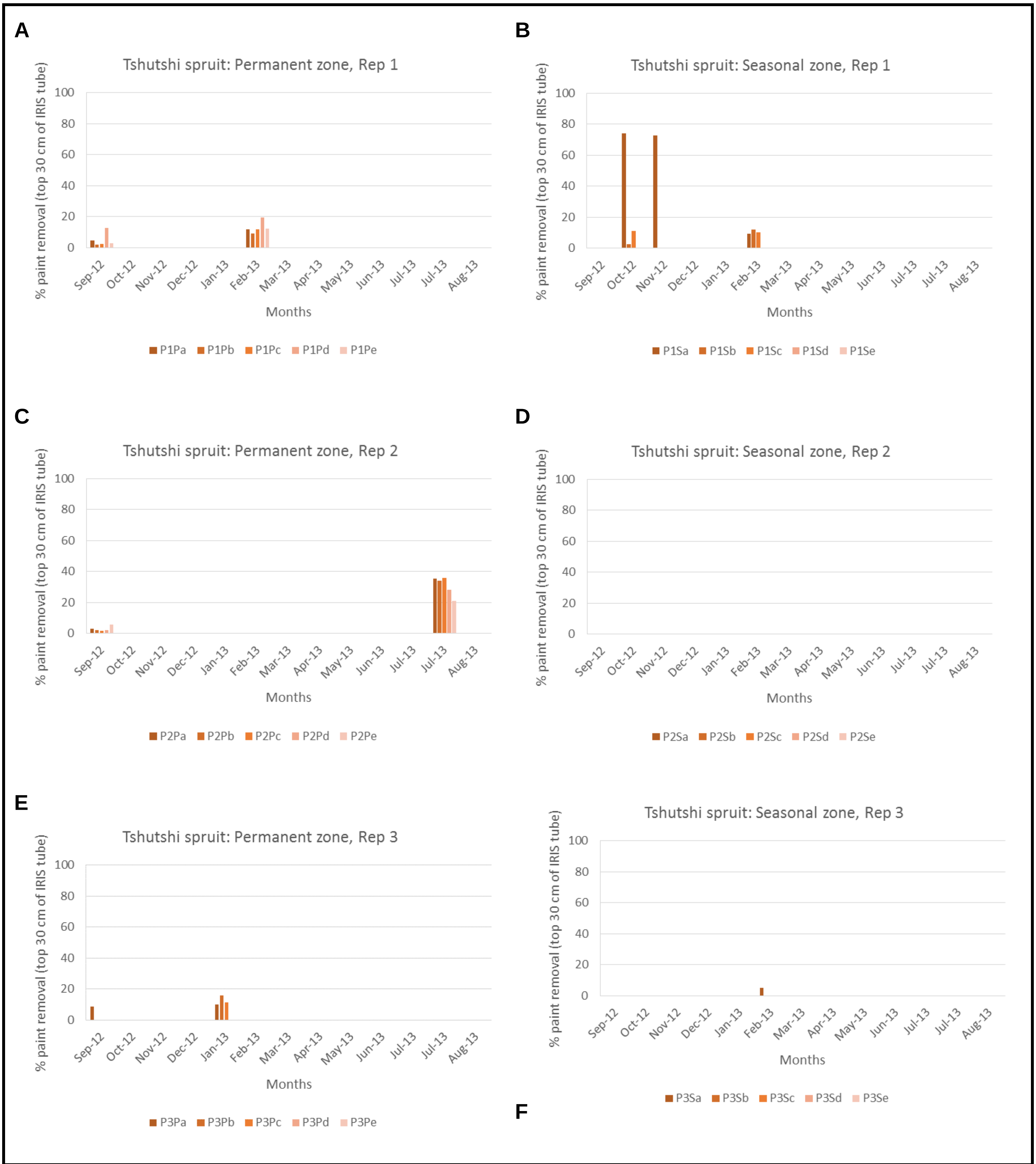
[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U) , then the tube No.]

Figure 37 Paint removal for the permanent and seasonal sites at Nshawu over the study period



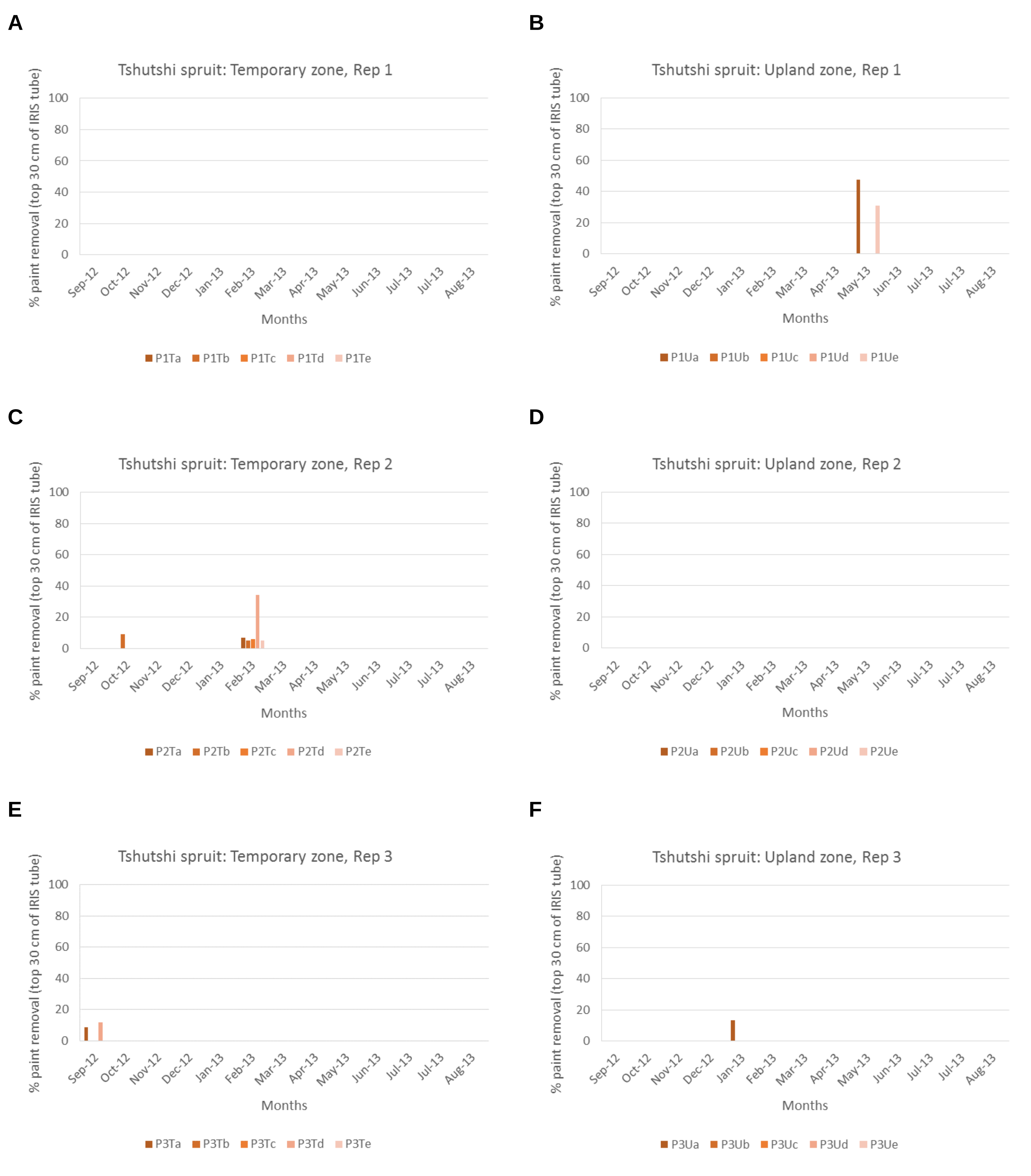
[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U) , then the tube No.]

Figure 38 Paint removal for the temporary and upland sites at Nshawu over the study period



[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U) , then the tube No.]

Figure 39 Paint removal for each site at the Tshutshi spruit over the study period



[The codes refer first to the wetland (Malahlapanga=M, Nshawu=N, Tshutshi spruit or Phalaborwa wetland=P), then the repetition number (1, 2 or 3), and then the wetness zone (permanently saturated=P, seasonally saturated=S, temporarily saturated=T and the terrestrial or upland zone=U) , then the tube No.]

Figure 40 Paint removal for the temporary and upland sites at the Tshutshi spruit over the study period

7.3.1. Malahlapanga

At Malahlapanga there was no obvious seasonal effect, due to it being spring fed. Because of the hydrology of this particular wetland, there was no substantial increase in reduction in the wetter summer months because the origin of the spring water may be governed by other factors.

7.3.2. Nshawu

At Nshawu there was an increase in reduction for the months of March and April due to the January 2013 floods. It is assumed that there was a lag effect due to the nature of the hydrology of the wetland. Being a valley bottom wetland, the water that infiltrated into the soil from the wetland's catchment had to move laterally through the hillslope to reach the wetland, causing a delay in the effects attributed to the floods.

7.3.3. Tshutshi spruit

There was an increase in reduction in January and February due to the January 2013 floods, but it was a more immediate effect due to the system being a channelled valley bottom wetland or borderline floodplain wetland. A flood hydrograph would show responses in this catchment to be much faster. One would see the best results after a rainfall event as the system is very temporal and responds quickly to rainfall.

7.4. Conditions required for iron reduction

Verpraskas and Faulkner (2001) outline the four conditions required for a soil to become anaerobic and support reducing reactions. Firstly, the soil should be inundated or saturated in order to exclude atmospheric oxygen. Secondly, there should be a sufficient source of organic material to be oxidised. Thirdly, a respiring microbial population is required in order to oxidise the organic material. Lastly, the water should be stagnant or moving slowly as moving water contains dissolved oxygen which is difficult to deplete. This retards the onset of reduction and in particular the reduction of Fe. Jennings and Van Huyssteen (2011; 2013) have determined through laboratory trials with soil taken from the Weatherly catchment, in the Eastern Cape, South Africa, that there is an increase in variability of pe, pH, Fe^{2+} and Mn^{2+} at saturation values between S_{70} to S_{80}. They found that the onset of Fe^{3+} reduction occurred between S_{72} and S_{78} which confirmed the hypothesis that the onset of reduction can occur from S_{70} onwards. The conditions required for the onset of reduction will be explored for each wetland.

7.4.1. Nutrients

At Malahlapanga there was sufficient nitrogen for reduction to occur throughout the zones, with the seasonal zone having the highest nitrogen content and the upland and permanent zones having the least amounts of nitrogen (Figure 15 A). This can be attributed to the low organic carbon levels within the dry upland zone where the organic material mineralizes much faster than in the wetter zones. In the permanent zone, the nitrogen was easily reduced because of the constant inundation of water and satisfactory reducing conditions present. Phosphorous levels in the soil were more variable with depth when compared to the nitrogen values, and it was found that there was less phosphorous in the wetter zones (Figure 15 B). Fe levels showed that there was less Fe in the wetter zones, presumably due to reduction and mobilization (Figure 15 C). There was a decrease in Fe with depth in the permanent and seasonal zones and an increase in Fe with depth in the temporary and upland zones indicative of a reducing water table in the wetter zones and the presence of Fe yielding saprolite at depth in the rocky drier soils. There was very little Mn in the permanent and seasonal zones with the drier soils of the temporary and upland zones having the highest Mn content (Figure 15 D). This is because the Mn would be easily reduced and removed in the wetter zones. There are sufficient nutrients within the soils at Malahlapanga to provide alternate electron acceptors for microbes in the anaerobic process of reduction.

At Nshawu that there was more nitrogen in the wetter zones, probably because these zones have higher organic matter levels. There was also a decrease in nitrogen levels with depth (Figure 20 A). The phosphorous values were more variable with depth than the nitrogen values, and there was much more phosphorous in the wetter zones, most likely attributed also to the higher presence of organic matter (Figure 20 B). The upland zone at Nshawu had the most Fe in the soil with the temporary zone having the least (Figure 20 C). While this cannot be explained it can be noted that the temporary zone was dominated by the presence of calcareous nodules which the other zones did not display. It was found that the wetter zones had the least amounts of Mn, due to the ease of its reduction (Figure 20 D). There were sufficient nutrients within the soils at Nshawu to provide alternate electron acceptors for microbes in the anaerobic process of reduction.

At the Tshutshi spruit there was sufficient nitrogen for reduction to occur (Figure 25 A). There was more nitrogen in the wetter zones as well as in the soil surface, decreasing with depth. The phosphorous was more variable than the nitrogen with depth and there was more phosphorous in the wetter zones (Figure 25B). There was more Fe in the wetter zones at the Tshutshi spruit which was different to the other two wetlands. Values ranged from 10-30 $cmol_c$/kg of Fe with the Fe content decreasing slightly with depth (Figure 25C). The permanent and seasonal zones had the lowest Mn contents. The upland zone had the most Mn, >3 $cmol_c$/kg (Figure 25D). This suggests that the Mn was easily reduced and removed in the wetter zones, but this was not true for Fe.

7.4.2. Organic carbon content

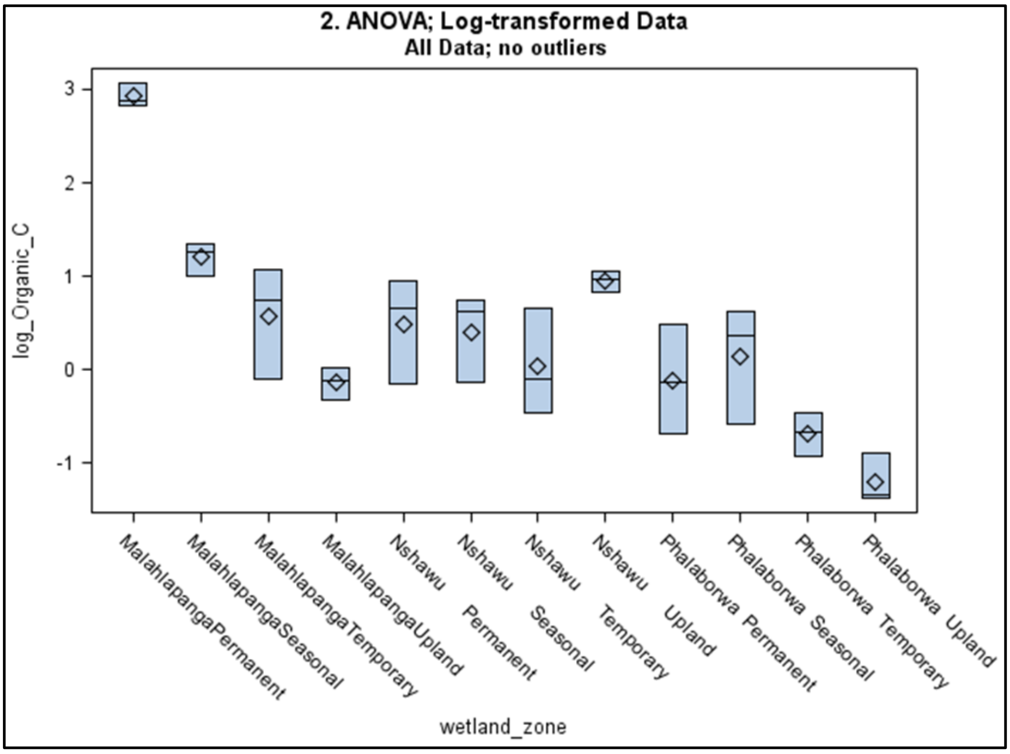


Figure 41 Anova, log transformed graph comparing the organic carbon contents for the three wetlands

At Malahlapanga there was an accumulation of organic carbon in the wetter zones (Figure 14 C). The permanent zone had organic carbon values greater than 5% while the seasonal, temporary and upland zones had less than 5%. This suggests that there was adequate organic material for microbial respiration at this wetland and organic carbon was not a limiting factor for reduction.

At Nshawu organic carbon contents ranged from 0.5% to 3% with sufficient organic carbon within the top 500 mm of the soil profile for reduction to take place (Figure 19 C). There was more organic carbon in the drier upland zone than the wetter zones, presumably because of the lower vegetation biomass (no trees) in the wetter zones and the utilization by microbes.

The organic carbon at the Tshutshi spruit were predominately low with the majority of samples having organic carbon contents of less than 1% (Figure 24 C). This wetland had the lowest carbon content of the three wetlands (Figure 41). While vegetation at this site was abundant, the low organic carbon contents suggest a fast rate of mineralization which could be attributed to the sandier texture of the soil. The low carbon content could therefore be inhibiting reduction.

7.4.3. Hydrology

The hydrological data was presented and the systems where characterised and described in chapter 5. To summarise: the water table was within the top 0.5 m of the profile only in the permanent zone at Malahlapanga, the permanent and seasonal zones at Nshawu and within 300 mm after the January 2013 floods in the temporary zone. At Nshawu there was some paint removal from the IRIS tubes when the soil was not 100% saturated, however, there was not enough paint removal to meet the criteria for wetland conditions. At the Tshutshi spruit, the water table only rose within the top 0.5 m for all of the zones during the January 2013 floods, despite the presence of hydrophytes.

7.5. Evaluation of the method

7.5.1. Advantages

The advantages of the IRIS methodology are that it is in a good agreement with the DWAF (2005) indicators with the only exception being under high pH environments, where Fe may not be the best electron acceptor for the environment (Table 23). A further advantage of this method is that it is time integrated, most other methods only provide a snapshot into the conditions at that point in time. There is a wide range of potential applications in South Africa, such as in soils whose parent materials contain insufficient Fe to express soil morphological features associated with fluctuating water tables - e.g. the coastal sandy plains. In the urban environment there are also a wide range of applications due to areas often being disturbed, changes in hydrology, disturbance of the natural horizon sequence, ploughing, and the clearing or burning of vegetation. This method would be able to ascertain whether or not the area is functioning as a wetland and detect if reduction is actually occurring. The method has potential application as it could be utilised in the consulting sector by individuals who do not specifically have an in depth knowledge of soil science but would be able to install and retrieve the IRIS tubes and follow procedures to analyse them. Lastly, there is already substantial literature available describing the method.

7.5.2. Limitations

The disadvantages (Table 23) of the method are problems such as scratching (which could be rectified by refining the paint recipe using a more accurate XRD analysis in order to determine the optimal goethite concentrations for abrasion resistance and ease of reduction of the paint). When the tubes are stained it causes problems when analysing via scanning, but then visual estimation would be more accurate. The logistics in scanning round tubes create hassles. Modifying a flatbed scanner, using multiple scans per tube, converting images on Photoshop, are all very labour intensive. Perhaps using a flat sheet would be easier to analyse using photos, higher quality, less distortion and labour in cropping images and stitching as suggested by Gale (2008). However, this might be harder to install. There is a lot of time and expense that goes into constructing the tubes, installing them, analysing them so that it does not make economic sense to use them in every wetland delineation, but rather in cases where a high degree of accuracy is required and with larger budgets where more is at stake. It would then be a helpful tool. The study showed that the tubes did not perform well in a high pH environment or in the calcareous soils.

Perhaps different elements could be explored such as Mn being higher up in the electron reaction sequence would have merit. Further work is therefore required to test the MIRIS tubes in various different environments.

Table 23 Summary of pro's and con's encountered regarding the IRIS tube methodology

Pro's	Con's
• Time integrated	• Scratching, staining and fading
• Successfully detects reduction	• Damage by animals and people
• Use in soils whose parent material does not contain sufficient Fe to show indicators	• Logistics in scanning round tube
• Disturbed wetlands where indicators have been removed	• Expense, time and expertise required in analysing tubes
• Requires little training to install and retrieve	• High pH environments and calcareous soils

7.6. Conclusion

There was generally a strong agreement between the DWAF (2005) indicators and the IRIS data. However, at the Tshutshi spruit, the high pH inhibited the reduction of Fe and so the wetland indicators were not in agreement with the IRIS results. The use of MIRIS tubes should be explored in order to find an element that is reducing in the system. It would seem that one would obtain the best results from the IRIS tubes in the rainy season, but systems such as Malahlapanga which are not governed by rainfall within the catchment would have to be treated differently. Thus an understanding of the nature of the hydrology of the system is important for knowing when to install the tubes - i.e. installing IRIS tubes in the summer months in the winter rainfall region would be impractical. One must also take the climate and hydrology of the system into account. Another example would be pans, which only flood every 50-100 years, and would be impossible to delineate during the dry years unless they are solely ground water fed. There are both advantages and disadvantages of the method. As mentioned earlier the IRIS tubes did not perform well in a sodic, high pH environment. Scratching and staining of the tubes was problematic for the analysis phase and could be overcome by refining the paint mineralogy as well as visually estimating paint removal or using mylar grids in cases when tubes are badly stained by organic matter. It is not feasible in terms of time and expense to use the method for every wetland delineation, but in problem cases such as described in the literature review, IRIS tubes offer a useful tool for wetland practitioners to definitively determine whether reducing conditions are actively occurring within a wetland. There is a need for further studies to test the IRIS tubes in different areas within South Africa and also a need to determine a technical standard to delineate sodic wetlands.

8. Conclusions

8.1. Introduction

The following chapter will summarise the main findings of the study. Each of the three objectives will be addressed. The IRIS methodology will be evaluated for implementation in South Africa and areas for future research will be identified.

8.2. Charactisation of the wetlands

8.2.1. Malahlapanga

Malahlapanga had a permanent source of water due to the fractured geology of the area. This resulted in the favourable conditions required for peat formation. The accumulation of organic material and the accumulation of salts from the artesian water influenced the chemistry of this system. There was evidence to suggest that there had been a fire in the past, due to the presence of an ash layer which resembled an E horizon. The system was under pressure from animal activity, due to it being the only water point for many kilometres, and this was observed in the vegetation data, particularly in the seasonal and temporary zones.

8.2.2. Nshawu

Nshawu was basic and there was an abundance of carbonate nodules noted, especially at the wetland boundary. This can be attributed to the Basaltic parent material. The accumulation of carbonates in the temporarily saturated zones resulted in high coarse size fractions and a distinct change in morphology. At Nshawu there was a higher variety of vegetation species recorded than at any of the other wetlands. This may be attributed to the more “fertile” parent material or the amount of water available within this catchment.

8.2.3. Tshutshi spruit

Because of the high exchangeable sodium (>15%) at this site, yielded by the Granitic parent material, the pH was incredibly high. This meant that conditions were not necessarily favourable for the reduction of Fe unless the water were to stagnate for an extended period of time. The wetland was mostly dry thought the year with the only exception being during the January 2013 Floods. This system had the highest number of alien species noted out of the three wetlands.

8.3. Evaluation of the IRIS tube methodology

8.3.1. Success in documenting reducing conditions

The IRIS tubes were successful in documenting reducing conditions. In chapter 6, the IRIS results related well to the DWAF (2005) wetland indicators and the two methods were generally in agreement. There was a strong agreement in the permanently saturated zone at Malahlapanga as well as in the permanently and seasonally saturated zones at Nshawu. At the Tshutshi spruit the method was not in agreement, but the reason for this discrepancy is linked to the chemistry of the system which will be elaborated on.

It was noted at Nshawu that 100% saturation was not required in order for the onset of reduction of Fe. This confirmed what was found to be the case in the work done by Smith and Van Huyssteen (2011; 2013). They found that reduction occurred at 70% saturation. Because of the higher clay content at Nshawu, it is hypothesised that the pore size distribution was finer than the soils at the other two wetlands and hence the capillary fringe was much higher and resulted in areas within the soil matrix where reduction was possible despite the water table falling below this depth.

It was found that the best IRIS results were obtained after large rainfall events during the growing season. However, at Malahlapanga the system was not fed by rainfall but rather by groundwater and so meaningful results were obtained year round. Thus it is important to understand the hydrological drivers of each wetland in order to know when the best time to install the IRIS tubes would be. Also, it must be noted that it is always stated to perform wetland studies in the wet summer months but in the Cape, rainfall is received in winter rather than summer and so it is important to look both at the hydrology and climate region that the wetland falls within when deciding when to install the tubes for the optimum results.

As mentioned earlier, at the Tshutshi spruit there was not agreement between the IRIS results and the DWAF (2005) indicators. While the soil wetness, vegetation, soil form (partially) and terrain unit were met there was no reduction recorded from the IRIS tubes. It was a very dry year over the study but despite the January 2013 floods no substantial reduction was noted from the tubes in order to declare the area wetland. The reason is probably the high pH levels that were recorded in the soil. The wetland was adjacent to a sodic site and pH values as high as 11.36 (H_2O) were recorded. The implication of this is that in order for the onset of the reduction of Fe to take place, the soil would have to be inundated for a very long period of time as the conditions were not favourable for the reduction of Fe. Perhaps the use of MIRIS tubes would be more successful in documenting reducing conditions as Mn is higher up in the reduction reaction sequence.

8.3.1.1. Practicality of the method

In terms of practicality of the method, the tubes proved easy enough to install and retrieve and could be done by an individual with no experience in soil science. However, the majority of work is in the construction of the tubes themselves and in the analysis of the tubes after retrieval. Due to the need of a centrifuge, the synthesis of the paint requires a laboratory which is not always accessible for most environmental consultants. However, if it were possible to purchase ready-made tubes this would make it more accessible for the commercial sector. In terms of the financial feasibility of using the tubes, it would certainly be feasible for a large wetland delineation project however not practical from a time perspective for everyday wetland delineations. It is believed that the tubes would be a useful tool in cases where DWAF (2005) indicators are not present and where a high degree of accuracy in the delineation is required i.e. big budget urban developments.

8.3.1.2. Problems encountered

One of the processes identified in the method as being tedious and cumbersome was the scanning of the IRIS tubes. One has to modify a flatbed scanner in order to limit the distortion of the image as the tubes are round and cannot be photographed. If an A4 scanner is modified, the width of the scanner is such that 2 scans have to be done per IRIS tube which adds labour. Each greyscale image has to be converted to black and white with each image having a unique threshold value because of the variation of the paint colour on the tubes, atmospheric lighting, as well as lighting variations from the scanner itself. Threshold values had to be worked out through trial and error for each image in order to accurately represent what was seen on the tubes to be paint removal via reduction. Only after this was done could the percentage of black and white pixels be calculated. The images also had to be cropped to the correct size and a total value of paint removal be calculated from the two image. This was time consuming but with a larger scanner could possibly be streamlined. However, the process still would require a lot of time when dealing with the number of tubes especially in this particular study: 180 tubes/ month over 13 months each with 2 images per tube, a total of 4680 scans! Because of the sheer number of scans only the tubes that had paint removal were scanned, so while the number of tubes was less than this it was still a large volume of work. A solution was proposed by Gale (2008), by having flat sheets rather than round tubes. This would increase the effort in installation but would greatly reduce the work involved in analysing the tubes. One would then be able to use a photograph instead of a scan which would have less distortion, a higher quality image and hence a higher degree of accuracy.

Another problem that was identified was that of the paint mineralogy and the susceptibility of the paint to abrasion. Work has been done by Rabenhorst and Burch (2006) into the optimum percentage of goethite and ferrihydrite required to ensure ease of reduction but also maximum resistance to abrasion. More work could have been done in this study on perfecting the mineral composition of the paint. In the paint samples that were sent to be analysed via XRD, they came back as being identified as goethite only. A more sensitive analysis needs to be conducted to differentiate the relative percentages of the various Fe oxide minerals to know when the paint is ready to be applied.

8.3.2. Limitations of the study

In hindsight, while it was prudent to determine when the best results were found during the year and to document seasonal variation, it would be suggested for future studies to rather test more wetlands rather than the tubes in dry months as it was a waste of resources. The chemistry of the wetlands had an influence on the success of the method and so it would be suggested to test the tubes in the different wetland types that occur across South Africa. Due to the sheer number of tubes that were collected over a year at 3 wetland with repetitions it was not possible to test both the NTCHS and Rabenhorst's criteria to see which performed best due to time constraints.

8.3.3. Potential applications

The use of IRIS tubes in South Africa has much potential especially in urban environments, in wetlands which are exceptions to the norm, in testing the success of artificial wetland as well as in remediation efforts. Often in urban environments there has been much disturbance and so the soils may be disrupted by excavation, dumping and the digging of canals. The vegetation is usually disturbed and not in a natural state, it is often cleared, burnt or invaded by alien vegetation. IRIS tubes would provide a solution in urban wetlands where the normal indicators are absent for various anthropogenic reasons. The tubes would also be of use in situations where there are exceptions to the norms, such as in the case of the PAP site where there was difference in opinion regarding the presence of a wetland at the site. By having a technical standard such as the IRIS tubes, it would be able to provide a definitive answer whether or not reduction was indeed occurring. Artificial wetlands are increasing in popularity in the purification of waste water and sequestration of contaminants in both sewage as well as water in mining environments. The IRIS tubes could be used in order to establish whether the success of the chemical conditions required for reduction and also the immobilization of potential contaminants are met. The tubes could also be implemented in remediation projects to assess whether or not the hydrology and functioning of the wetland has indeed been restored.

8.4. Lithology and wetland indicators

It was found that the terrain unit indicator performed well for each lithology when the lower foot slope was included as a position in the landscape where wetlands are likely to occur. The soil form indicator performed well for the Gneiss and Basalt wetland but was misleading for the Granite wetland. The soil wetness indicator did not perform well for any of the wetlands as it could not distinguish between seasonal and temporary zones at the Gneiss wetland, it did not distinguish the temporary zone at the Basalt wetland and it implied that all four of the zones at the Granitic wetland were wet. The vegetation indicator performed well at all three of the different wetlands. When consulting the ancillary data, it was found that pH, organic carbon and exchangeable sodium showed a pleasing trend for all 3 of the lithologies (with the exception of the upland zone at Nshawu). However, the Granitic wetland showed opposite trends to the Basalt and Gneiss wetland when referring to the Fe and Mn data.

8.5. Further research

While the study concludes that IRIS tubes are successful in documenting reducing conditions and the results relate well to the current DWAF (2005) indicators, there are wetlands that are not favourable to the reduction of Fe. It is therefore suggested that the tubes continue to be tested in a wider range of wetland systems to address the limitations of this study. An area which would provide a useful insight would be in the coastal aquifer systems where the soils are particularly sandy and often do not show soil morphology indicative of their hydrological regimes due to insufficient Fe. It is also suggested that MIRIS tubes be tested concurrently with the IRIS tubes to provide further clarity in those wetlands which are not favourable to the reduction of Fe such as the Tshutshi spruit. In future studies it would be suggested to test the two criteria for analysis to determine which performs best under South African conditions.

CW Van Huyssteen

9. References

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Appendix A

- The soil chemical and physical analytical data measured in the laboratory.
- Statistical analysis of soil data.

Table 24 Laboratory analyses for the permanent zones at Malahlapanga

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
M1P 0-50	Malahlapanga	1	Permanent	M1P	0	50	25	401	1604,00											4,82	4,9	71	16,43	28,26	1340	0,31	2061,83	27,37														
M1P 50-100	Malahlapanga	1	Permanent	M1P	50	100	75	402	536,00											5,06	5,07	120	18,35	31,56	1590	0,52	1869,62	20,53														
M1P 100-150	Malahlapanga	1	Permanent	M1P	100	150	125	403	322,40											5,5	5,47	150	18,19	31,28	1590	0,36	1820,70	18,25														
M1P 150-200	Malahlapanga	1	Permanent	M1P	150	200	175	404	230,86											5,8	5,64	430	18,02	30,99	1520	0,13	2131,72	15,97														
M1P 200-250	Malahlapanga	1	Permanent	M1P	200	250	225	405	180,00											5,81	5,66	282	17,45	30,01	1350	0,07	1855,65	11,41														
M1P 250-300	Malahlapanga	1	Permanent	M1P	250	300	275	406	147,64											6,41	6,36	226	18,02	30,99	1380	0,05	1163,71	9,12														
M1P 300-400	Malahlapanga	1	Permanent	M1P	300	400	350	407	116,29											6,85	6,97	158	17,77	30,56	1430	0,06	555,65	4,56														
M1P 400-500	Malahlapanga	1	Permanent	M1P	400	500	450	408	90,67											7,31	7,31	168	17,51	30,12	1130	0,03	990,73	4,56														
M1P 500-600	Malahlapanga	1	Permanent	M1P	500	600	550	409	74,36											6,88	7	150	17,63	30,32	830	0,04	782,80	6,84														
M1P 600-700	Malahlapanga	1	Permanent	M1P	600	700	650	410	63,08											7,28	7,41	180	13,31	22,89	750	0,02	1778,76	4,56														
M1P 700-800	Malahlapanga	1	Permanent	M1P	700	800	750	411	54,80											7,42	7,51	180	11,67	20,07	740	0,13	1106,05	6,84														
M1P 800-900	Malahlapanga	1	Permanent	M1P	800	900	850	412	48,47											7,05	7,24	160	9,42	16,20	670	0,13	744,35	6,84														
M1P 900-1000	Malahlapanga	1	Permanent	M1P	900	1000	950	413	43,47											7,36	7,68	154	5,40	9,29	500	0,23	714,65	4,56														
M1P 1000-1100	Malahlapanga	1	Permanent	M1P	1000	1100	1050	414	39,43											7,85	8	140	2,39	4,11	330	0,63	557,39	4,56														
M1P 1100-1200	Malahlapanga	1	Permanent	M1P	1100	1200	1150	415	36,09											7,27	7,87	119	2,87	4,94	330	0,19	933,06	4,56														
M2P 0-50	Malahlapanga	2	Permanent	M2P	0	50	25	416	1664,00											5,04	5,23	81	22,04	37,91	2090	0,32	2170,16	100,36														
M2P 50-100	Malahlapanga	2	Permanent	M2P	50	100	75	417	556,00											5,08	5,08	109	22,71	39,06	1920	0,17	2147,45	29,65														
M2P 100-150	Malahlapanga	2	Permanent	M2P	100	150	125	418	334,40											5,05	5,03	112	20,73	35,66	2180	0,20	2883,06	11,41														
M2P 150-200	Malahlapanga	2	Permanent	M2P	150	200	175	419	239,43											5,56	5,57	132	20,37	35,04	1880	0,13	2089,78	4,56														
M2P 200-250	Malahlapanga	2	Permanent	M2P	200	250	225	420	186,67											4,9	4,91	136	21,29	36,62	2360	0,15	1829,44	9,12														
M2P 250-300	Malahlapanga	2	Permanent	M2P	250	300	275	421	153,09											5,46	5,64	162	22,03	37,88	1870	0,14	1853,90	4,56														
M2P 300-400	Malahlapanga	2	Permanent	M2P	300	400	350	422	120,57											5,12	5,27	120	22,76	39,15	2100	0,14	1707,12	6,84														
M2P 400-500	Malahlapanga	2	Permanent	M2P	400	500	450	423	94,00											5,27	5,38	150	14,48	24,91	1260	0,03	1452,02	9,12														
M2P 500-600	Malahlapanga	2	Permanent	M2P	500	600	550	424	77,09											6,25	6,29	214	15,39	26,47	600	0,08	681,45	4,56														
M2P 600-700	Malahlapanga	2	Permanent	M2P	600	700	650	425	65,38											6,45	6,48	190	18,38	31,61	920	0,29	497,98	6,84														
M2P 700-800	Malahlapanga	2	Permanent	M2P	700	800	750	426	56,80											6,13	6,2	152	19,40	33,37	750	0,15	1186,42	4,56														
M2P 800-900	Malahlapanga	2	Permanent	M2P	800	900	850	427	50,24											6,55	6,54	140	20,42	35,12	850	0,23	950,54	6,84														
M2P 900-1000	Malahlapanga	2	Permanent	M2P	900	1000	950	428	45,05											6,87	6,88	138	14,34	24,66	920	0,21	1673,92	11,41														
M2P 1000-1100	Malahlapanga	2	Permanent	M2P	1000	1100	1050	429	40,86											7,42	7,49	126	14,01	24,10	580	0,53	1065,86	11,41														
M2P 1100-1200	Malahlapanga	2	Permanent	M2P	1100	1200	1150	430	37,39											6,46	6,65	118	13,25	22,79	840	0,23	3162,63	15,97														
M3P 0-50	Malahlapanga	3	Permanent	M3P	0	50	25	431	1724,00											5,31	5,36	114			850	0,18	2005,91	11,41														
M3P 50-100	Malahlapanga	3	Permanent	M3P	50	100	75	432	576,00											5,63	5,42	250	17,64	30,34	110	0,24	2019,89	9,12														
M3P 100-150	Malahlapanga	3	Permanent	M3P	100	150	125	433	346,40											5,92	5,83	178	22,01	37,86	920	0,23	1340,19	6,84														
M3P 150-200	Malahlapanga	3	Permanent	M3P	150	200	175	434	248,00											5,24	5,3	114	19,38	33,33	940	0,24	2876,08	13,69														
M3P 200-250	Malahlapanga	3	Permanent	M3P	200	250	225	435	193,33											6,21	6,1	152	21,93	37,72	770	0,06	849,19	6,84														
M3P 250-300	Malahlapanga	3	Permanent	M3P	250	300	275	436	158,55											6,23	6,15	166	19,77	34,00	840	0,06	1168,95	9,12														
M3P 300-400	Malahlapanga	3	Permanent	M3P	300	400	350	437	124,86											6,46	6,4	160	17,60	30,27	50	0,07	2150,94	11,41														
M3P 400-500	Malahlapanga	3	Permanent	M3P	400	500	450	438	97,33											6,32	6,72	130	9,95	8,38	350	0,30	1079,84	15,97														
M3P 500-600	Malahlapanga	3	Permanent	M3P	500	600	550	439	79,82											8,03	7,79	144	5,73	7,16	110	0,08	450,81	6,84														
M3P 600-700	Malahlapanga	3	Permanent	M3P	600	700	650	440	67,69											7,91	7,77	140	2,00	3,44	110	0,20	557,39	13,69														
M3P 700-800	Malahlapanga	3	Permanent	M3P	700	800	750	441	58,80											8,09	7,89	132	1,54	2,65	70	0,47	499,73	13,69														
M3P 800-900	Malahlapanga	3	Permanent	M3P	800	900	850	442	52,00											8	7,96	178	1,73	2,98	90	0,15	443,82	11,41														
M3P 900-1000	Malahlapanga	3	Permanent	M3P	900	1000	950	443	46,63											8,17	8,06	134	1,40	2,41	90	0,07	365,19	9,12														
M3P 1000-1100	Malahlapanga	3	Permanent	M3P	1000	1100	1050	444	42,29											8,16	8,09	154	1,43	2,46	90	0,08	340,73	9,12														
M3P 1100-1200	Malahlapanga	3	Permanent	M3P	1100	1200	1150	445	38,70											8,22	8,1	128	1,28	2,20	160	0,10	312,77	9,12														

Table 25 Laboratory analyses for the seasonal zones at Malahlapanga

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
M1S 0-50	Malahlapanga	1	Seasonal	M1S	0	50	25	446	1784,00											4,97	5,71	30,5	5,33	9,17	7810	0,21	3826,61	45,62	0,66	0,66	0,06	0,35	17,99	1,80	1,46	13,59	19,57		22,97	178,05	0,69	69,44
M1S 50-100	Malahlapanga	1	Seasonal	M1S	50	100	75	447	596,00	5,88	3,86	4,64	7,85	10,82	33,93	30,34	22,23	44,75	30,34	4,99	5,56	47	5,18	8,91	7720	0,22	3477,15	22,81	0,45	0,19	0,03	0,38	13,79	1,09	1,11	15,33	22,50	74,17	17,04	139,14	1,03	68,12
M1S 100-150	Malahlapanga	1	Seasonal	M1S	100	150	125	448	358,40											5,18	5,64	97	3,95	6,79	5010	0,18	2414,78	13,69	0,60	0,06	0,01	5,30	16,26	0,72	0,75	7,28	33,59		23,71	74,48	0,43	21,68
M1S 150-200	Malahlapanga	1	Seasonal	M1S	150	200	175	449	256,57	3,53	2,42	3,47	6,54	10,63	33,72	35,42	15,96	44,35	35,42	5,52	5,94	162	2,99	5,14	3770	0,55	2390,32	13,69	0,34	0,03	0,01	3,79	15,64	0,66	0,68	5,02	26,63	75,18	21,15	82,61	0,31	18,86
M1S 200-250	Malahlapanga	1	Seasonal	M1S	200	250	225	450	200,00											5,75	6,38	200	2,27	3,90	3110	0,35	2549,33	15,97	0,24	0,02	0,01	0,43	16,35	0,64	0,61	4,09	25,33		18,29	85,60	0,24	16,14
M1S 250-300	Malahlapanga	1	Seasonal	M1S	250	300	275	451	164,00	10,04	6,30	6,89	7,94	12,01	33,24	22,64	31,17	45,25	22,64	5,95	6,51	272	1,34	2,30	2150	0,07	1983,20	22,81	0,17	0,02	0,01	0,32	16,93	0,78	1,55	3,53	20,65	91,21	19,77	110,35	0,20	17,11
M1S 300-400	Malahlapanga	1	Seasonal	M1S	300	400	350	452	129,14	5,90	3,59	4,10	7,75	8,49	32,17	33,10	21,34	40,66	33,10	5,79	6,83	315	0,62	1,07	1680	0,15	1376,88	15,97	0,16	0,02	0,01	0,32	10,94	0,49	0,45	2,64	13,59	41,05	12,38	106,85	0,23	19,44
M1S 400-500	Malahlapanga	1	Seasonal	M1S	400	500	450	453	100,67	17,22	8,48	7,91	7,08	8,51	22,70	23,43	40,68	31,21	23,43	5,89	6,71	405	1,16	2,00	1690	0,12	2738,04	31,93	0,11	0,02	0,01	0,23	16,84	0,74	0,47	2,97	20,54	87,66	18,40	102,27	0,17	14,44
M1S 500-600	Malahlapanga	1	Seasonal	M1S	500	600	550	454	82,55	18,83	8,91	8,21	5,88	5,69	19,49	30,42	41,83	25,18	30,42	5,76	6,34	375	1,05	1,81	1600	0,12	3337,37	27,37	0,08	0,02	0,01	0,19	18,23	0,90	0,49	3,10	14,78	48,59	19,91	153,67	0,16	20,96
M1S 600-700	Malahlapanga	1	Seasonal	M1S	600	700	650	455	70,00	16,79	8,20	7,94	6,33	2,94	27,25	25,76	39,26	30,19	25,76	5,53	5,9	415	1,24	2,13	1680	0,09	3739,25	18,25	0,08	0,02	0,01	0,18	18,79	0,98	0,49	3,07	23,37	90,71	20,55	99,82	0,16	13,12
M1S 700-800	Malahlapanga	1	Seasonal	M1S	700	800	750	456	60,80	15,09	8,61	7,90	6,09	7,51	26,23	29,11	37,69	33,74	29,11	5,66	5,84	395	1,43	2,46	1860	0,07	3809,14	15,97	0,08	0,02	0,01	0,19	22,13	1,29	0,54	3,51	23,15	79,53	24,25	118,62	0,15	15,16
M1S 800-900	Malahlapanga	1	Seasonal	M1S	800	900	850	457	53,76	15,05	9,41	9,15	6,03	6,26	16,97	37,22	39,64	23,24	37,22	5,74	6,4	310	0,39	0,67	760	0,17	4997,31	15,97	0,03	0,01	0,01	0,16	21,50	1,45	0,61	3,64	22,72	61,03	23,78	119,78	0,16	16,03
M1S 900-1000	Malahlapanga	1	Seasonal	M1S	900	1000	950	458	48,21	13,34	8,51	8,51	5,91	5,75	19,50	36,58	36,26	25,24	36,58	6,08	6,87	280	0,14	0,24	420	0,71	3581,99	20,53	0,04	0,01	0,01	0,14	24,13	1,76	0,73	3,93	27,07	73,99	26,81	112,88	0,15	14,54
M1S 1000-1100	Malahlapanga	1	Seasonal	M1S	1000	1100	1050	459	43,71	12,80	8,49	9,80	2,29	9,63	16,82	38,01	33,37	26,45	38,01	6,12	6,9	260	0,15	0,26	390	0,09	2428,76	20,53	0,05	0,02	0,01	0,16	24,00	1,80	0,83	4,07	19,67	51,76	26,86	156,04	0,16	20,66
M1S 1100-1200	Malahlapanga	1	Seasonal	M1S	1100	1200	1150	460	40,00	14,63	8,93	9,06	7,19	7,74	25,99	29,78	39,81	33,73	29,78	5,94	7,56	222	0,61	1,05	410	0,10	3127,69	22,81	0,07	0,02	0,01	0,20	23,25	1,76	0,70	3,70	21,63	72,64	26,01	135,94	0,15	17,09
M1S 1200-1300	Malahlapanga	1	Seasonal	M1S	1200	1300	1250	461	36,88	18,51	8,48	11,39	3,56	7,15	22,81	33,59	41,94	29,97	33,59	5,56	7,18	144	0,16	0,28	440	0,12	4053,76	22,81	0,09	0,02	0,01	0,17	27,00	1,99	0,74	3,45	18,59	55,33	30,01	178,45	0,12	18,54
M2S 0-50	Malahlapanga	2	Seasonal	M2S	0	50	25	462	1848,00											5,52	6,55	67	4,36	7,50	380	0,22	4228,49	63,87	2,28	0,75	0,08	0,38	26,38	1,60	1,85	2,66	24,89		33,32	130,53	0,10	10,70
M2S 50-100	Malahlapanga	2	Seasonal	M2S	50	100	75	463	617,33	4,96	4,06	5,47	9,14	14,49	36,64	26,79	23,63	51,12	26,79	5,47	6,37	77	3,67	6,31	510	0,07	6797,04	41,06	1,66	0,52	0,05	6,70	28,00	1,74	1,25	3,34	21,85	81,57	39,92	157,14	0,11	15,27
M2S 100-150	Malahlapanga	2	Seasonal	M2S	100	150	125	464	371,20											5,35	6,44	74	2,39	4,11	160	0,44	4647,85	15,97	1,44	0,24	0,03	7,48	23,63	1,39	0,83	3,63	22,93		35,03	128,54	0,15	15,83
M2S 150-200	Malahlapanga	2	Seasonal	M2S	150	200	175	465	265,71	6,49	4,07	4,65	6,55	9,51	33,22	31,69	21,76	42,73	31,69	5,44	6,32	70	2,91	5,01	320	0,13	6500,00	25,09	1,42	0,59	0,03	7,65	19,50	1,99	1,06	3,68	21,41	67,56	32,24	122,51	0,17	17,21
M2S 200-250	Malahlapanga	2	Seasonal	M2S	200	250	225	466	207,11											5,36	6,3	87	1,85	3,18	100	0,18	2341,40	13,69	1,24	0,14	0,02	6,00	17,78	1,13	0,65	3,24	18,48		26,95	123,32	0,17	17,53
M2S 250-300	Malahlapanga	2	Seasonal	M2S	250	300	275	467	169,82	11,90	7,95	8,28	7,76	9,05	20,37	32,72	35,89	29,42	32,72	5,45	6,45	98	1,15	1,98	320	0,14	2814,92	9,12	0,99	0,08	0,01	4,09	16,13	1,09	0,59	3,85	19,67	60,13	22,97	110,06	0,22	19,56
M2S 300-400	Malahlapanga	2	Seasonal	M2S	300	400	350	468	133,71	19,82	14,38	14,84	8,75	6,96	11,73	23,16	57,79	18,69	23,16	5,94	7,39	132	0,61	1,05	140	0,26	2699,60	9,12	0,24	0,05	0,01	2,77	7,98	1,08	0,37	3,48	15,22	65,70	12,50	84,86	0,38	22,86
M2S 400-500	Malahlapanga	2	Seasonal	M2S	400	500	450	469	104,22	18,39	14,52	16,94	7,74	4,60	9,39	26,47	57,58	13,98	26,49	5,75	6,7	148	0,44	0,76	160	0,36	2865,59	9,12	0,10	0,02	0,01	1,77	8,44	0,90	0,36	3,39	16,96	64,06	11,60	77,20	0,36	20,00
M2S 500-600	Malahlapanga	2	Seasonal	M2S	500	600	550	470	85,45	17,65	14,71	16,92	6,31	6,35	8,15	27,42	55,59	14,51	27,42	5,94	6,85	194	0,24	0,41	140	0,05	2475,94	6,84	0,06	0,01	0,01	1,17	9,65	0,97	0,38	3,65	14,35	52,33	12,24	102,13	0,34	25,45
M2S 600-700	Malahlapanga	2	Seasonal	M2S	600	700	650	471	72,46	16,91	14,90	16,91	4,88	8,11	6,92	28,36	53,60	15,03	28,36	5,94	6,82	206	0,17	0,29	200	0,31	2652,42	13,69	0,06	0,01	0,00	0,92	10,69	1,00	0,39	3,57	21,85	77,02	13,09	71,63	0,30	16,32
M2S 700-800	Malahlapanga	2	Seasonal	M2S	700	800	750	472	62,93	19,95	14,19	16,15	7,22	4,81	5,86	29,61	57,51	10,67	29,61	6,15	6,84	288	0,11	0,19	160	0,23	2184,14	34,22	0,07	0,01	0,00	0,79	12,56	1,16	0,45	3,48	22,61	76,36	15,05	78,08	0,25	15,38
M2S 800-900	Malahlapanga	2	Seasonal	M2S	800	900	850	473	55,65	17,97	15,10	16,53	8,20	4,62	6,87	26,52	57,80	11,49	26,52	6,35	7,1	264	0,09	0,15	70	0,26	2201,61	47,90	0,08	0,02	0,00	0,86	13,11	1,46	0,47	3,65	17,07	64,34	15,99	109,50	0,25	21,40
M2S 900-1000	Malahlapanga	2	Seasonal	M2S	900	1000	950	474	49,89	13,14	12,44	15,81	9,46	5,87	10,76	31,32	50,84	16,63	31,32	6,53	7,61	286	0,11	0,19	340	0,24	2308,20	38,78	0,06	0,02	0,00	0,57	13,49	1,48	0,41	3,22	9,46	30,19	16,03	196,66	0,21	34,02
M2S 1000-1100	Malahlapanga	2	Seasonal	M2S	1000	1100	1050	475	45,24	18,52	11,28	13,63	7,89	6,26	11,70	31,52	51,31	17,96	31,52	6,63	7,55	355	0,12	0,21	90	0,20	1799,73	54,74	0,09	0,01	0,01	0,91	13,43	1,64	0,39	2,52	14,57	46,20	16,48	123,44	0,17	17,31
M2S 1100-1200	Malahlapanga	2	Seasonal	M2S	1100	1200	1150	476	41,39	15,64	12,66	15,83	8,99	5,41	11,87	28,84	53,12	17,29	28,84	6,76	7,64	405	0,09	0,15	160	0,21	2481,18	66,15	0,02	0,01	0,00	0,45	14,55	1,90	0,47	2,70	19,78	68,59	17,40	99,14	0,16	13,63
M3S 0-50	Malahlapanga	3	Seasonal	M3S	0	50	25	477	1908,00											5,38	7,01	31	3,82	6,57	6570	0,26	1869,62	61,59	0,44	0,69	0,14	14,17	21,30	1,69	1,43	5,83	23,80		39,86	127,04	0,25	24,47
M3S 50-100	Malahlapanga	3	Seasonal	M3S	50	100	75	478	637,33	22,71	11,09	10,50	7,55	8,66	18,47	19,95	51,84	27,14	19,95	5,21	6,28	28,8	3,87	6,66	6400	0,48	1799,73	100,36	0,29	0,61	0,12	16,96	37,10	1,69	1,30	7,39	21,20	106,24	58,07	224,03	0,19	34,87
M3S 100-150	Malahlapanga	3	Seasonal	M3S	100	150	125	479	383,20											4,81	5,85	55	3,44	5,92	5730	0,15	1659,95	109,49	0,25	0,09	0,03	4,26	57,40	0,72	0,95	4,00	21,96		63,70	287,26	0,07	18,22
M3S 150-200	Malahlapanga	3	Seasonal	M3S	150	200	175	480	274,29	12,60	6,83	8,52	7,46	9,65	27,17	23,19	35,41	36,82	23,19	4,38	4,98	92	4,21	7,24	6230	0,16	1887,10	31,93	0,19	0,04	0,02	2,00	42,90	0,57	0,84	2,78	29,24	126,08	46,57	161,09	0,06	9,52
M3S 200-250	Malahlapanga	3	Seasonal	M3S	200	250	225	481	213,78											4,27	4,73	124	4,49	7,72	7060	0,39	1799,73	25,09	0,20	0,04	0,01	1,41	14,28	0,51	0,63	2,09	29,24		17,09	59,88	0,14	7,14
M3S 250-300	Malahlapanga	3	Seasonal	M3S	250	300	275	482	175,27	16,03	8,34	8,65	8,02	11,55	24,78	22,72	41,04	36,33	22,72	4,36	5,47	154	3,28	5,64	4970	0,13	1712,37	20,53	0,23	0,04	0,01	1,40	9,51	0,49	0,53	1,65	24,46	107,66	12,21	49,81	0,17	6,76
M3S 300-400	Malahlapanga	3	Seasonal	M3S	300	400	350	483	138,00	20,65	9,77	8,41	6,67	10,36	20,62	22,75	45,50	30,97	22,75	4,37	5,56	200	2,19	3,77	3610	0,11	4280,91	15,97	0,17	0,03	0,01	0,90	7,40	0,46	0,42	1,83	23,48	103,19	9,38	43,06	0,23	7,78
M3S 400-500	Malahlapanga	3	Seasonal	M3S	400	500	450	484	107,56	13,25	8,79	9,65	7,72	10,58	20,23	26,99	39,40	30,82	26,99	4,32	5,22	230	1,97	3,39	3110	0,08	3127,69	11,41	0,14	0,02	0,00	0,84	6,87	0,48	0,39	1,57	21,41	79,33	8,74	43,43	0,21	7,31
M3S 500-600	Malahlapanga	3	Seasonal	M3S	500	600	550	485	88,18	18,20	11,46	11,26	6,76	10,01	15,64	23,89	47,68	25,65	23,89	4,34	5,07	216	1,50	2,58	2420	0,07	3092,74	13,69	0,12	0,02	0,01	0,81	7,51	0,52	0,35	1,39	17,93	75,07	9,34	54,50	0,17	7,76
M3S 600-700	Malahlapanga	3	Seasonal	M3S	600	700	650	486	74,77	23,15	14,13	12,87	5,80	9,43	11,04	20,79	55,96	20,47	20,79	4,42	5,09	207	1,29	2,22	2090	0,33	3232,53	13,69	0,18	0,04	0,01	0,81	7,93	0,57	0,34	1,65	19,24	92,55	9,87	54,54	0,19	8,59
M3S 700-800	Malahlapanga	3	Seasonal	M3S	700	800	750	487	64,93	21,29	12,75	13,25	7,10	6,12	10,27	25,59	54,39	16,39	25,59	4,35	5,68	183	1,64	2,82	1090	0,29	3442,20	15,97	0,08	0,02	0,00	0,70	8,45	0,66	0,43	1,65	15,43	60,31	10,33	72,48	0,18	10,70
M3S 800-900	Malahlapanga	3	Seasonal	M3S	800	900	850	488	57,41	22,57	14,66	14,73	8,04	5,94	8,24	23,58	60,00	14,17	23,58	4,58	6,9	172	0,22	0,38	830	0,24	1754,30	15,97	0,05	0,01	0,01	0,68	9,29	0,70	0,40	1,91	14,13	59,93	11,14	87,10	0,19	13,54
M3S 900-1000	Malahlapanga	3	Seasonal	M3S	900	1000	950	489	51,47	20,84	15,27	17,23	9,44	5,77	6,32	20,87	62,77	12,09	20,87	4,72	6,83	164	0,19	0,33	490	0,32	1721,10	18,25	0,04	0,01	0,01	0,63	10,35	0,79	0,42	1,83	13,70	65,63	12,24	97,71	0,16	13,33
M3S 1000-1100	Malahlapanga	3	Seasonal	M3S	1000	1100	1050	490	46,67	17,71	12,38	13,60	7,62	5,37	10,09	28,84	51,31	15,46	28,84	5,15	7,34	150	0,74	1,27	490	0,27	1308,74	27,37	0,04	0,01	0,01	0,76	9,76	0,74	0,40	1,91	13,04	45,22	11,71	98,25	0,18	14,67
M3S 1100-1200	Malahlapanga	3	Seasonal	M3S	1100	1200	1150	491	42,70	14,58	9,50	9,96	5,81	4,98	13,86	36,82	39,86	18,84	36,82	5,69	7,46	134	0,16	0,28	490	0,23	2056,59	86,68	0,05	0,02	0,01	0,85	15,75	1,13	0,60	2,61	19,57	53,14	18,42	102,70	0,15	13,33

Table 26 Laboratory analyses for the temporary zones at Malahlapanga

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
M1T 0-50	Malahlapanga	1	Temporary	M1T	0	50	25	492	1968,00											6,07	6,5	350	2,69	4,63	6040	0,63	4438,17	100,36	0,17	0,06	0,05	0,45	10,25	1,87	2,83	0,87	23,48		15,68	67,37	0,07	3,70
M1T 50-100	Malahlapanga	1	Temporary	M1T	50	100	75	493	657,33	15,22	11,77	7,84	5,32	7,71	26,76	27,26	40,15	34,47	27,26	5,54	6,39	370	3,18	5,47	9140	0,44	5119,62	136,86	0,18	0,05	0,03	0,46	11,96	2,00	2,13	0,78	27,39	100,49	16,81	61,59	0,06	2,86
M1T 100-150	Malahlapanga	1	Temporary	M1T	100	150	125	494	395,20											5,26	5,86	228	4,08	7,02	7400	0,28	6150,54	145,99	0,49	0,12	0,03	0,93	15,17	2,18	1,91	1,13	32,93		20,83	61,91	0,07	3,43
M1T 150-200	Malahlapanga	1	Temporary	M1T	150	200	175	495	282,86	4,97	2,68	4,02	5,16	3,31	33,50	40,95	16,83	36,81	40,95	5,29	5,78	184	3,89	6,69	9270	0,75	5801,08	111,77	0,55	0,10	0,01	1,34	21,90	1,89	0,75	1,83	33,26	81,22	26,53	79,25	0,08	5,49
M1T 200-250	Malahlapanga	1	Temporary	M1T	200	250	225	496	220,44											5,59	6,04	204	2,82	4,85	5900	0,56	4455,65	132,30	0,34	0,06	0,00	1,30	22,20	1,30	0,39	2,17	30,22		25,60	86,25	0,09	7,19
M1T 250-300	Malahlapanga	1	Temporary	M1T	250	300	275	497	180,73	5,79	3,86	3,86	4,82	8,95	30,26	39,06	18,33	39,21	39,06	5,79	6,43	176	0,95	1,63	4380	0,29	3983,87	95,80	0,36	0,05	0,00	1,51	25,50	1,13	0,45	2,87	30,33	77,63	29,00	98,75	0,11	9,46
M1T 300-400	Malahlapanga	1	Temporary	M1T	300	400	350	498	142,29	8,05	3,93	4,91	5,04	7,69	30,58	36,99	21,91	38,27	36,99	5,92	6,51	186	1,80	3,10	3770	0,32	4350,81	38,78	0,28	0,03	0,00	1,49	25,80	0,85	0,41	3,48	28,37	76,69	28,87	107,67	0,13	12,26
M1T 400-500	Malahlapanga	1	Temporary	M1T	400	500	450	499	110,89	8,39	5,61	4,58	6,32	28,58	36,55	0,11	24,91	65,13	0,11	5,99	6,73	174	1,42	2,44	2610	0,07	5469,09	15,97	0,17	0,02	0,00	1,54	19,90	0,85	0,42	3,65	24,02	22038,29	22,91	103,34	0,18	15,20
M1T 500-600	Malahlapanga	1	Temporary	M1T	500	600	550	500	90,91	9,46	5,86	5,70	5,61	17,27	28,75	20,74	26,64	46,02	20,74	5,88	6,51	154	1,04	1,79	2110	0,36	7163,98	15,97	0,13	0,02	0,01	1,64	21,50	0,92	0,43	5,13	23,04	111,12	24,65	121,44	0,23	22,26
M1T 600-700	Malahlapanga	1	Temporary	M1T	600	700	650	501	77,08	10,54	6,10	6,83	4,91	5,97	20,95	41,37	28,37	26,91	41,37	5,8	6,95	148	0,92	1,58	1760	0,15	4682,80	6,84	0,14	0,03	0,00	1,62	14,90	0,87	0,39	5,22	18,70	45,20	17,95	114,36	0,33	27,91
M1T 700-800	Malahlapanga	1	Temporary	M1T	700	800	750	502	66,93	14,32	7,06	7,00	4,60	5,93	18,34	39,79	32,99	24,27	39,79	5,71	7,01	140	0,96	1,65	1410	0,26	5643,82	6,84	0,13	0,02	0,00	1,65	20,30	1,05	0,49	6,26	23,80	59,82	23,65	118,05	0,29	26,30
M1T 800-900	Malahlapanga	1	Temporary	M1T	800	900	850	503	59,18	14,28	7,74	8,40	5,49	6,68	16,66	37,03	35,90	23,34	37,03	5,73	6,98	138	0,69	1,19	1120	0,44	6744,62	9,12	0,12	0,03	0,01	2,00	12,98	0,90	0,41	6,43	24,13	65,17	16,45	85,91	0,46	26,67
M1T 900-1000	Malahlapanga	1	Temporary	M1T	900	1000	950	504	53,05	14,55	7,86	8,31	4,94	6,79	14,74	38,26	35,66	21,53	38,26	5,85	6,85	112	0,79	1,36	890	0,28	4805,11	13,69	0,10	0,02	0,00	2,27	13,09	1,13	0,43	5,48	24,24	63,36	17,05	83,04	0,39	22,60
M2T 0-50	Malahlapanga	2	Temporary	M2T	0	50	25	505	2020,00											5,82	6,56	148	3,74	6,43	590	0,43	5189,52	191,61	0,64	0,09	0,02	2,71	21,60	1,66	1,26	3,22	29,78		27,99	93,13	0,14	10,80
M2T 50-100	Malahlapanga	2	Temporary	M2T	50	100	75	506	674,67	5,64	5,70	6,87	5,12	7,55	30,50	35,85	23,34	38,05	35,85	6,3	6,55	186	3,41	5,87	600	0,36	4158,60	157,39	0,30	0,04	0,01	2,25	18,90	1,28	0,93	3,22	28,48	79,44	23,71	85,41	0,16	11,30
M2T 100-150	Malahlapanga	2	Temporary	M2T	100	150	125	507	405,60											6,56	7,03	200	2,10	3,61	350	0,17	3704,30	143,70	0,24	0,04	0,01	2,05	14,51	0,89	0,90	3,91	24,24		18,63	83,35	0,25	16,14
M2T 150-200	Malahlapanga	2	Temporary	M2T	150	200	175	508	290,29	8,22	8,16	10,71	6,40	8,71	23,08	29,90	33,49	31,79	29,90	6,9	7,41	166	1,42	2,44	270	0,47	4508,06	139,14	0,18	0,03	0,01	2,31	10,16	0,56	0,54	4,61	23,04	77,08	13,78	68,84	0,43	20,00
M2T 200-250	Malahlapanga	2	Temporary	M2T	200	250	225	509	226,22											7,18	7,6	108	1,10	1,89	250	0,17	4193,55	189,32	0,35	0,04	0,01	4,50	11,82	0,61	0,71	9,22	26,63		18,04	83,95	0,74	34,61
M2T 250-300	Malahlapanga	2	Temporary	M2T	250	300	275	510	185,45	7,56	8,35	11,90	7,37	9,27	15,46	36,07	35,19	24,73	36,07	7,41	7,88	76	0,78	1,34	180	0,89	4630,38	200,73	0,23	0,03	0,01	3,18	11,74	0,54	0,66	7,57	24,02	66,59	16,39	85,39	0,62	31,49
M2T 300-400	Malahlapanga	2	Temporary	M2T	300	400	350	511	146,00	10,87	10,87	14,33	5,93	27,09	0,32	29,02	41,99	27,42	29,02	7,35	8,12	67	0,55	0,95	240	0,07	4106,18	189,32	0,44	0,05	0,01	6,20	11,04	0,44	0,76	9,22	203,26	700,40	18,95	10,56	0,80	4,53
M2T 400-500	Malahlapanga	2	Temporary	M2T	400	500	450	512	113,78	11,54	10,51	13,37	6,48	16,52	5,66	32,74	41,91	22,17	32,74	7,32	7,81	56	0,71	1,22	90	0,55	4315,86	218,98	0,36	0,04	0,01	6,41	13,83	0,68	0,95	12,39	28,15	85,99	22,27	98,89	0,85	44,02
M2T 500-600	Malahlapanga	2	Temporary	M2T	500	600	550	513	93,27	12,22	10,16	12,42	7,04	5,94	10,99	36,46	41,84	16,93	36,46	7,38	7,77	51	0,47	0,81	100	0,29	4403,23	228,10	0,46	0,05	0,01	8,48	12,69	0,53	1,13	13,37	26,85	73,64	23,35	103,23	1,01	49,80
M2T 600-700	Malahlapanga	2	Temporary	M2T	600	700	650	514	79,08	14,62	11,43	13,69	7,54	6,81	11,19	31,25	47,27	18,00	31,25	7,6	8,24	47	0,35	0,60	100	0,58	4455,65	237,23	0,26	0,05	0,01	9,78	11,88	0,45	1,15	15,11	27,17	86,95	23,58	105,19	1,23	55,60
M2T 700-800	Malahlapanga	2	Temporary	M2T	700	800	750	515	68,67	17,01	12,69	14,95	8,04	7,68	11,40	26,05	52,70	19,07	26,05	7,23	7,96	43	0,26	0,45	100	0,08	4630,38	262,32	0,12	0,04	0,01	9,57	12,10	0,45	1,01	14,78	26,74	102,65	23,30	106,00	1,18	55,28
M2T 800-900	Malahlapanga	2	Temporary	M2T	800	900	850	516	60,71	15,24	11,02	13,21	7,44	6,44	11,94	31,15	46,92	18,38	31,15	7,37	8,24	43,5	0,28	0,48	80	0,07	5870,97	374,09	0,20	0,05	0,02	10,65	12,14	0,49	1,00	15,54	26,41	84,78	24,54	110,44	1,23	58,85
M2T 900-1000	Malahlapanga	2	Temporary	M2T	900	1000	950	517	54,42	13,47	9,36	11,48	6,83	5,21	12,47	36,26	41,14	17,68	36,26	7,45	8,12	41	0,15	0,26	80	0,63	4979,84	412,86	0,12	0,05	0,02	11,74	12,26	0,53	1,05	15,54	29,24	80,64	25,78	100,53	1,21	53,16
M2T 1000-1100	Malahlapanga	2	Temporary	M2T	1000	1100	1050	518	49,33	12,06	7,81	9,07	5,68	5,60	18,78	36,08	34,62	24,38	36,08	7,25	8,08	43,5	0,29	0,50	100	0,58	5364,25	421,99	0,11	0,05	0,02	13,04	11,56	0,49	0,98	15,00	29,46	81,63	26,26	95,19	1,24	50,92
M2T 1100-1200	Malahlapanga	2	Temporary	M2T	1100	1200	1150	519	45,13	10,66	6,26	6,66	4,53	6,00	25,08	35,91	28,11	31,08	35,91	7,28	8,16	42	0,34	0,58	180	0,09	4350,81	344,43	0,12	0,07	0,02	14,89	10,61	0,45	0,88	13,37	24,02	66,90	27,04	105,38	1,21	55,66
M3T 0-50	Malahlapanga	3	Temporary	M3T	0	50	25	520	2080,00											6,27	7,78	37,5	1,67	2,87	110	0,29	2725,81	91,24	0,51	0,29	0,04	13,15	10,94	0,70	0,72	4,02	125,00		26,34	13,10	0,35	3,22
M3T 50-100	Malahlapanga	3	Temporary	M3T	50	100	75	521	694,67	18,09	14,10	15,36	12,30	12,97	9,61	17,15	59,84	22,57	17,15	6,22	7,77	45,5	1,52	2,61	170	0,66	4927,42	79,84	1,87	0,15	0,02	10,11	10,99	0,66	0,86	5,00	16,09	93,78	24,65	108,78	0,43	31,08
M3T 100-150	Malahlapanga	3	Temporary	M3T	100	150	125	522	417,60											6,41	8,23	65	1,07	1,84	20	0,23	2084,54	75,27	0,67	0,10	0,01	5,86	8,85	0,51	0,51	4,24	13,70		16,53	103,05	0,45	30,95
M3T 150-200	Malahlapanga	3	Temporary	M3T	150	200	175	523	298,86	23,26	24,53	21,86	2,67	12,56	3,77	10,53	72,31	16,33	10,53	7,23	8,97	97	0,46	0,79	20	0,01	2839,38	319,34	0,32	0,04	0,01	3,71	5,89	0,33	0,38	4,02	9,02	85,67	10,67	117,72	0,65	44,58
M3T 200-250	Malahlapanga	3	Temporary	M3T	200	250	225	524	232,89											7,65	8,51	69	0,32	0,55	0	0,58	3389,78	104,93	0,48	0,05	0,01	6,09	8,10	0,45	0,58	6,96	14,78		15,76	108,84	0,81	47,06
M3T 250-300	Malahlapanga	3	Temporary	M3T	250	300	275	525	190,91	21,79	22,06	14,39	6,20	4,90	7,76	20,36	64,44	12,66	20,36	7,5	8,26	62	0,43	0,74	0	0,34	4333,33	127,74	0,42	0,05	0,01	6,20	9,73	0,37	0,73	6,41	16,96	83,29	17,50	101,65	0,64	37,82
M3T 300-400	Malahlapanga	3	Temporary	M3T	300	400	350	526	150,29	22,14	23,83	17,97	5,73	7,75	5,63	15,62	69,66	13,38	15,62	7,56	8,54	60,3	0,27	0,46	100	0,54	3983,87	77,55	0,33	0,03	0,01	5,22	10,85	0,27	0,54	8,04	14,78	94,61	17,24	133,24	0,72	54,41
M3T 400-500	Malahlapanga	3	Temporary	M3T	400	500	450	527	117,11	23,30	21,84	15,80	6,84	4,41	6,47	20,05	67,78	10,89	20,05	7,76	8,1	55	0,21	0,36	0	0,55	6063,17	116,33	0,21	0,06	0,01	6,20	11,28	0,23	0,57	8,48	18,59	92,71	18,54	110,55	0,74	45,61
M3T 500-600	Malahlapanga	3	Temporary	M3T	500	600	550	528	96,00	34,47	24,24	13,87	4,56	3,14	4,46	14,23	77,13	7,59	14,23	7,77	8,11	56	0,22	0,38	190	0,48	7862,90	88,96	0,14	0,03	0,01	6,17	10,33	0,16	0,42	6,43	16,52	116,10	17,26	105,00	0,61	38,95
M3T 600-700	Malahlapanga	3	Temporary	M3T	600	700	650	529	81,38	37,00	26,80	12,63	4,42	3,01	3,98	12,31	80,85	6,99	12,31	7,72	8,73	78	0,13	0,22	10	0,33	11077,96	278,28	0,12	0,03	0,01	4,70	6,66	0,13	0,30	2,97	9,57	77,70	11,95	105,15	0,44	31,00
M3T 700-800	Malahlapanga	3	Temporary	M3T	700	800	750	530	70,67	25,33	27,03	18,28	6,79	3,59	5,94	12,86	77,43	9,53	12,86	7,42	8,35	56	0,13	0,22	0	1,25	10099,46	200,73	0,13	0,03	0,01	6,09	7,86	0,20	0,38	5,22	9,89	76,91	14,70	138,03	0,65	52,75
M3T 800-900	Malahlapanga	3	Temporary	M3T	800	900	850	531	62,47	38,04	21,98	17,39	4,12	4,78	4,08	7,87	81,53	8,86	7,87	7,71	8,72	76	0,15	0,26	80	0,06	2689,11	50,18	0,10	0,032786885	0,01	4,695652174	5,67	0,180327869	0,26	1,72173913	7,39	93,95002752	10,95	105,91	0,29	23,29
M3T 900-1000	Malahlapanga	3	Temporary	M3T	900	1000	950	532	56,00	38,04	21,98	17,39	4,12	4,78	4,08	7,87	81,53	8,86	7,87	7,71	8,72	73	0,15	0,00	80	0,06	2738,04	54,74	0,19	0,037704918	0,01	4,608695652	5,89	0,180327869	0,28	2,513043478	7,93	100,8581178	11,20	111,66	0,41	31,67
M3T 1000-1100	Malahlapanga	3	Temporary	M3T	1000	1100	1050	533	50,76	34,79	24,82	17,72	5,86	3,58	6,35	7,39	83,19	9,93	7,39	7,36	8,82	72	0,11	0,19	10	0,42	2203,36	41,06	0,22	0,040983607	0,01	4,52173913	7,33	0,213114754	0,35	2,947826087	7,93	107,3153132	12,68	136,60	0,39	37,15
M3T 1100-1200	Malahlapanga	3	Temporary	M3T	1100	1200	1150	534	46,43	17,76	25,34	26,65	8,88	4,28	4,21	7,97	78,63	8,49	7,97	7,19	8,69	71	0,10	0,17	90	0,46	1319,22	20,53	0,19	0,039344262	0,01	4,434782609	5,08	0,180327869	0,23	1,669565217	5,11	64,11831789	10,16	140,15	0,32	32,68

Table 27 Laboratory analyses for the upland zones at Malahlapanga

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
M1U 0-50	Malahlapanga	1	Upland	M1U	0	50	25	535	2140,00											7,09	8,23	640	0,68	1,17	1760	0,49	4473,12	346,72	0,85	0,162295082	0,04	0,159130435	11,42	1,295081967	0,80	0,07826087	12,39		14,73	109,73	0,01	0,63
M1U 50-100	Malahlapanga	1	Upland	M1U	50	100	75	536	714,67	17,81	12,73	21,93	13,50	8,20	5,59	16,27	65,98	13,79	16,27	7,52	8,01	375	0,88	1,51	1690	0,47	4315,86	383,21	1,32	0,17704918	0,05	0,149565217	14,85	1,049180328	0,70	0,060869565	13,48	82,84016154	18,28	123,57	0,00	0,45
M1U 100-150	Malahlapanga	1	Upland	M1U	100	150	125	537	429,60											7,69	8,19	305	0,78	1,34	2010	0,60	4123,66	415,15	1,60	0,159016393	0,03	0,211304348	26,2	1,032786885	0,66	0,069565217	13,80		29,90	202,60	0,00	0,50
M1U 150-200	Malahlapanga	1	Upland	M1U	150	200	175	538	307,43	20,64	13,76	19,16	11,30	6,81	13,81	15,04	64,86	20,61	15,04	7,7	8,18	288	0,64	1,10	1690	0,32	4647,85	465,33	1,52	0,157377049	0,03	0,226086957	26,8	1,278688525	0,80	0,12173913	11,52	76,62446007	30,81	251,68	0,00	1,06
M1U 200-250	Malahlapanga	1	Upland	M1U	200	250	225	539	239,56											7,82	8,36	330	0,70	1,20	1380	0,44	5014,78	417,43	1,63	0,168852459	0,03	0,22	25,9	1,180327869	0,73	0,113043478	17,07		29,86	163,64	0,00	0,66
M1U 250-300	Malahlapanga	1	Upland	M1U	250	300	275	540	196,36	17,91	12,90	19,15	11,66	6,03	8,96	21,76	61,62	14,98	21,76	7,8	8,3	276	0,69	1,19	1650	0,80	4630,38	399,18	1,50	0,160655738	0,03	0,252173913	26,1	1,213114754	0,61	0,147826087	14,35	65,94802135	29,87	195,67	0,01	1,03
M1U 300-400	Malahlapanga	1	Upland	M1U	300	400	350	541	154,57	20,48	13,49	18,48	8,99	20,15	1,65	15,26	61,43	21,80	15,26	7,83	8,41	250	0,92	1,58	1670	0,55	4455,65	485,86	0,47	0,206557377	0,03	0,296521739	30,3	1,31147541	0,62	0,130434783	15,98	104,7180175	33,24	202,56	0,00	0,82
M1U 400-500	Malahlapanga	1	Upland	M1U	400	500	450	542	120,44	17,66	12,75	16,19	9,81	7,63	9,88	25,04	56,41	17,51	25,04	7,78	8,3	226	0,88	1,51	1940	0,44	3809,14	501,82	0,61	0,22295082	0,03	0,286086957	40,9	1,573770492	0,61	0,147826087	17,83	71,1901631	44,23	242,51	0,00	0,83
M1U 500-600	Malahlapanga	1	Upland	M1U	500	600	550	543	98,73	21,64	10,10	14,42	7,21	5,22	32,91	5,41	53,37	38,13	5,41	7,74	8,23	192	0,78	1,34	2180	1,05	8963,71	481,30	0,74	0,23442623	0,02	0,275652174	47	1,655737705	0,64	0,130434783	16,20	299,4194589	50,57	305,18	0,00	0,81
M2U 0-50	Malahlapanga	2	Upland	M2U	0	50	25	544	2176,00											6,67	7,79	1660	0,97	1,67	570	0,15	10344,09	435,68	0,36	0,257377049	0,05	0,025217391	6,46	2,409836066	0,69	0,052173913	9,13		10,24	105,22	0,01	0,57
M2U 50-100	Malahlapanga	2	Upland	M2U	50	100	75	545	726,67	18,18	17,69	22,11	7,86	6,68	8,38	18,18	65,85	15,06	18,18	6,47	6,92	1660	1,20	2,06	600	0,15	10693,55	469,89	0,30	0,252459016	0,04	0,033043478	6,74	2,655737705	0,58	0,052173913	11,52	63,36707403	10,60	87,06	0,01	0,45
M2U 100-150	Malahlapanga	2	Upland	M2U	100	150	125	546	436,80											6,26	7,3	1540	1,10	1,89	570	0,17	11689,52	499,54	0,31	0,255737705	0,02	0,04173913	7,54	34,42622951	0,41	0,060869565	14,24		43,00	298,03	0,00	0,43
M2U 150-200	Malahlapanga	2	Upland	M2U	150	200	175	547	312,57	12,36	14,84	20,28	10,38	7,10	9,05	25,32	57,86	16,15	25,32	6,47	7,16	1800	1,11	1,91	820	0,45	14607,53	558,85	0,42	0,262295082	0,01	0,042608696	8,67	36,06557377	0,28	0,07826087	12,93	51,08607549	45,75	348,60	0,00	0,61
M2U 200-250	Malahlapanga	2	Upland	M2U	200	250	225	548	243,56											6,56	6,81	1780	0,92	1,58	660	0,05	14555,11	581,66	0,52	0,295081967	0,01	0,046956522	10,17	47,54098361	0,22	0,07826087	16,52		58,80	351,11	0,00	0,47
M2U 250-300	Malahlapanga	2	Upland	M2U	250	300	275	549	199,64	18,32	16,09	15,00	7,92	5,11	11,65	20,94	57,33	16,76	20,94	6,62	6,71	1160	0,86	1,48	1010	0,21	15096,77	593,07	0,68	0,393442623	0,01	0,053913043	11,06	47,54098361	0,21	0,069565217	15,54	74,23100809	59,96	378,84	0,00	0,45
M2U 300-400	Malahlapanga	2	Upland	M2U	300	400	350	550	157,14	14,29	12,68	15,07	8,54	7,08	9,80	27,62	50,58	16,88	27,62	6,77	7,01	1120	0,85	1,46	930	0,22	15026,88	636,41	0,69	0,360655738	0,01	0,056521739	10,85	47,54098361	0,21	0,086956522	15,98	57,85851746	59,72	367,30	0,00	0,54
M2U 400-500	Malahlapanga	2	Upland	M2U	400	500	450	551	122,44	13,35	12,96	12,16	9,98	7,87	4,63	39,04	48,46	12,49	39,04	6,85	7,54	1140	0,71	1,22	1090	0,22	15463,71	702,55	0,87	0,442622951	0,01	0,060869565	11,39	49,18032787	0,20	0,07826087	15,98	40,92951257	62,15	380,82	0,00	0,49
M2U 500-600	Malahlapanga	2	Upland	M2U	500	600	550	552	100,36	16,76	12,33	14,30	6,90	16,84	9,54	22,63	50,29	26,38	22,63	6,9	6,7	880	0,90	1,55	1090	0,20	14223,12	675,18	0,92	0,459016393	0,01	0,07826087	12,03	52,45901639	0,21	0,07826087	14,89	65,80172161	66,17	435,00	0,00	0,53
M3U 0-50	Malahlapanga	3	Upland	M3U	0	50	25	553	2212,00											7,12	8,21	116	1,35	2,32	740	0,73	2145,70	253,19	0,16	0,108196721	0,04	3,486956522	6,19	0,852459016	1,13	2,217391304	9,67		11,97	107,41	0,31	22,92
M3U 50-100	Malahlapanga	3	Upland	M3U	50	100	75	554	738,67	15,73	15,73	19,07	5,24	5,79	27,15	8,61	55,78	32,94	8,61	8,08	8,4	60	1,25	2,15	660	0,50	2266,26	239,51	0,13	0,070491803	0,03	6,52173913	7,18	0,901639344	1,83	7,565217391	15,65	181,8921354	16,67	111,67	0,94	48,33
M3U 100-150	Malahlapanga	3	Upland	M3U	100	150	125	555	444,00											8,5	8,51	44	1,04	1,79	680	0,83	2364,11	230,38	0,19	0,081967213	0,03	9,304347826	14,67	0,885245902	1,60	8,52173913	15,98		26,76	160,71	0,55	53,33
M3U 150-200	Malahlapanga	3	Upland	M3U	150	200	175	556	317,71	13,67	11,89	12,41	6,60	6,11	10,23	34,44	44,57	16,34	34,44	8,56	8,39	32,5	0,76	1,31	490	1,36	2535,35	234,95	0,17	0,081967213	0,03	13,73913043	37,5	1,032786885	1,79	12,08695652	18,80	54,60724916	54,34	278,69	0,31	64,28
M3U 200-250	Malahlapanga	3	Upland	M3U	200	250	225	557	247,56											8,53	8,47	28	0,49	0,84	330	0,72	2935,48	282,85	0,12	0,068852459	0,04	15,65217391	40	1,016393443	1,81	13,73913043	20,76		58,70	272,47	0,33	66,18
M3U 250-300	Malahlapanga	3	Upland	M3U	250	300	275	558	202,91	14,68	9,06	13,16	8,93	6,78	13,29	32,73	45,83	20,07	32,73	8,46	8,59	26,2	0,41	0,71	330	0,34	4001,34	333,03	0,14	0,072131148	0,18	16,08695652	46,4	0,852459016	1,60	11,91304348	17,17	52,46578393	65,33	353,80	0,25	69,37
M3U 300-400	Malahlapanga	3	Upland	M3U	300	400	350	559	159,71	13,63	10,12	13,64	9,47	7,71	16,97	25,69	46,86	24,67	25,69	8,22	8,45	26,6	0,46	0,79	600	0,74	4036,29	337,59	0,09	0,063934426	0,04	15,73913043	48,4	0,819672131	1,53	11,73913043	12,93	50,3463503	66,69	483,14	0,24	90,76
M3U 400-500	Malahlapanga	3	Upland	M3U	400	500	450	560	124,44	12,58	11,17	14,12	10,01	8,63	20,64	18,65	47,89	29,27	18,65	8,17	8,33	27,8	0,33	0,57	690	0,25	4036,29	367,24	0,09	0,063934426	0,10	15,91304348	65,7	0,819672131	1,49	12,26086957	16,41	88,00724762	84,18	489,09	0,18	74,70
M3U 500-600	Malahlapanga	3	Upland	M3U	500	600	550	561	102,00	14,83	10,79	11,87	6,63	6,44	27,26	17,58	44,12	33,70	17,58	8,23	8,37	29,4	0,34	0,58	610	0,42	3529,57	362,68	0,12	0,083606557	0,17	15,73913043	55,1	0,704918033	1,39	10,60869565	16,52	93,99772071	73,31	410,40	0,19	64,21
M3U 600-700	Malahlapanga	3	Upland	M3U	600	700	650	562	86,46	12,85	10,19	10,95	6,14	4,81	18,76	31,33	40,12	23,57	31,33	8,56	8,64	35,5	0,30	0,52	610	0,59	3686,83	289,69	0,09	0,060655738	0,12	16,17391304	45	0,721311475	1,30	9,565217391	12,93	41,29148441	63,46	437,47	0,21	73,95
M3U 700-800	Malahlapanga	3	Upland	M3U	700	800	750	563	75,07	18,50	12,23	11,34	6,71	6,65	25,40	16,03	48,77	32,05	16,03	8,56	8,54	38,5	0,27	0,46	830	1,10	3424,73	246,35	0,10	0,063934426	0,24	15,56521739	49,9	0,721311475	1,29	10,17391304	12,83	80,03376869	67,89	484,09	0,20	79,32
M3U 800-900	Malahlapanga	3	Upland	M3U	800	900	850	564	66,35	19,43	11,80	10,76	6,23	6,90	24,75	17,86	48,23	31,65	17,86	8,5	8,52	44,5	0,26	0,45	1430	0,95	2750,27	196,17	0,11	0,067213115	0,09	12,26086957	46,2	0,655737705	1,14	8,434782609	13,15	73,62684902	60,52	429,06	0,18	64,13
M3U 900-1000	Malahlapanga	3	Upland	M3U	900	1000	950	565	59,47	20,36	11,38	10,18	5,76	7,15	24,10	19,70	47,69	31,24	19,70	8,58	8,62	51	0,21	0,36	350	0,79	2212,10	184,76	0,10	0,059016393	0,08	10,52173913	52,1	0,639344262	1,06	8,782608696	10,43	52,96648754	64,55	599,73	0,17	84,17
M3U 1000-1100	Malahlapanga	3	Upland	M3U	1000	1100	1050	566	53,90	20,75	12,08	10,79	5,98	6,68	23,23	18,31	49,60	29,91	18,31	8,67	8,85	53	0,22	0,38	760	0,34	2180,65	198,45	0,08	0,055737705	0,03	10,69565217	49,1	0,655737705	1,08	8,782608696	12,72	69,45034325	61,70	468,83	0,18	69,06
M3U 1100-1200	Malahlapanga	3	Upland	M3U	1100	1200	1150	567	49,30	21,92	29,69	11,43	5,87	5,46	23,37	0,19	68,91	28,83	0,19	8,78	8,78	58	0,18	0,31	620	0,45	2075,81	177,92	0,08	0,057377049	0,03	9,652173913	49,9	0,655737705	1,08	8,347826087	11,20	5908,65471	61,46	535,77	0,17	74,56

Table 28 Laboratory analyses for the permanent zones at Nshawu

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
N1P 0-50	Nshawu	1	Permanent	N1P	0	50	25	201	804,00	10,15	6,12	6,93	3,87	14,17	16,87	52,27	27,07	31,04	52,27	9,55	8,71	134	1,25	2,15	760	0,14	1078,09	43,34	0,05	0,02	0,00	1,83	29,55	13,85	0,80	16,70	19,13	36,60	46,10	318,35	0,38	87,27
N1P 50-100	Nshawu	1	Permanent	N1P	50	100	75	202	269,33	6,85	5,86	6,95	3,05	4,72	15,86	57,66	22,71	20,57	57,66	9,41	8,57	226	0,89	1,53	570	0,04	1252,82	38,78	0,02	0,01	0,00	1,04	26,39	15,52	0,50	13,46	19,13	33,18	43,49	292,06	0,32	70,36
N1P 100-150	Nshawu	1	Permanent	N1P	100	150	125	203	162,40	6,95	6,23	6,59	3,86	3,44	14,78	58,35	23,62	18,22	58,35	9,19	8,3	260	1,01	1,74	680	0,18	1279,03	41,06	0,05	0,02	0,00	0,75	28,13	16,11	0,40	8,48	22,61	38,74	45,46	234,96	0,19	37,50
N1P 150-200	Nshawu	1	Permanent	N1P	150	200	175	204	116,57	4,63	4,11	6,19	3,21	3,89	32,16	46,33	18,14	36,05	46,33	9,2	8,2	258	0,78	1,34	430	0,07	1638,98	36,50	0,05	0,02	0,00	0,83	31,67	15,25	0,41	9,57	20,00	43,17	48,22	284,50	0,20	47,87
N1P 200-250	Nshawu	1	Permanent	N1P	200	250	225	205	91,11	4,70	4,50	5,85	3,71	3,75	14,33	62,62	18,76	18,07	62,62	9,09	8,22	268	0,58	1,00	510	0,08	2004,17	47,90	0,04	0,02	0,00	0,70	31,54	15,00	0,38	7,70	21,74	34,71	47,69	251,29	0,17	35,44
N1P 250-300	Nshawu	1	Permanent	N1P	250	300	275	206	74,91	4,87	5,01	6,12	3,60	3,99	8,77	68,56	19,60	12,76	68,56	8,96	8,04	288	0,61	1,05	180	0,15	2018,15	61,59	0,04	0,02	0,00	0,63	27,75	15,16	0,37	6,81	22,61	32,98	43,98	221,58	0,16	30,12
N1P 300-400	Nshawu	1	Permanent	N1P	300	400	350	207	59,14	3,96	3,47	5,69	3,60	0,60	5,98	72,39	16,70	6,59	72,39	8,89	8,07	290	0,47	0,81	290	0,09	2002,42	75,27	0,05	0,02	0,00	0,64	27,62	14,69	0,38	5,78	21,74	30,03	43,40	222,98	0,14	26,60
N1P 400-500	Nshawu	1	Permanent	N1P	400	500	450	208	46,22	3,52	3,58	4,84	3,12	6,04	14,93	59,02	15,06	20,97	59,02	8,82	8,01	360	0,53	0,91	150	0,06	2332,66	86,68	0,04	0,02	0,00	0,41	27,55	14,87	0,40	4,59	22,61	38,31	43,29	209,69	0,11	20,31
N1P 500-600	Nshawu	1	Permanent	N1P	500	600	550	209	38,00	2,94	3,68	5,40	3,39	7,61	15,67	61,39	15,41	23,28	61,39	8,68	7,95	370	0,34	0,58	250	0,08	2437,50	104,93	0,05	0,02	0,00	0,41	29,29	13,23	0,39	3,58	21,74	35,41	43,39	213,88	0,08	16,48
N1P 600-700	Nshawu	1	Permanent	N1P	600	700	650	210	32,31	2,36	3,77	5,96	3,67	9,18	16,41	63,77	15,76	25,59	63,77	8,58	7,98	375	0,26	0,45	70	0,11	2727,55	107,21	0,04	0,01	0,00	0,30	28,17	13,84	0,39	3,51	21,74	34,09	42,76	211,20	0,08	16,16
N1P 700-800	Nshawu	1	Permanent	N1P	700	800	750	211	28,13	2,62	3,66	5,69	3,73	4,09	18,15	57,83	15,70	22,24	57,83	8,55	7,95	385	0,26	0,45	430	0,17	2883,06	107,21	0,04	0,01	0,00	0,18	31,29	14,92	0,43	3,22	21,74	37,59	46,87	229,36	0,07	14,80
N1P 800-900	Nshawu	1	Permanent	N1P	800	900	850	212	24,94	3,39	4,39	5,79	3,73	3,86	11,34	65,09	17,30	15,20	65,09	8,45	7,91	370	0,33	0,57	340	0,19	2800,94	107,21	0,05	0,01	0,00	0,18	30,25	15,36	0,46	2,79	23,48	36,07	46,30	208,10	0,06	11,89
N1P 900-1000	Nshawu	1	Permanent	N1P	900	1000	950	213	22,42	3,17	3,96	4,56	3,04	1,85	13,86	66,05	14,72	15,71	66,05	8,37	7,73	380	0,24	0,41	580	0,14	2769,49	91,24	0,05	0,01	0,01	0,17	33,43	15,25	0,47	2,89	23,48	35,54	49,38	221,60	0,06	12,30
N1P 1000-1100	Nshawu	1	Permanent	N1P	1000	1100	1050	214	20,38	4,26	3,13	4,86	2,99	3,49	12,30	64,58	15,23	15,80	64,58	8,45	7,77	380	0,22	0,38	180	0,19	2617,47	75,27	0,04	0,01	0,00	0,15	33,18	15,33	0,49	2,88	23,48	36,36	49,20	220,96	0,06	12,26
N1P 1100-1200	Nshawu	1	Permanent	N1P	1100	1200	1150	215	18,70	4,39	4,07	5,28	3,37	3,40	13,59	63,44	17,12	16,99	63,44	8,53	8,07	385	0,25	0,43	260	0,19	2566,80	75,27	0,04	0,01	0,00	0,15	35,01	16,95	0,51	3,50	23,48	37,01	52,67	238,36	0,07	14,89
N2P 0-50	Nshawu	2	Permanent	N2P	0	50	25	216	864,00											8,61	8,04	172	4,06	6,98	10960	0,41	562,63	79,84	0,14	0,05	0,00	3,39	30,71	18,38	1,36	10,98	34,78		54,03	176,61	0,22	31,58
N2P 50-100	Nshawu	2	Permanent	N2P	50	100	75	217	289,33	6,62	8,52	11,17	9,08	11,55	25,87	25,36	35,39	37,41	25,36	8,89	8,3	166	3,01	5,18	9070	0,26	452,55	75,27	1,70	0,66	0,60	5,83	1,01	0,70	0,04	1,71	34,78	137,15	10,54	9,96	1,00	4,93
N2P 100-150	Nshawu	2	Permanent	N2P	100	150	125	218	174,40											8,86	8,14	158	2,87	4,94	6410	0,26	531,18	66,15	0,17	0,11	0,00	11,74	30,03	20,28	0,31	14,03	31,30		62,63	206,49	0,28	44,81
N2P 150-200	Nshawu	2	Permanent	N2P	150	200	175	219	125,14	3,26	2,38	6,45	6,95	9,24	28,33	41,23	19,03	37,57	41,23	8,68	8,28	154	2,58	4,44	5800	0,16	531,18	52,46	0,14	0,05	0,00	2,43	31,01	17,28	0,25	10,99	31,30	75,93	51,17	190,17	0,23	35,11
N2P 200-250	Nshawu	2	Permanent	N2P	200	250	225	220	97,78											8,79	8,28	154	1,88	3,23	4190	0,42	684,95	57,03	0,13	0,07	0,00	1,80	34,92	18,82	0,29	9,77	24,35		56,03	262,06	0,18	40,14
N2P 250-300	Nshawu	2	Permanent	N2P	250	300	275	221	80,36	0,32	0,95	2,86	4,44	9,04	18,50	58,95	8,57	27,54	58,95	9,18	8,3	220	1,06	1,82	2530	0,29	1078,09	88,96	0,08	0,03	0,00	0,87	39,72	19,38	0,30	8,23	25,22	42,78	60,39	268,17	0,14	32,62
N2P 300-400	Nshawu	2	Permanent	N2P	300	400	350	222	63,43	0,50	1,13	4,26	6,02	7,84	17,74	59,78	11,91	25,58	59,78	9,13	8,24	268	0,72	1,24	1350	0,10	1147,98	93,52	0,08	0,03	0,00	0,69	37,76	18,23	0,33	7,39	24,35	40,73	57,11	261,66	0,13	30,36
N2P 400-500	Nshawu	2	Permanent	N2P	400	500	450	223	49,56	1,02	2,11	4,48	5,82	7,55	13,66	62,89	13,43	21,21	62,89	9,05	8,36	294	0,65	1,12	1170	0,16	1238,84	98,08	0,09	0,03	0,00	0,58	30,90	20,82	0,30	6,15	22,61	35,95	52,72	257,29	0,12	27,19
N2P 500-600	Nshawu	2	Permanent	N2P	500	600	550	224	40,73	2,53	2,66	4,93	4,93	7,08	17,26	58,37	15,05	24,35	58,37	9,04	8,14	325	0,58	1,00	1100	0,12	1319,22	93,52	0,06	0,01	0,00	0,39	20,44	16,56	0,32	5,48	20,00	34,27	37,78	213,96	0,15	27,39
N2P 600-700	Nshawu	2	Permanent	N2P	600	700	650	225	34,62	2,57	4,57	8,07	5,45	6,13	14,83	56,08	20,66	20,97	56,08	8,74	8,11	395	0,51	0,88	1080	0,39	1259,81	95,80	0,07	0,01	0,00	0,32	21,52	17,34	0,29	3,98	19,13	34,11	39,56	225,50	0,10	20,82
N2P 700-800	Nshawu	2	Permanent	N2P	700	800	750	226	30,13	2,81	4,51	7,58	5,55	5,62	16,56	56,08	20,44	22,18	56,08	8,81	8,02	405	0,45	0,77	840	0,22	1099,06	98,08	1,50	21,80	0,26	3,57	0,23	0,33	0,02	0,38	18,26	32,56	27,71	5,23	0,69	2,10
N2P 800-900	Nshawu	2	Permanent	N2P	800	900	850	227	26,71	2,26	3,19	5,58	3,79	4,92	14,12	65,68	14,82	19,04	65,68	8,72	8,06	385	0,40	0,69	930	0,01	908,60	86,68	0,09	0,02	0,00	0,46	20,64	17,21	0,33	3,69	18,26	27,80	38,75	229,30	0,10	20,19
N2P 900-1000	Nshawu	2	Permanent	N2P	900	1000	950	228	24,00	2,44	3,20	5,35	3,57	4,36	12,43	67,94	14,55	16,79	67,94	8,71	8,14	425	0,31	0,53	410	0,36	906,85	84,40	0,08	0,01	0,00	0,33	16,77	16,93	0,30	2,99	16,52	24,32	34,43	223,90	0,09	18,11
N2P 1000-1100	Nshawu	2	Permanent	N2P	1000	1100	1050	229	21,81	2,62	3,21	5,11	3,34	3,80	10,75	70,20	14,29	14,55	70,20	8,69	8,23	410	0,30	0,52	500	0,36	882,39	82,12	0,09	0,02	0,00	0,34	18,16	17,62	0,33	3,07	18,26	26,01	36,55	214,56	0,09	16,81
N2P 1100-1200	Nshawu	2	Permanent	N2P	1100	1200	1150	230	20,00	2,99	3,73	5,39	3,66	3,76	12,54	65,45	15,77	16,30	65,45	8,37	7,96	355	0,36	0,62	370	0,38	852,69	77,55	0,11	0,02	0,00	0,41	23,12	20,16	0,41	3,50	20,00	30,56	44,24	236,01	0,08	17,52
N3P 0-50	Nshawu	3	Permanent	N3P	0	50	25	231	924,00											8,64	8,09	240	2,92	5,02	15150	0,71	1154,97	127,74	0,10	0,04	0,01	1,66	34,49	22,01	1,43	12,13	60,87		59,74	115,10	0,21	19,93
N3P 50-100	Nshawu	3	Permanent	N3P	50	100	75	232	309,33	6,56	2,23	9,90	8,53	9,64	27,05	35,87	27,22	36,69	35,87	8,83	8,11	264	2,69	4,63	13590	0,42	1013,44	118,61	0,06	0,03	0,00	1,20	29,90	20,70	0,76	12,13	84,78	236,33	52,64	74,88	0,24	14,31
N3P 100-150	Nshawu	3	Permanent	N3P	100	150	125	233	186,40											8,83	8,19	240	2,50	4,30	11620	0,37	774,06	91,24	0,05	0,02	0,00	1,12	28,79	16,62	0,26	8,39	52,17		46,86	103,61	0,18	16,08
N3P 150-200	Nshawu	3	Permanent	N3P	150	200	175	234	133,71	6,01	6,54	12,15	11,16	10,07	17,37	35,80	35,87	27,45	35,80	8,91	8,51	250	1,65	2,84	7250	0,18	1029,17	84,40	0,05	0,02	0,00	1,09	27,94	13,75	0,16	5,60	43,48	121,44	43,01	109,12	0,13	12,88
N3P 200-250	Nshawu	3	Permanent	N3P	200	250	225	235	104,44											8,96	8,42	325	1,01	1,74	4430	0,25	1165,46	68,43	0,04	0,01	0,00	0,86	25,89	13,05	0,18	5,66	41,30		40,02	108,42	0,15	13,71
N3P 250-300	Nshawu	3	Permanent	N3P	250	300	275	236	85,82	6,77	5,82	8,73	6,64	5,00	15,25	50,83	27,96	20,24	50,83	8,94	8,41	300	0,85	1,46	3260	0,25	957,53	57,03	0,05	0,01	0,00	0,77	27,66	16,50	0,27	7,05	33,70	66,29	45,27	152,80	0,16	20,94
N3P 300-400	Nshawu	3	Permanent	N3P	300	400	350	237	67,71	7,72	4,41	7,85	5,58	3,93	15,29	54,23	25,58	19,21	54,23	8,89	8,26	340	0,76	1,31	3280	0,05	938,31	54,74	0,05	0,01	0,00	0,82	22,34	14,69	0,20	4,32	34,78	64,13	38,11	119,46	0,12	12,41
N3P 400-500	Nshawu	3	Permanent	N3P	400	500	450	238	52,89	4,48	4,10	5,69	4,10	11,68	7,26	61,49	18,36	18,94	61,49	8,85	8,01	325	0,66	1,14	2730	0,42	1172,45	91,24	0,06	0,02	0,00	0,82	25,03	20,14	0,38	7,86	39,13	63,64	46,44	136,48	0,17	20,08
N3P 500-600	Nshawu	3	Permanent	N3P	500	600	550	239	43,45	3,69	4,22	6,47	4,16	5,15	13,95	60,27	18,54	19,10	60,27	8,6	7,92	305	0,81	1,39	2840	0,45	1450,27	120,89	0,09	0,03	0,00	1,05	26,21	19,08	0,44	6,79	34,78	57,71	46,91	151,01	0,15	19,53
N3P 600-700	Nshawu	3	Permanent	N3P	600	700	650	240	36,92	3,22	2,76	4,34	3,22	4,87	13,33	67,75	13,56	18,20	67,75	8,52	7,95	335	0,67	1,15	2600	0,43	1794,49	159,67	0,07	0,02	0,00	0,99	24,73	20,98	0,45	6,52	40,22	59,36	47,25	131,00	0,14	16,22
N3P 700-800	Nshawu	3	Permanent	N3P	700	800	750	241	32,13	1,27	2,10	4,45	3,88	5,92	23,18	59,25	11,70	29,10	59,25	8,49	8,02	345	0,57	0,98	2080	0,12	1930,78	212,14	0,08	0,02	0,00	0,75	23,31	22,62	0,48	5,74	39,13	66,04	47,26	133,28	0,12	14,67
N3P 800-900	Nshawu	3	Permanent	N3P	800	900	850	242	28,47	2,60	3,05	5,59	4,70	5,30	13,08	63,79	15,93	18,38	63,79	8,35	8,26	365	0,45	0,77	1560	0,23	2600,00	198,45	0,08	0,02	0,00	0,64	21,16	20,35	0,47	4,40	55,43	86,90	42,73	83,68	0,11	7,94
N3P 900-1000	Nshawu	3	Permanent	N3P	900	1000	950	243	25,58	7,13	4,61	6,19	3,85	4,29	13,92	59,70	21,78	18,22	59,70	8,33	7,92	375	0,33	0,57	1330	0,10	2374,60	148,27	0,08	0,02	0,00	0,54	20,38	20,43	0,49	4,28	44,57	74,65	41,94	102,26	0,10	9,61
N3P 1000-1100	Nshawu	3	Permanent	N3P	1000	1100	1050	244	23,24	4,09	4,28	6,04	4,65	4,72	16,03	59,77	19,05	20,75	59,77	8,27	7,95	395	0,34	0,58	1130	0,35	2182,39	102,65	0,08	0,02	0,00	0,51	18,16	20,39	0,51	4,54	44,57	74,56	39,68	97,85	0,12	10,20
N3P 1100-1200	Nshawu	3	Permanent	N3P	1100	1200	1150	245	21,30	5,23	4,12	6,34	4,97	4,94	15,01	58,43	20,67	19,95	58,43	8,33	8,11	410	0,32	0,55	750	0,14	2297,72	68,43	0,10	0,02	0,00	0,64	16,20	16,86	0,45	4,05	40,22	68,83	34,28	93,42	0,12	10,08

Table 29 Laboratory analyses for the seasonal zones at Nshawu

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)
Sample description									Textures											pH	
N1S 0-50	Nshawu	1	Seasonal	N1S	0	50	25	246	984,00											8,98	8,53
N1S 50-100	Nshawu	1	Seasonal	N1S	50	100	75	247	329,33	7,67	7,73	8,84	7,80	11,20	28,01	28,47	32,04	39,21	28,47	9,12	8,79
N1S 100-150	Nshawu	1	Seasonal	N1S	100	150	125	248	198,40											9,17	8,68
N1S 150-200	Nshawu	1	Seasonal	N1S	150	200	175	249	142,29	5,64	5,51	8,43	5,13	5,16	17,46	49,39	24,71	22,62	49,39	9,09	8,8
N1S 200-250	Nshawu	1	Seasonal	N1S	200	250	225	250	111,11											9,14	8,63
N1S 250-300	Nshawu	1	Seasonal	N1S	250	300	275	251	91,27	2,89	3,35	5,39	3,74	4,76	17,11	61,00	15,37	21,88	61,00	9,22	8,56
N1S 300-400	Nshawu	1	Seasonal	N1S	300	400	350	252	72,00	3,71	2,14	4,33	3,14	3,45	19,00	59,76	13,32	22,45	59,76	9,17	8,53
N1S 400-500	Nshawu	1	Seasonal	N1S	400	500	450	253	56,22	5,69	2,75	3,47	2,23	5,07	18,62	58,38	14,14	23,69	58,38	9,13	8,51
N1S 500-600	Nshawu	1	Seasonal	N1S	500	600	550	254	46,18	4,90	3,50	5,03	3,76	4,11	15,89	58,68	17,19	20,00	58,68	8,9	8,46
N1S 600-700	Nshawu	1	Seasonal	N1S	600	700	650	255	39,23	6,51	3,69	5,26	3,75	4,07	14,49	60,63	19,21	18,55	60,63	8,75	8,73
N1S 700-800	Nshawu	1	Seasonal	N1S	700	800	750	256	34,13	6,02	5,17	6,88	4,58	4,03	17,39	52,03	22,66	21,41	52,03	8,87	8,56
N1S 800-900	Nshawu	1	Seasonal	N1S	800	900	850	257	30,24	6,13	4,74	6,00	5,05	5,53	18,47	50,77	21,91	24,00	50,77	8,65	8,44
N1S 900-1000	Nshawu	1	Seasonal	N1S	900	1000	950	258	27,16	5,03	5,09	8,24	6,16	6,26	19,84	47,26	24,53	26,10	47,26	8,55	8,44
N1S 1000-1100	Nshawu	1	Seasonal	N1S	1000	1100	1050	259	24,67	8,12	6,38	8,38	6,57	7,51	17,36	45,07	29,45	24,87	45,07	8,54	8,4
N1S 1100-1200	Nshawu	1	Seasonal	N1S	1100	1200	1150	260	22,61	9,42	7,53	9,09	7,14	7,37	21,66	37,69	33,18	29,03	37,69	8,42	8,51
N2S 0-50	Nshawu	2	Seasonal	N2S	0	50	25	261	1044,00											8,7	8,02
N2S 50-100	Nshawu	2	Seasonal	N2S	50	100	75	262	349,33	8,37	6,12	11,07	11,14	12,84	26,59	23,17	36,69	39,43	23,17	8,88	8,08
N2S 100-150	Nshawu	2	Seasonal	N2S	100	150	125	263	210,40											8,89	8,31
N2S 150-200	Nshawu	2	Seasonal	N2S	150	200	175	264	150,86	3,26	2,88	7,17	7,23	9,34	22,37	44,99	20,54	31,71	44,99	9,15	8,32
N2S 200-250	Nshawu	2	Seasonal	N2S	200	250	225	265	117,78	4,00	4,19	7,60	3,80	9,73	21,73	47,09	19,60	31,46	47,09	9,03	8,22
N2S 250-300	Nshawu	2	Seasonal	N2S	250	300	275	266	96,73	2,83	2,39	5,29	5,16	6,83	16,06	57,63	15,68	22,89	57,63	8,99	8,32
N2S 300-400	Nshawu	2	Seasonal	N2S	300	400	350	267	76,29	3,14	2,68	4,44	4,18	3,37	15,88	61,95	14,44	19,24	61,95	9,18	8,73
N2S 400-500	Nshawu	2	Seasonal	N2S	400	500	450	268	59,56	3,55	2,86	4,70	3,30	5,33	18,98	60,15	14,41	24,31	60,15	8,8	8,34
N2S 500-600	Nshawu	2	Seasonal	N2S	500	600	550	269	48,91	4,00	2,77	4,64	3,67	3,93	17,86	60,50	15,09	21,79	60,50	8,89	8,34
N2S 600-700	Nshawu	2	Seasonal	N2S	600	700	650	270	41,54	4,27	3,11	4,66	3,37	4,56	17,45	58,92	15,41	22,01	58,92	8,87	8,36
N2S 700-800	Nshawu	2	Seasonal	N2S	700	800	750	271	36,13	5,35	3,96	5,47	3,96	1,92	19,82	55,25	18,75	21,74	55,25	8,73	8,43
N2S 800-900	Nshawu	2	Seasonal	N2S	800	900	850	272	32,00	4,61	4,54	6,84	4,87	4,87	23,40	46,43	20,86	28,27	46,43	8,73	8,31
N2S 900-1000	Nshawu	2	Seasonal	N2S	900	1000	950	273	28,74	6,26	5,80	8,51	5,09	3,06	22,38	45,47	25,67	25,44	45,47	8,79	8,37
N2S 1000-1100	Nshawu	2	Seasonal	N2S	1000	1100	1050	274	26,10	8,72	7,83	9,62	5,60	6,94	24,93	37,92	31,78	31,87	37,92	8,63	8,37
N2S 1100-1200	Nshawu	2	Seasonal	N2S	1100	1200	1150	275	23,91	7,55	6,54	8,30	5,66	5,82	23,02	41,29	28,05	28,84	41,29	8,6	8,51
N3S 0-50	Nshawu	3	Seasonal	N3S	0	50	25	276	1104,00											9,91	9
N3S 50-100	Nshawu	3	Seasonal	N3S	50	100	75	277	369,33	2,19	3,35	12,48	8,17	7,63	15,73	47,33	26,19	23,36	47,33	9,89	8,85
N3S 100-150	Nshawu	3	Seasonal	N3S	100	150	125	278	222,40											9,83	8,98
N3S 150-200	Nshawu	3	Seasonal	N3S	150	200	175	279	159,43	11,62	5,78	10,67	7,81	7,34	14,67	44,88	35,89	22,01	44,88	9,69	8,84
N3S 200-250	Nshawu	3	Seasonal	N3S	200	250	225	280	124,44											9,61	8,84
N3S 250-300	Nshawu	3	Seasonal	N3S	250	300	275	281	102,18	3,31	4,35	8,17	6,55	6,03	16,54	50,34	22,38	22,58	50,34	9,54	8,75
N3S 300-400	Nshawu	3	Seasonal	N3S	300	400	350	282	80,57	2,02	2,73	6,83	3,97	6,02	17,21	56,46	15,55	23,22	56,46	9,45	8,6
N3S 400-500	Nshawu	3	Seasonal	N3S	400	500	450	283	62,89	2,87	3,20	6,52	5,09	4,93	16,21	57,87	17,68	21,14	57,87	9,4	8,68
N3S 500-600	Nshawu	3	Seasonal	N3S	500	600	550	284	51,64	3,32	3,84	6,31	4,81	4,23	14,04	60,10	18,27	18,27	60,10	9,23	8,56
N3S 600-700	Nshawu	3	Seasonal	N3S	600	700	650	285	43,85	3,60	2,75	4,58	3,14	6,02	20,60	58,04	14,06	26,62	58,04	9,04	8,3
N3S 700-800	Nshawu	3	Seasonal	N3S	700	800	750	286	38,13	2,52	2,33	4,97	3,96	4,28	23,84	55,45	13,78	28,12	55,45	8,94	8,4
N3S 800-900	Nshawu	3	Seasonal	N3S	800	900	850	287	33,76	3,39	3,45	5,37	3,58	3,99	21,22	55,74	15,79	25,22	55,74	8,71	8,03
N3S 900-1000	Nshawu	3	Seasonal	N3S	900	1000	950	288	30,32	4,27	4,27	6,04	3,94	3,45	17,56	57,48	18,52	21,01	57,48	8,55	7,95
N3S 1000-1100	Nshawu	3	Seasonal	N3S	1000	1100	1050	289	27,52	4,09	3,43	5,41	3,90	4,09	19,18	56,02	16,84	23,27	56,02	8,41	7,92
N3S 1100-1200	Nshawu	3	Seasonal	N3S	1100	1200	1150	290	25,22	3,81	3,68	5,32	4,20	4,17	18,26	61,10	17,02	22,43	61,10	8,44	7,96

Sample	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
	ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
N1S 0-50	116	3,06	5,26	8230	0,30	672,72	57,03	0,10	0,03	0,01	2,61	19,41	16,50	1,62	18,48	47,83		40,28	117,11	0,51	38,64
N1S 50-100	78	2,83	4,87	7370	0,06	531,18	50,18	0,09	0,05	0,01	5,65	19,05	17,38	1,11	28,37	51,09	179,46	43,34	129,01	0,78	55,53
N1S 100-150	74	2,21	3,80	5860	0,05	485,75	29,65	0,13	0,07	0,01	5,11	15,09	16,76	0,64	23,59	46,74		37,80	119,98	0,74	50,47
N1S 150-200	80	1,23	2,12	3410	0,19	477,02	25,09	0,15	0,11	0,01	5,33	9,14	18,61	0,43	17,83	38,04	77,02	33,77	120,93	0,64	46,86
N1S 200-250	88	1,11	1,91	3040	0,09	534,68	27,37	0,15	0,16	0,00	5,98	11,23	16,68	0,48	21,63	42,39		34,68	117,98	0,78	51,03
N1S 250-300	91	0,70	1,20	2020	0,23	536,42	27,37	0,18	0,20	0,00	5,22	7,93	18,36	0,40	12,50	41,30	67,71	32,28	94,86	0,48	30,26
N1S 300-400	108	0,57	0,98	1770	0,18	525,94	27,37	0,15	0,23	0,00	5,33	7,56	18,65	0,37	18,00	41,30	69,11	32,29	107,93	0,69	43,58
N1S 400-500	134	0,54	0,93	1460	0,16	506,72	25,09	0,15	0,19	0,00	2,83	10,13	20,10	0,38	16,41	35,87	61,44	33,78	131,10	0,54	45,76
N1S 500-600	126	0,57	0,98	1090	0,11	515,46	20,53	0,14	0,19	0,00	4,02	9,28	18,65	0,36	13,68	34,78	59,27	32,64	120,65	0,49	39,34
N1S 600-700	152	0,40	0,69	1020	0,21	449,06	18,25	0,13	0,14	0,00	4,78	9,21	17,27	0,34	11,05	35,87	59,16	31,88	105,61	0,42	30,82
N1S 700-800	192	0,20	0,34	930	0,18	587,10	18,25	0,14	0,08	0,00	2,07	10,50	17,83	0,26	8,10	29,35	56,41	30,87	124,99	0,29	27,59
N1S 800-900	242	0,25	0,43	1020	0,32	548,66	15,97	0,13	0,08	0,00	1,96	9,11	16,80	0,88	9,25	19,24	37,89	28,97	187,37	0,36	48,08
N1S 900-1000	284	0,43	0,74	520	0,04	643,01	22,81	0,14	0,05	0,00	1,57	8,81	14,92	0,26	5,75	31,52	66,70	25,74	94,34	0,24	18,24
N1S 1000-1100	390	0,10	0,17	430	0,05	802,02	22,81	0,13	0,03	0,00	0,88	10,35	16,50	0,87	7,55	22,61	50,16	28,76	156,00	0,28	33,41
N1S 1100-1200	460	0,06	0,10	660	0,22	809,01	20,53	0,12	0,03	0,00	0,89	11,29	16,54	0,49	4,51	42,39	112,46	29,36	77,42	0,16	10,64
N2S 0-50	490	3,99	6,86	10140	0,15	767,07	109,49	0,04	0,01	0,00	0,16	29,38	1,76	1,14	4,34	51,74		32,50	70,78	0,14	8,38
N2S 50-100	320	3,50	6,02	8110	0,27	740,86	114,05	0,02	0,00	0,00	0,25	25,00	2,15	0,99	10,00	42,93	185,27	28,41	88,84	0,37	23,29
N2S 100-150	280	2,13	3,66	6470	0,22	702,42	79,84	0,02	0,00	0,00	0,29	25,38	2,05	0,74	9,78	35,98		28,48	105,46	0,36	27,19
N2S 150-200	236	1,10	1,89	3190	0,22	686,69	47,90	0,03	0,00	0,00	0,29	24,13	2,03	0,47	9,02	27,50	61,12	26,94	129,61	0,34	32,81
N2S 200-250	260	0,73	1,26	2180	0,10	663,98	29,65	0,02	0,01	0,00	0,81	17,19	1,99	0,36	8,91	24,46	51,93	20,37	116,31	0,46	36,44
N2S 250-300	258	1,07	1,84	1280	0,04	599,33	25,09	0,02	0,01	0,00	0,84	15,79	2,23	0,34	8,70	21,41	37,16	19,23	126,35	0,48	40,61
N2S 300-400	256	0,47	0,81	1220	0,02	524,19	22,81	0,02	0,01	0,00	0,91	12,00	1,93	0,32	7,93	21,63	34,92	15,19	102,54	0,57	36,68
N2S 400-500	206	0,49	0,84	1350	0,02	595,83	20,53	0,03	0,02	0,00	1,37	13,79	2,01	0,34	8,15	20,76	34,52	17,55	116,98	0,52	39,27
N2S 500-600	250	0,36	0,62	1010	0,02	630,78	15,97	0,04	0,02	0,00	1,20	12,74	1,84	0,34	6,74	18,70	30,90	16,18	115,85	0,46	36,05
N2S 600-700	282	0,45	0,77	930	0,04	749,60	20,53	0,02	0,01	0,00	0,35	14,24	1,86	0,31	6,09	18,37	31,18	16,80	122,50	0,38	33,14
N2S 700-800	315	0,18	0,31	760	0,06	730,38	18,25	0,03	0,01	0,00	0,34	13,78	1,89	0,30	4,84	19,57	35,41	16,34	106,30	0,31	24,72
N2S 800-900	360	0,16	0,28	590	0,18	681,45	18,25	0,03	0,01	0,00	0,24	16,90	1,93	0,33	4,10	19,78	42,61	19,43	117,53	0,22	20,71
N2S 900-1000	455	0,16	0,28	430	0,31	749,60	22,81	0,03	0,01	0,00	0,20	16,69	1,91	0,28	3,65	18,15	39,92	19,12	124,10	0,20	20,12
N2S 1000-1100	490	0,53	0,91	260	0,12	859,68	25,09	0,02	0,00	0,00	0,13	19,06	1,64	0,33	2,98	28,04	73,95	21,19	85,60	0,14	10,62
N2S 1100-1200	540	0,14	0,24	500	0,02	917,34	29,65	0,03	0,01	0,00	0,17	19,25	1,84	0,35	2,88	19,67	47,65	21,65	123,62	0,14	14,64
N3S 0-50	68	1,18	2,03	2280	0,29	1860,89	145,99	0,04	0,01	0,00	2,30	25,00	0,70	1,75	40,00	41,63		29,80	162,00	1,56	96,08
N3S 50-100	70	1,19	2,05	2530	0,16	1700,13	127,74	0,04	0,01	0,00	2,63	26,88	0,78	1,59	41,52	56,96	120,33	31,92	124,25	1,50	72,90
N3S 100-150	84	0,97	1,67	2340	0,07	1044,89	61,59	0,04	0,01	0,00	2,53	24,38	1,00	0,86	29,67	29,24		28,81	191,22	1,17	101,49
N3S 150-200	116	0,77	1,32	2270	0,16	803,76	31,93	0,03	0,01	0,00	2,12	21,38	1,25	0,65	26,63	28,70	63,94	25,43	173,90	1,18	92,80
N3S 200-250	134	0,61	1,05	1930	0,03	887,63	36,50	0,04	0,01	0,00	1,80	19,98	1,48	0,65	23,26	26,30		23,95	172,46	1,08	88,43
N3S 250-300	156	0,53	0,91	1520	0,01	1270,30	45,62	0,04	0,01	0,00	1,43	14,65	1,64	0,53	20,76	26,63	52,90	18,29	141,12	1,27	77,96
N3S 300-400	188	0,72	1,24	1340	0,02	1439,78	50,18	0,03	0,01	0,00	1,10	12,10	1,76	0,48	17,17	25,22	44,66	15,49	124,98	1,24	68,10
N3S 400-500	192	0,39	0,67	1090	0,02	1261,56	45,62	0,03	0,01	0,00	0,83	12,85	1,86	0,50	16,09	26,09	45,08	16,09	119,98	1,09	61,67
N3S 500-600	250	0,37	0,64	840	0,06	1310,48	43,34	0,04	0,01	0,00	0,76	12,45	2,19	0,47	12,39	25,11	41,78	15,91	109,53	0,85	49,35
N3S 600-700	292	0,26	0,45	920	0,02	1581,32	43,34	0,03	0,01	0,00	0,29	12,10	2,34	0,47	9,67	24,78	42,70	15,25	99,20	0,67	39,04
N3S 700-800	320	0,71	1,22	750	0,03	1918,55	43,34	0,03	0,01	0,00	0,25	11,55	2,13	0,48	8,48	26,63	48,03	14,45	85,01	0,62	31,84
N3S 800-900	445	0,16	0,28	680	0,02	1929,03	38,78	0,02	0,00	0,00	0,17	14,08	2,50	0,46	5,22	23,04	41,34	17,24	96,57	0,31	22,64
N3S 900-1000	460	0,12	0,21	500	0,02	1846,91	38,78	0,03	0,00	0,00	0,15	17,83	2,09	0,41	3,61	21,96	38,20	20,51	109,00	0,18	16,44
N3S 1000-1100	530	0,11	0,19	420	0,16	1343,68	43,34	0,03	0,00	0,00	0,14	17,64	2,07	0,40	2,84	19,02	33,95	20,29	120,64	0,14	14,91
N3S 1100-1200	550	0,06	0,10	420	0,09	1546,37	52,46	0,03	0,00	0,00	0,14	18,43	2,09	0,40	2,78	19,35	31,67	21,09	122,50	0,14	14,38

Table 30 Laboratory analyses for the temporary zones at Nshawu

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)
Sample description									Textures											pH		ER
N1T 0-50	Nshawu	1	Temporary	N1T	0	50	25	291	1164,00											7,88	7,96	990
N1T 50-100	Nshawu	1	Temporary	N1T	50	100	75	292	389,33	10,02	8,13	16,33	7,25	9,84	19,29	25,12	41,74	29,13	25,12	7,9	8,17	810
N1T 100-150	Nshawu	1	Temporary	N1T	100	150	125	293	234,40											7,9	8,47	790
N1T 150-200	Nshawu	1	Temporary	N1T	150	200	175	294	168,00	9,88	6,38	11,13	8,19	6,19	20,05	34,53	35,59	26,24	34,53	8,1	8,43	920
N1T 200-250	Nshawu	1	Temporary	N1T	200	250	225	295	131,11											8,28	8,67	990
N1T 250-300	Nshawu	1	Temporary	N1T	250	300	275	296	107,64	14,69	7,77	9,38	7,05	6,73	21,52	29,51	38,90	28,25	29,51	8,35	8,64	890
N1T 300-400	Nshawu	1	Temporary	N1T	300	400	350	297	84,86	16,28	8,37	11,49	7,18	6,35	19,20	27,94	43,32	25,55	27,94	8,76	8,9	820
N1T 400-500	Nshawu	1	Temporary	N1T	400	500	450	298	66,22	17,86	8,04	10,87	7,97	5,90	19,11	29,65	44,74	25,00	29,65	9,41	8,97	560
N1T 500-600	Nshawu	1	Temporary	N1T	500	600	550	299	54,36	19,93	8,90	18,07	8,10	5,65	12,55	30,62	55,00	18,20	30,62	9,92	9,34	365
N1T 600-700	Nshawu	1	Temporary	N1T	600	700	650	300	46,15	16,07	9,06	10,71	8,13	8,17	14,91	29,43	43,98	23,08	29,43	9,89	9,28	264
N1T 700-800	Nshawu	1	Temporary	N1T	700	800	750	301	40,13	21,18	8,90	10,39	7,28	7,60	15,69	28,06	47,75	23,29	28,06	9,85	9,22	224
N1T 800-900	Nshawu	1	Temporary	N1T	800	900	850	302	35,53	19,09	9,69	12,55	8,99	8,92	18,80	22,30	50,33	27,72	22,30	9,72	9,09	246
N1T 900-1000	Nshawu	1	Temporary	N1T	900	1000	950	303	31,89	24,79	11,86	15,26	8,00	9,13	16,96	15,53	59,90	26,09	15,53	9,58	8,91	266
N1T 1000-1100	Nshawu	1	Temporary	N1T	1000	1100	1050	304	28,95	25,93	12,54	17,44	11,67	10,81	14,49	7,40	67,59	25,30	7,40	9,46	8,82	385
N1T 1100-1200	Nshawu	1	Temporary	N1T	1100	1200	1150	305	26,52	27,32	14,19	16,68	10,64	9,13	12,81	8,44	68,83	21,94	8,44	9,4	8,88	380
N2T 0-50	Nshawu	2	Temporary	N2T	0	50	25	306	1224,00											8,78	8,2	450
N2T 50-100	Nshawu	2	Temporary	N2T	50	100	75	307	409,33	10,58	6,37	12,42	13,54	12,06	20,50	21,13	42,91	32,56	21,13	9,28	8,67	226
N2T 100-150	Nshawu	2	Temporary	N2T	100	150	125	308	246,40											9,52	8,76	158
N2T 150-200	Nshawu	2	Temporary	N2T	150	200	175	309	176,57	11,90	6,01	9,52	7,73	8,10	19,36	32,58	35,16	27,46	32,58	9,88	9,25	124
N2T 200-250	Nshawu	2	Temporary	N2T	200	250	225	310	137,78											9,97	9,1	120
N2T 250-300	Nshawu	2	Temporary	N2T	250	300	275	311	113,09	15,01	7,25	9,30	6,16	5,16	18,41	34,99	37,72	23,58	34,99	10,12	9,39	84
N2T 300-400	Nshawu	2	Temporary	N2T	300	400	350	312	89,14	13,30	6,98	9,06	7,56	7,92	22,36	29,73	36,90	30,28	29,73	10,19	9,49	73
N3T 0-50	Nshawu	3	Temporary	N3T	0	50	25	313	1252,00											9,03	8,69	158
N3T 50-100	Nshawu	3	Temporary	N3T	50	100	75	314	418,67	8,21	7,56	12,49	10,32	9,33	18,99	28,52	38,58	28,32	28,52	9,89	9,14	116
N3T 100-150	Nshawu	3	Temporary	N3T	100	150	125	315	252,00											10,02	9,29	91
N3T 150-200	Nshawu	3	Temporary	N3T	150	200	175	316	180,57	8,72	6,84	15,10	8,14	8,69	18,85	28,74	38,80	27,54	28,74	10,16	9,46	85
N3T 200-250	Nshawu	3	Temporary	N3T	200	250	225	317	140,89											10,2	9,51	77
N3T 250-300	Nshawu	3	Temporary	N3T	250	300	275	318	115,64	11,75	6,63	12,38	7,52	7,68	20,85	28,93	38,28	28,52	28,93	10,23	9,55	83
N3T 300-400	Nshawu	3	Temporary	N3T	300	400	350	319	91,14	9,31	6,85	10,67	9,44	9,60	20,92	29,09	36,27	30,52	29,09	10,21	9,57	89
N3T 400-500	Nshawu	3	Temporary	N3T	400	500	450	320	71,11	8,01	7,16	11,16	9,06	9,45	19,11	32,89	35,39	28,56	32,89	10,18	9,55	95
N3T 500-600	Nshawu	3	Temporary	N3T	500	600	550	321	58,36	9,83	7,65	11,61	8,25	7,65	18,04	33,02	37,34	25,69	33,02	10,14	9,52	122
N3T 600-700	Nshawu	3	Temporary	N3T	600	700	650	322	49,54	9,58	6,58	10,79	9,01	7,89	23,66	27,85	35,96	31,55	27,85	10,01	9,34	162
N3T 700-800	Nshawu	3	Temporary	N3T	700	800	750	323	43,07	7,66	6,39	11,52	9,24	13,23	24,91	25,74	34,82	38,14	25,74	9,92	9,14	190
N3T 800-900	Nshawu	3	Temporary	N3T	800	900	850	324	38,12	12,05	11,55	22,98	9,38	11,12	16,49	13,29	55,96	27,61	13,29	9,68	8,96	320
N3T 900-1000	Nshawu	3	Temporary	N3T	900	1000	950	325	34,21	12,76	12,38	19,57	12,88	13,20	15,54	11,66	57,60	28,74	11,66	9,54	8,74	460
N3T 1000-1100	Nshawu	3	Temporary	N3T	1000	1100	1050	326	31,05	12,94	15,08	18,05	10,03	9,09	16,63	23,17	56,10	25,72	23,17	9,38	8,67	440
N3T 1100-1200	Nshawu	3	Temporary	N3T	1100	1200	1150	327	28,43	15,28	15,15	17,33	8,20	6,35	19,22	17,10	55,97	25,57	17,10	9,1	8,34	430

Sample	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
N1T 0-50	2,47	4,25	5620	0,20	2372,85	191,61	0,17	0,03	0,01	0,05	49,50	8,20	1,57	1,09	28,91		59,52	208,73	0,02	3,76
N1T 50-100	2,41	4,15	5970	0,11	2184,14	184,76	0,10	0,03	0,01	0,03	54,00	8,20	1,71	0,34	28,26	112,48	64,07	227,34	0,01	1,19
N1T 100-150	2,03	3,49	4140	0,08	1565,59	134,58	0,11	0,03	0,00	0,02	53,13	7,38	1,37	0,26	24,67		62,04	251,84	0,00	1,06
N1T 150-200	2,09	3,59	4030	0,08	1747,31	132,30	0,09	0,02	0,00	0,03	55,88	7,79	1,23	0,30	24,24	70,21	65,04	268,99	0,00	1,26
N1T 200-250	1,37	2,36	3530	0,07	1611,02	116,33	0,06	0,02	0,00	0,04	57,25	8,40	1,29	0,52	20,87		67,05	323,24	0,01	2,50
N1T 250-300	1,29	2,22	2690	0,05	1420,56	102,65	0,06	0,02	0,00	0,04	54,38	8,20	0,98	0,51	19,57	66,29	63,66	327,42	0,01	2,61
N1T 300-400	0,69	1,19	1680	0,04	1600,54	68,43	0,04	0,01	0,00	0,07	54,00	9,43	0,70	1,16	16,41	58,74	64,24	397,77	0,02	7,09
N1T 400-500	0,44	0,76	1270	0,15	1577,82	45,62	0,04	0,01	0,00	0,11	44,50	8,81	0,59	4,73	14,57	49,13	54,06	402,52	0,09	32,46
N1T 500-600	0,21	0,36	930	0,05	1284,27	29,65	0,03	0,01	0,00	0,19	32,00	9,02	0,39	10,11	13,37	43,66	41,64	385,32	0,25	75,61
N1T 600-700	0,07	0,12	600	0,03	1492,20	31,93	0,04	0,01	0,00	0,28	14,01	13,11	0,32	13,48	15,11	51,34	27,77	270,87	0,50	89,21
N1T 700-800	0,15	0,26	340	0,03	1317,47	31,93	0,04	0,01	0,00	1,48	11,21	12,50	0,23	14,35	16,30	58,10	25,47	234,85	0,61	88,00
N1T 800-900	0,13	0,22	350	0,03	1018,68	27,37	0,06	0,01	0,00	0,30	9,96	15,16	0,22	15,65	18,37	82,38	25,71	223,17	0,62	85,21
N1T 900-1000	0,10	0,17	270	0,03	1030,91	25,09	0,02	0,01	0,00	0,26	6,93	14,55	0,33	16,20	24,57	158,22	22,09	154,70	0,75	65,93
N1T 1000-1100	0,05	0,09	250	0,19	1043,15	31,93	0,02	0,01	0,00	0,16	4,96	17,01	0,20	11,20	27,28	368,91	22,36	122,29	0,51	41,04
N1T 1100-1200	0,04	0,07	180	0,11	1030,91	38,78	0,01	0,01	0,00	0,14	4,91	18,85	0,17	10,43	27,72	328,41	24,09	123,99	0,44	37,65
N2T 0-50	1,31	2,25	670	0,21	2970,43	260,04	0,04	0,01	0,00	0,17	50,88	7,17	1,30	4,21	25,76		59,57	246,72	0,07	16,33
N2T 50-100	1,14	1,96	680	0,33	2489,92	187,04	0,04	0,01	0,00	1,29	50,00	5,94	1,13	12,72	24,57	116,28	58,41	284,11	0,23	51,77
N2T 100-150	0,91	1,57	920	0,09	2332,66	161,95	0,04	0,01	0,00	1,93	47,88	5,33	0,96	19,13	26,30		56,14	278,63	0,36	72,73
N2T 150-200	1,03	1,77	490	0,07	2304,70	143,70	0,04	0,01	0,00	2,51	44,25	4,71	0,86	24,24	26,74	82,07	52,39	276,99	0,50	90,65
N2T 200-250	0,62	1,07	350	0,06	2708,33	148,27	0,04	0,01	0,00	2,71	46,88	4,51	0,65	25,43	21,74		54,79	356,33	0,50	117,00
N2T 250-300	0,45	0,77	170	0,05	2558,06	100,36	0,02	0,01	0,00	3,64	43,75	3,14	0,56	27,83	23,80	68,02	51,11	316,19	0,59	116,89
N2T 300-400	0,37	0,64	240	0,07	2482,93	79,84	0,01	0,00	0,00	4,23	46,38	3,69	0,52	29,13	25,65	86,28	54,83	310,77	0,58	113,56
N3T 0-50	1,17	2,01	760	0,16	1764,78	114,05	0,13	0,02	0,00	2,12	43,50	5,12	0,92	9,46	18,37		51,82	321,18	0,19	51,48
N3T 50-100	0,81	1,39	510	0,11	1860,89	111,77	0,05	0,01	0,00	2,90	44,38	4,30	1,02	22,61	13,59	47,64	52,66	532,15	0,46	166,40
N3T 100-150	0,77	1,32	440	0,19	988,98	72,99	0,05	0,01	0,00	3,17	39,38	4,10	0,75	24,35	13,59		47,44	504,67	0,56	179,20
N3T 150-200	0,48	0,83	660	0,05	1411,83	72,99	0,02	0,01	0,00	3,84	44,75	3,89	0,56	26,20	24,67	85,84	53,07	305,57	0,54	106,17
N3T 200-250	0,32	0,55	490	0,05	1715,86	75,27	0,01	0,00	0,00	4,23	44,50	3,11	0,47	24,89	21,09		52,33	346,06	0,52	118,04
N3T 250-300	0,24	0,41	320	0,04	2330,91	79,84	0,01	0,00	0,00	4,47	45,63	4,10	0,34	24,35	20,76	71,76	54,55	358,41	0,49	117,28
N3T 300-400	0,13	0,22	330	0,05	2110,75	86,68	0,01	0,00	0,00	4,15	43,88	4,71	0,26	21,74	18,04	62,02	53,01	391,18	0,45	120,48
N3T 400-500	0,17	0,29	100	0,04	1717,61	84,40	0,01	0,00	0,00	3,95	32,75	8,81	0,22	20,87	15,33	46,59	45,75	408,81	0,50	136,17
N3T 500-600	0,19	0,33	250	0,05	1495,70	145,99	0,02	0,01	0,00	3,65	8,23	10,04	0,17	20,43	18,80	56,95	22,12	206,73	1,12	108,67
N3T 600-700	0,15	0,26	330	0,03	1111,29	61,59	0,03	0,02	0,01	0,39	8,54	13,32	0,12	21,63	24,24	87,04	22,42	179,91	0,99	89,24
N3T 700-800	0,16	0,28	160	0,07	618,55	38,78	0,02	0,02	0,01	0,33	10,35	21,11	0,11	22,28	28,48	110,66	31,95	189,08	0,71	78,24
N3T 800-900	0,06	0,10	510	0,16	651,75	166,51	0,02	0,01	0,01	0,18	4,56	17,42	0,15	14,89	25,98	195,44	22,36	142,52	0,68	57,32
N3T 900-1000	0,05	0,09	250	0,04	697,18	428,83	0,02	0,01	0,00	0,11	4,19	22,34	0,13	10,76	27,07	232,05	26,80	138,23	0,41	39,76
N3T 1000-1100	0,07	0,12	410	0,16	464,78	43,34	0,01	0,01	0,01	0,09	6,30	29,51	0,13	8,80	30,22	130,44	36,06	148,08	0,25	29,14
N3T 1100-1200	0,08	0,14	100	0,40	672,72	31,93	0,00	0,02	0,00	0,09	9,78	29,10	0,23	6,96	32,39	189,39	39,22	142,20	0,18	21,48

Table 31 Laboratory analyses for the upland zones at Nshawu

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
N1U 0-50	Nshawu	1	Upland	N1U	0	50	25	328	1312,00											7,99	7,79	780	4,13	7,10	2610	0,40	4071,24	273,72	0,09	0,04	0,01	0,04	42,63	12,30	1,21	0,18	39,46		56,31	142,74	0,00	0,47
N1U 50-100	Nshawu	1	Upland	N1U	50	100	75	329	438,67	11,27	7,60	17,26	16,10	9,08	10,73	23,61	52,24	19,81	23,61	7,95	7,86	780	3,36	5,78	2360	0,17	4176,08	253,19	0,10	0,04	0,01	0,02	52,13	8,61	0,56	0,18	31,20	132,13	61,45	197,06	0,00	0,59
N1U 100-150	Nshawu	1	Upland	N1U	100	150	125	330	264,00											7,89	7,78	810	2,91	5,01	2360	0,27	4071,24	232,66	0,14	0,04	0,01	0,02	55,25	8,40	0,45	0,35	36,20		64,30	178,05	0,01	0,96
N1U 150-200	Nshawu	1	Upland	N1U	150	200	175	331	189,14	12,31	6,25	15,69	7,10	6,15	15,63	32,04	41,35	21,78	32,04	8,05	7,95	970	2,76	4,75	1750	0,30	3634,41	212,14	0,11	0,07	0,01	0,02	53,75	7,17	0,30	0,20	41,63	129,93	61,43	147,53	0,00	0,47
N1U 200-250	Nshawu	1	Upland	N1U	200	250	225	332	147,56											8,1	7,95	970	2,02	3,47	1170	0,07	3372,31	143,70	0,12	0,03	0,01	0,02	61,25	7,58	0,24	0,18	29,89		69,24	231,68	0,00	0,62
N1U 250-300	Nshawu	1	Upland	N1U	250	300	275	333	121,09	20,96	6,36	11,42	10,77	8,82	21,44	17,19	49,51	30,27	17,19	7,94	7,74	870	1,99	3,42	690	0,09	3127,69	161,95	0,10	0,03	0,01	0,02	68,25	8,20	0,27	0,20	27,72	161,20	76,87	277,51	0,00	0,71
N1U 300-400	Nshawu	1	Upland	N1U	300	400	350	334	95,43	19,45	6,75	11,46	9,49	7,13	20,02	22,74	47,14	27,15	22,74	8,24	8,39	1040	1,71	2,94	2100	0,13	3337,37	132,30	0,10	0,03	0,01	0,02	51,50	6,76	0,22	0,18	26,85	118,04	58,63	218,51	0,00	0,69
N1U 400-500	Nshawu	1	Upland	N1U	400	500	450	335	74,44	17,94	7,14	11,49	8,21	5,43	18,60	28,30	44,78	24,03	28,30	8,17	8,35	1140	1,26	2,17	780	0,10	3057,80	116,33	0,10	0,03	0,01	0,02	52,25	7,58	0,17	0,17	22,50	79,52	60,16	267,43	0,00	0,77
N2U 0-50	Nshawu	2	Upland	N2U	0	50	25	336	1344,00											7,94	7,9	640	2,45	4,21	1010	0,23	5451,61	376,37	0,20	0,05	0,01	0,02	51,75	7,58	2,05	0,25	36,74		61,66	167,74	0,00	0,68
N2U 50-100	Nshawu	2	Upland	N2U	50	100	75	337	449,33	16,95	7,38	13,76	7,38	5,38	17,88	26,89	45,46	23,26	26,89	7,98	7,88	740	2,56	4,40	1160	0,13	5206,99	378,65	0,11	0,04	0,01	0,02	55,25	7,79	0,92	0,23	37,39	139,07	64,14	171,66	0,00	0,61
N2U 100-150	Nshawu	2	Upland	N2U	100	150	125	338	270,40											8,02	7,76	745	2,44	4,20	1320	0,34	5294,35	355,84	0,09	0,03	0,01	0,02	53,50	8,61	0,63	0,33	35,76		62,89	176,34	0,01	0,91
N2U 150-200	Nshawu	2	Upland	N2U	150	200	175	339	193,71	7,40	4,70	11,78	5,08	5,37	19,02	41,71	28,96	24,39	41,71	8,06	8,02	860	2,45	4,21	820	0,30	5241,94	280,57	0,08	0,03	0,01	0,03	51,88	7,58	0,45	0,38	33,48	80,27	60,05	180,07	0,01	1,14
N2U 200-250	Nshawu	2	Upland	N2U	200	250	225	340	151,11											8,06	7,82	840	2,00	3,44	1330	0,07	5084,68	250,91	0,12	0,03	0,01	0,02	54,50	7,58	0,34	0,25	28,80		62,60	217,57	0,00	0,87
N2U 250-300	Nshawu	2	Upland	N2U	250	300	275	341	124,00	11,49	7,39	9,04	7,49	5,39	26,10	28,44	35,41	31,49	28,44	8,01	7,76	720	1,93	3,32	1350	0,10	5014,78	255,47	0,13	0,04	0,01	0,02	53,38	7,79	0,52	0,24	34,02	119,61	61,87	182,00	0,00	0,70
N2U 300-400	Nshawu	2	Upland	N2U	300	400	350	342	97,71	15,90	10,17	12,86	3,57	9,76	26,50	19,27	42,49	36,26	19,27	7,95	7,78	800	2,11	3,63	1830	0,23	4962,37	271,44	0,12	0,03	0,01	0,02	59,38	7,99	0,77	0,18	29,57	153,41	68,31	231,10	0,00	0,63
N2U 400-500	Nshawu	2	Upland	N2U	400	500	450	343	76,22	12,23	5,21	8,06	6,19	6,22	25,30	32,16	31,69	31,52	32,16	8,14	8,16	910	1,42	2,44	1420	0,05	4473,12	171,08	0,10	0,03	0,00	0,02	60,25	7,79	0,23	0,17	26,63	82,81	68,42	257,00	0,00	0,65
N2U 500-600	Nshawu	2	Upland	N2U	500	600	550	344	62,55	26,13	9,57	10,65	6,30	6,50	19,71	18,27	52,65	26,20	18,27	10,27	9,52	81	0,14	0,24	660	0,20	2482,93	86,68	0,03	0,01	0,00	0,36	17,70	4,51	0,19	31,52	23,70	129,73	22,80	227,56	1,42	133,03
N2U 600-700	Nshawu	2	Upland	N2U	600	700	650	345	53,08	25,67	8,64	9,79	7,29	5,88	14,54	23,70	51,39	20,42	23,70	10,21	9,45	93	0,14	0,24	580	0,19	2355,38	59,31	0,01	0,00	0,00	0,43	17,94	7,17	0,17	23,91	23,48	99,05	25,72	209,51	0,95	101,85
N2U 700-800	Nshawu	2	Upland	N2U	700	800	750	346	46,13	19,21	8,84	11,42	9,38	8,66	17,20	23,18	48,84	25,86	23,18	9,87	8,95	174	0,11	0,19	400	0,05	1785,75	68,43	0,03	0,01	0,00	0,31	8,30	13,32	0,15	19,35	25,87	111,60	22,12	158,93	0,89	74,79
N2U 800-900	Nshawu	2	Upland	N2U	800	900	850	347	40,82	31,68	11,19	10,84	8,23	8,50	15,03	13,18	61,94	23,53	13,18	9,77	9	280	0,07	0,12	240	0,11	1738,58	123,18	0,02	0,01	0,00	0,17	8,00	19,67	0,12	14,46	26,30	199,56	27,99	160,60	0,52	54,96
N2U 900-1000	Nshawu	2	Upland	N2U	900	1000	950	348	36,63	30,13	10,08	9,19	5,93	7,73	17,14	16,97	55,33	24,87	16,97	9,26	8,61	455	0,09	0,15	570	0,05	1818,95	171,08	0,02	0,01	0,01	0,11	8,76	23,98	0,12	6,74	26,41	155,66	33,00	149,92	0,21	25,51
N2U 1000-1100	Nshawu	2	Upland	N2U	1000	1100	1050	349	33,24	42,01	14,18	12,50	7,21	6,47	10,41	5,72	75,91	16,87	5,72	9,22	8,67	515	0,08	0,14	420	0,05	2551,08	556,57	0,01	0,01	0,00	0,07	8,14	29,92	0,09	4,46	29,57	516,83	38,25	144,09	0,12	15,07
N2U 1100-1200	Nshawu	2	Upland	N2U	1100	1200	1150	350	30,43	33,06	14,28	13,06	9,24	8,36	12,74	7,92	69,65	21,11	7,92	9,28	8,81	650	0,04	0,07	230	0,24	1635,48	296,53	0,01	0,01	0,00	0,07	8,28	27,05	0,06	3,15	34,78	438,98	35,49	110,80	0,09	9,06
N3U 0-50	Nshawu	3	Upland	N3U	0	50	25	351	1404,00											7,93	8,07	750	2,82	4,85	1340	0,22	3948,92	344,43	0,16	0,04	0,01	0,03	46,38	12,70	1,89	0,21	31,20		61,20	196,11	0,00	0,66
N3U 50-100	Nshawu	3	Upland	N3U	50	100	75	352	469,33	12,05	8,39	13,11	9,45	12,82	25,43	16,61	43,00	38,25	16,61	7,93	7,92	830	2,85	4,90	1180	0,37	4420,70	349,00	0,11	0,04	0,01	0,02	53,50	9,22	0,67	0,25	30,00	180,66	63,56	212,14	0,00	0,83
N3U 100-150	Nshawu	3	Upland	N3U	100	150	125	353	282,40											7,96	7,9	800	2,80	4,82	1000	0,11	4612,90	351,28	0,11	0,03	0,01	0,02	51,88	8,81	1,02	0,20	32,07		61,88	193,06	0,00	0,61
N3U 150-200	Nshawu	3	Upland	N3U	150	200	175	354	202,29	13,36	6,71	12,24	10,13	7,57	21,52	25,50	42,45	29,09	25,50	8,02	7,83	730	2,56	4,40	970	0,09	4822,58	362,68	0,10	0,03	0,01	0,02	61,63	8,81	0,45	0,30	30,76	120,63	71,04	231,43	0,00	0,99
N3U 200-250	Nshawu	3	Upland	N3U	200	250	225	355	157,78											8,04	8,24	760	2,47	4,25	580	0,08	4315,86	321,62	0,12	0,03	0,01	0,02	72,00	10,66	0,38	0,29	21,63		83,21	385,23	0,00	1,36
N3U 250-300	Nshawu	3	Upland	N3U	250	300	275	356	129,45	15,83	8,28	12,94	9,51	7,52	22,23	19,60	46,56	29,75	19,60	8,01	7,93	690	2,25	3,87	1070	0,08	4298,39	246,35	0,10	0,03	0,00	0,02	62,13	9,02	0,35	0,34	27,39	139,73	71,64	262,21	0,00	1,23
N3U 300-400	Nshawu	3	Upland	N3U	300	400	350	357	102,00	20,47	8,03	9,95	5,86	8,07	23,33	22,15	44,31	31,41	22,15	7,99	7,98	790	2,25	3,87	1080	0,08	4018,82	218,98	0,12	0,03	0,00	0,02	73,63	8,40	0,25	0,23	27,93	126,09	82,44	295,35	0,00	0,82
N3U 400-500	Nshawu	3	Upland	N3U	400	500	450	358	79,56	24,98	7,42	10,64	8,85	6,46	15,85	21,49	51,89	22,31	21,49	7,98	7,83	860	1,85	3,18	920	0,08	3739,25	193,89	0,13	0,03	0,00	0,02	76,50	9,02	0,23	0,23	24,57	114,29	85,94	349,99	0,00	0,93

Table 32 Laboratory analyses for the permanent zones at the Tshutshi spruit

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
P1P 0-50	Phalaborwa	1	Permanent	P1P	0	50	25	1	4,00	5,32	18,62	35,92	12,97	7,64	5,56	9,11	72,83	13,20	9,11	7,13	6,42	400	2,39	4,11	6330		3477,15	317,06	0,35	0,27	0,00	0,12	6,25	2,59	0,24	0,49	278,26	3055,34	9,82	3,44	0,06	0,18
P1P 50-100	Phalaborwa	1	Permanent	P1P	50	100	75	2	2,67	3,67	10,00	28,99	15,66	9,49	9,30	18,63	58,31	18,79	18,63	7,65	6,67	500	2,08	3,58	5790	0,73	4036,29	367,24	0,16	0,10	0,00	0,06	4,29	1,39	0,10	0,12	295,65	1586,80	6,10	2,00	0,02	0,04
P1P 100-150	Phalaborwa	1	Permanent	P1P	100	150	125	3	2,40	2,00	6,33	24,65	16,99	11,38	11,20	23,33	49,96	22,58	23,33	7,74	6,85	475	2,19	3,77	4980	0,56	4280,91	410,58	0,21	0,14	0,00	0,06	5,26	2,00	0,13	0,22	234,78	1006,39	7,80	3,24	0,03	0,09
P1P 150-200	Phalaborwa	1	Permanent	P1P	150	200	175	4	2,29	2,66	5,33	23,98	18,32	12,23	10,66	22,75	50,29	22,89	22,75	8,27	7,39	600	1,17	2,01	3670	0,18	3599,46	264,60	0,13	0,07	0,00	0,04	4,48	0,82	0,08	0,05	18,09	79,49	5,62	30,01	0,01	0,29
P1P 200-250	Phalaborwa	1	Permanent	P1P	200	250	225	5	2,22	1,33	3,33	24,65	19,65	16,46	11,34	19,19	48,97	27,80	19,19	8,55	7,43	560	1,04	1,79	2750	0,18	4036,29	307,94	0,11	0,06	0,00	0,05	6,23	1,07	0,10	0,08	18,35	95,62	7,61	40,75	0,01	0,43
P1P 250-300	Phalaborwa	1	Permanent	P1P	250	300	275	6	2,18	0,67	2,33	17,31	21,96	20,55	12,93	19,26	42,26	33,48	19,26	8,9	7,45	465	0,94	1,62	2540	0,18	4682,80	351,28	0,11	0,06	0,00	0,06	9,27	2,33	0,23	0,17	200,00	1038,32	12,06	6,00	0,01	0,08
P1P 300-400	Phalaborwa	1	Permanent	P1P	300	400	350	7	2,00	3,99	6,32	18,30	19,97	20,37	10,12	16,78	48,59	30,49	16,78	8,98	7,84	310	0,69	1,19	1810	0,18	4018,82	271,44	0,19	0,14	0,00	0,12	8,42	1,93	0,24	0,06	16,96	101,04	11,05	62,81	0,01	0,36
P1P 400-500	Phalaborwa	1	Permanent	P1P	400	500	450	8	1,78	11,31	11,98	30,28	17,30	9,82	5,72	10,67	70,87	15,55	10,67	9,58	8,25	330	0,38	0,65	1240	0,13	2620,97	168,80	0,14	0,09	0,00	0,15	5,28	2,52	0,60	0,10	9,65	90,42	8,78	88,14	0,01	1,08
P1P 500-600	Phalaborwa	1	Permanent	P1P	500	600	550	9	1,64	9,99	19,32	36,31	13,66	6,23	4,22	6,76	79,28	10,44	6,76	9,54	7,94	430	0,25	0,43	660	0,09	2330,91	155,11	0,11	0,06	0,00	0,13	6,21	6,23	0,41	0,30	7,74	114,40	13,14	169,84	0,02	3,82
P1P 600-700	Phalaborwa	1	Permanent	P1P	600	700	650	10	1,54	7,65	24,29	35,26	11,64	3,63	4,36	8,41	78,84	8,00	8,41	9,61	8,09	430	0,24	0,41	470	0,09	2093,28	109,49	0,12	0,06	0,00	0,13	4,84	2,38	0,74	0,13	7,39	87,92	8,28	109,44	0,02	1,76
P1P 700-800	Phalaborwa	1	Permanent	P1P	700	800	750	11	1,47	12,97	36,92	30,94	6,99	2,34	0,98	5,92	87,82	3,33	5,92	9,3	7,38	855	0,20	0,34	350	0,07	1976,21	57,03	0,08	0,04	0,00	0,08	2,28	1,43	0,38	0,09	5,30	89,55	4,28	78,65	0,02	1,64
P1P 800-900	Phalaborwa	1	Permanent	P1P	800	900	850	12	1,41	5,99	37,29	37,95	8,32	3,09	0,72	3,88	89,55	3,81	3,88	9,15	7,22	760	0,18	0,31	210	0,09	2068,82	59,31	0,08	0,04	0,00	0,07	2,05	1,33	0,30	0,08	10,09	259,99	3,88	37,26	0,02	0,78
P1P 900-1000	Phalaborwa	1	Permanent	P1P	900	1000	950	13	1,37	9,65	29,60	33,26	8,32	3,37	1,82	11,48	80,82	5,19	11,48	8,22	8,98	690	0,07	0,12	410	0,09	2678,63	111,77	0,11	0,05	0,00	0,08	2,29	0,74	0,11	0,05	7,83	68,20	3,39	40,79	0,02	0,67
P1P 1000-1100	Phalaborwa	1	Permanent	P1P	1000	1100	1050	14	1,33	13,63	29,25	33,57	9,97	3,23	2,46	7,12	86,42	5,69	7,12	8,62	9,25	650	0,14	0,24	470	0,10	2142,20	120,89	0,18	0,08	0,00	0,10	14,62	4,10	0,39	0,20	8,26	116,02	19,46	233,72	0,01	2,42
P1P 1100-1200	Phalaborwa	1	Permanent	P1P	1100	1200	1150	15	1,30	15,64	34,61	25,29	6,66	2,50	1,45	9,74	82,21	3,95	9,74	8,83	9,34	720	0,08	0,14	10	0,14	2014,65	123,18	0,20	0,09	0,00	0,09	12,94	4,26	0,40	0,20	7,65	78,55	17,98	232,70	0,01	2,61
P2P 0-50	Phalaborwa	2	Permanent	P2P	0	50	25	16	64,00	5,00	20,66	39,65	12,66	3,76	4,73	9,33	77,96	8,49	9,33	7,52	6,91	510	1,55	2,67	4100	0,18	2489,92	187,04	0,23	0,16	0,00	0,04	4,99	1,61	0,07	0,17	14,35	153,80	7,10	47,63	0,03	1,15
P2P 50-100	Phalaborwa	2	Permanent	P2P	50	100	75	17	22,67	10,66	28,31	27,97	8,33	5,23	3,37	11,64	75,26	8,60	11,64	7,73	6,97	740	1,38	2,37	3520	0,23	2514,38	173,36	0,13	0,08	0,00	0,03	4,73	1,67	0,10	0,21	8,15	70,02	6,74	82,28	0,03	2,56
P2P 100-150	Phalaborwa	2	Permanent	P2P	100	150	125	18	14,40	12,31	32,27	33,27	8,32	2,77	2,17	7,13	86,16	4,94	7,13	8,36	7,52	980	0,57	0,98	1590	0,30	1993,68	100,36	0,05	0,04	0,00	0,06	4,91	1,61	0,14	0,21	5,57	78,09	6,81	123,33	0,03	3,75
P2P 150-200	Phalaborwa	2	Permanent	P2P	150	200	175	19	10,86	3,99	26,26	38,89	10,97	4,72	3,42	8,67	80,10	8,14	8,67	9	7,83	830	0,59	1,01	1390	0,33	2540,59	152,83	0,09	0,04	0,00	0,05	5,30	0,97	0,13	0,05	8,87	102,34	6,58	72,75	0,01	0,59
P2P 200-250	Phalaborwa	2	Permanent	P2P	200	250	225	20	8,89	2,33	16,63	33,92	18,62	9,64	3,76	10,39	71,50	13,41	10,39	9,48	7,99	540	0,71	1,22	1670	0,31	3127,69	189,32	0,07	0,03	0,00	0,08	13,72	2,67	0,66	0,17	11,39	109,68	17,24	151,19	0,01	1,45
P2P 250-300	Phalaborwa	2	Permanent	P2P	250	300	275	21	7,64	1,33	12,98	35,27	18,97	8,74	5,06	13,96	68,55	13,80	13,96	9,58	8,2	570	0,46	0,79	1010	0,30	2872,58	155,11	0,10	0,04	0,00	0,09	8,30	1,39	0,32	0,05	10,96	78,47	10,25	91,84	0,01	0,48
P2P 300-400	Phalaborwa	2	Permanent	P2P	300	400	350	22	6,29	5,66	30,65	42,97	9,99	2,23	1,75	5,78	89,27	3,97	5,78	9,59	8,46	720	0,34	0,58	520	0,28	2240,05	91,24	0,08	0,04	0,00	0,07	5,84	1,89	0,49	0,10	7,91	136,95	8,40	105,09	0,01	1,32
P2P 400-500	Phalaborwa	2	Permanent	P2P	400	500	450	23	5,11	8,31	35,91	35,58	9,31	3,01	1,56	3,75	89,11	4,56	3,75	9,42	8,35	750	0,31	0,53	470	0,26	2014,65	70,71	0,10	0,04	0,00	0,08	6,66	1,38	0,27	0,08	6,26	167,09	8,52	133,87	0,01	1,25
P2P 500-600	Phalaborwa	2	Permanent	P2P	500	600	550	24	4,36	6,98	23,61	32,59	14,63	6,00	3,44	9,12	77,81	9,44	9,12	9,48	8,23	670	0,31	0,53	610	0,24	2619,22	116,33	0,11	0,05	0,00	0,08	7,24	1,33	0,21	0,05	8,43	92,50	9,02	104,68	0,01	0,62
P2P 600-700	Phalaborwa	2	Permanent	P2P	600	700	650	25	3,85	2,99	18,61	41,88	13,96	4,61	5,37	10,15	77,44	9,98	10,15	9,17	8,05	595	0,39	0,67	730	0,23	2593,01	118,61	0,15	0,06	0,00	0,07	5,77	1,15	0,19	0,12	9,13	89,95	7,40	79,23	0,02	1,33
P2P 700-800	Phalaborwa	2	Permanent	P2P	700	800	750	26	3,47	1,33	19,99	48,31	11,66	2,80	3,00	8,53	81,29	5,80	8,53	9,43	8,15	690	0,24	0,41	550	0,22	2444,49	116,33	0,12	0,06	0,00	0,06	6,31	2,36	0,35	0,10	8,96	104,95	9,26	101,86	0,01	1,17
P2P 800-900	Phalaborwa	2	Permanent	P2P	800	900	850	27	3,18	2,33	11,97	44,54	16,62	5,05	4,67	10,94	75,45	9,72	10,94	8,88	7,78	480	0,38	0,65	780	0,27	2640,19	100,36	0,22	0,11	0,00	0,09	4,77	1,41	0,19	0,07	9,91	90,59	6,80	65,00	0,01	0,70
P2P 900-1000	Phalaborwa	2	Permanent	P2P	900	1000	950	28	2,95	7,98	9,97	31,24	17,28	10,10	6,13	14,04	66,47	16,23	14,04	8,62	7,29	450	0,51	0,88	970	0,22	2781,72	70,71	0,19	0,10	0,00	0,07	6,32	4,75	0,42	0,11	12,43	88,60	11,87	93,34	0,01	0,91
P2P 1000-1100	Phalaborwa	2	Permanent	P2P	1000	1100	1050	29	2,76	55,93	13,65	14,32	4,33	2,69	0,56	6,89	88,22	3,25	6,89	8,91	7,66	680	0,17	0,29	520	0,24	1754,30	45,62	0,20	0,10	0,00	0,08	3,98	1,82	0,32	0,07	5,13	74,47	6,50	120,58	0,01	1,36
P2P 1100-1200	Phalaborwa	2	Permanent	P2P	1100	1200	1150	30	2,61	48,00	18,00	21,00	6,33	1,75	1,59	2,36	93,33	3,33	2,36	9,28	8,12	1060	0,18	0,31	180	0,23	1462,50	38,78	0,13	0,06	0,00	0,08	3,14	1,20	0,20	0,05	5,04	213,81	4,80	90,98	0,01	1,03
P3P 0-50	Phalaborwa	3	Permanent	P3P	0	50	25	31	124,00	30,43	28,23	23,88	6,95	2,05	2,25	4,40	89,48	4,30	4,40	7,6	6,96	730	0,74	1,27	1010	0,78	1607,53	98,08	0,31	0,17	0,00	0,03	5,01	1,59	0,04	0,23	5,48	124,43	7,15	125,35	0,03	4,13
P3P 50-100	Phalaborwa	3	Permanent	P3P	50	100	75	32	42,67	49,73	26,70	13,50	3,57	1,39	1,16	2,99	93,49	2,55	2,99	7,89	7,2	1260	0,43	0,74	610	0,35	1317,47	70,71	0,21	0,11	0,00	0,03	3,94	1,13	0,04	0,17	4,17	139,77	5,46	126,31	0,03	3,96
P3P 100-150	Phalaborwa	3	Permanent	P3P	100	150	125	33	26,40	16,00	22,75	31,20	13,17	5,51	3,46	5,26	83,12	8,97	5,26	8,27	7,48	720	0,64	1,10	910	0,30	2082,80	125,46	0,22	0,11	0,00	0,06	7,05	2,07	0,09	0,30	6,96	132,37	9,60	136,73	0,03	4,38
P3P 150-200	Phalaborwa	3	Permanent	P3P	150	200	175	34	19,43	13,19	22,78	33,98	11,89	4,88	3,56	7,29	81,84	8,44	7,29	8,76	7,83	645	0,55	0,95	660	0,37	2309,95	134,58	0,24	0,09	0,02	0,13	8,55	2,08	0,16	0,18	9,48	130,05	11,27	115,77	0,02	1,93
P3P 200-250	Phalaborwa	3	Permanent	P3P	200	250	225	35	15,56	12,40	40,72	31,98	6,12	2,60	1,61	2,66	91,22	4,21	2,66	9,34	8,12	770	0,29	0,50	350	0,41	1950,00	84,40	0,19	0,08	0,00	0,09	5,12	1,49	0,34	0,23	4,96	186,38	7,32	144,87	0,03	4,56
P3P 250-300	Phalaborwa	3	Permanent	P3P	250	300	275	36	13,09	9,37	23,33	30,57	11,90	6,96	5,54	9,44	75,16	12,50	9,44	9,9	8,26	470	0,36	0,62	410	0,09	3110,22	168,80	0,16	0,06	0,00	0,14	9,07	3,93	0,41	0,19	6,61	70,03	13,78	205,86	0,01	2,89
P3P 300-400	Phalaborwa	3	Permanent	P3P	300	400	350	37	10,57	4,23	15,25	38,15	15,91	8,86	5,49	9,46	73,55	14,34	9,46	10,27	8,61	278	0,48	0,83	410	0,06	2841,13	155,11	0,21	0,10	0,00	0,70	12,33	5,41	0,31	0,17	7,83	82,77	19,06	232,82	0,01	2,22
P3P 400-500	Phalaborwa	3	Permanent	P3P	400	500	450	38	8,44	4,42	11,81	29,10	18,56	11,77	7,82	12,54	63,89	19,59	12,54	10,06	8,4	180	0,26	0,45	460	0,21	3477,15	184,76	0,23	0,11	0,00	1,09	10,42	4,43	0,46	0,20	11,83	94,27	16,73	131,12	0,01	1,69
P3P 500-600	Phalaborwa	3	Permanent	P3P	500	600	550	39	7,09	3,69	15,14	42,72	14,81	7,50	4,64	9,22	76,36	12,14	9,22	10,05	8,5	184	0,38	0,65	360	0,30	2720,56	134,58	0,19	0,11	0,01	1,17	5,97	4,26	0,36	0,16	6,26	67,88	12,06	171,65	0,02	2,50
P3P 600-700	Phalaborwa	3	Permanent	P3P	600	700	650	40	6,15	2,43	13,89	42,87	15,19	6,91	4,90	11,31	74,39	11,81	11,31	9,54	8,11	170	0,34	0,58	360	0,33	2514,38	134,58	0,23	0,16	0,00	1,35	6,22	3,77	0,31	0,15	8,35	73,79	12,04	125,13	0,01	1,77
P3P 700-800	Phalaborwa	3	Permanent	P3P	700	800	750	41	5,47	7,36	7,53	30,67	16,02	10,10	7,34	17,06	61,58	17,44	17,06	9,12	7,84	178	0,62	1,07	910	1,77	2970,43	189,32	0,24	0,19	0,00	0,97	7,45	6,07	0,46	0,25	14,35	84,08	15,37	99,17	0,02	1,76
P3P 800-900	Phalaborwa	3	Permanent	P3P	800	900	850	42	4,94	15,63	10,30	17,43	12,50	11,34	9,35	18,64	55,86	20,68	18,64	8,69	7,39	290	0,71	1,22	860	0,37	3005,38	193,89	0,18	0,11	0,00	0,46	9,10	6,72	0,51	0,36	14,00	75,12	17,09	119,21	0,02	2,55
P3P 900-1000	Phalaborwa	3	Permanent	P3P	900	1000	950	43	4,53	37,05	15,02	17,94	10,13	6,09	3,44	8,33	80,14	9,53	8,33	8,56	7,31	520	0,35	0,60	460	0,56	2025,13	88,96	0,25	0,17	0,00	0,19	5,03	4,10	0,49	0,22	7,65	91,83	10,22	128,55	0,02	2,84
P3P 1000-1100	Phalaborwa	3	Permanent	P3P	1000	1100	1050	44	4,19	32,54	19,40	24,62	7,65	4,41	1,90	7,77	84,21	6,31	7,77	9,04	7,89	560	0,36	0,62	260	0,55	2070,56	75,27	0,20	0,11	0,00	0,14	6,42	4,59	0,42	0,24	8,70	111,88	11,87	134,24	0,02	2,80
P3P 1100-1200	Phalaborwa	3	Permanent	P3P	1100	1200	1150	45	3,91	46,54	21,06	16,20	5,32	2,61	1,62	5,02	89,13	4,23	5,02	8,94	7,94	680	0,20	0,34	50	1,14	1897,58	54,74	0,17	0,09	0,00	0,12	4,16	1,87	0,26	0,24	3,39	67,60	6,67	192,65	0,04	7,18

Table 33 Laboratory analyses for the seasonal zones at the Tshutshi spruit

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
P1S 0-50	Phalaborwa	1	Seasonal	P1S	0	50	25	46	184,00	23,57	18,42	22,48	10,74	9,23	5,27	6,73	75,21	14,50	6,73	8,7	7,43	190	1,32	2,27	1820	0,28	2309,95	173,36	0,30	0,22	0,00	1,12	5,49	1,98	0,92	0,87	8,52	126,64	10,04	108,71	0,12	10,20
P1S 50-100	Phalaborwa	1	Seasonal	P1S	50	100	75	47	62,67	16,80	13,66	18,80	10,43	12,09	20,01	3,36	59,69	32,10	3,36	10,52	9,07	64	0,75	1,29	960	0,25	2771,24	244,07	0,18	0,07	0,01	3,48	4,56	0,62	1,18	1,14	9,74	289,91	10,10	76,99	0,22	11,70
P1S 100-150	Phalaborwa	1	Seasonal	P1S	100	150	125	48	38,40	10,24	12,24	21,78	13,44	13,12	19,55	4,71	57,70	32,67	4,71	11,24	9,98	88	0,42	0,72	560	0,13	2862,10	282,85	0,09	0,03	0,00	1,81	2,40	0,23	0,77	0,73	11,13	236,37	5,33	37,08	0,28	6,56
P1S 150-200	Phalaborwa	1	Seasonal	P1S	150	200	175	49	28,00	11,85	12,48	24,66	14,15	15,50	11,53	4,93	63,14	27,03	4,93	11,33	1,29	56	0,31	0,53	560	0,73	2570,30	244,07	0,11	0,03	0,00	4,00	2,03	0,43	0,97	0,82	13,04	264,78	7,57	32,55	0,33	6,27
P1S 200-250	Phalaborwa	1	Seasonal	P1S	200	250	225	50	22,22	11,10	13,30	24,60	14,89	12,20	14,53	5,41	63,89	26,73	5,41	11,3	10,28	49	0,37	0,64	460	0,44	2105,51	221,26	0,09	0,03	0,00	4,61	6,60	0,79	0,77	0,73	13,13	242,65	12,88	67,66	0,10	5,56
P1S 250-300	Phalaborwa	1	Seasonal	P1S	250	300	275	51	18,55	9,54	12,60	26,36	13,96	11,45	16,12	8,04	62,46	27,56	8,04	11,36	10,41	48,5	0,20	0,34	310	0,63	1902,82	221,26	0,14	0,04	0,01	3,91	4,64	0,66	0,77	0,64	18,26	226,99	10,17	36,73	0,12	3,52
P1S 300-400	Phalaborwa	1	Seasonal	P1S	300	400	350	52	14,86	5,92	13,11	28,71	13,14	11,94	16,81	7,25	60,88	28,74	7,25	11,31	10,09	66	0,15	0,26	300	0,56	2140,46	244,07	0,06	0,02	0,00	2,17	2,10	0,51	0,61	0,57	14,52	200,24	5,48	26,14	0,22	3,95
P1S 400-500	Phalaborwa	1	Seasonal	P1S	400	500	450	53	11,78	5,52	14,67	37,54	12,01	7,41	8,59	13,24	69,75	15,99	13,24	10,85	9,04	140	0,17	0,29	150	0,86	2175,40	196,17	0,06	0,03	0,00	1,28	2,52	0,92	0,56	0,57	11,39	86,01	5,37	40,08	0,16	4,96
P1S 500-600	Phalaborwa	1	Seasonal	P1S	500	600	550	54	9,82	8,82	14,54	38,20	13,21	4,81	5,54	12,83	74,78	10,35	12,83	10,71	8,49	168	0,17	0,29	100	0,11	2040,86	152,83	0,05	0,02	0,00	0,63	2,56	1,11	0,46	0,38	13,91	108,42	4,85	32,47	0,10	2,75
P1S 600-700	Phalaborwa	1	Seasonal	P1S	600	700	650	55	8,46	4,35	13,46	42,41	11,33	5,76	6,95	10,79	71,56	12,72	10,79	10,37	8,2	206	0,16	0,28	150	0,16	1913,31	168,80	0,06	0,03	0,00	0,56	2,49	1,90	0,66	0,39	11,30	104,72	5,71	48,19	0,09	3,46
P1S 700-800	Phalaborwa	1	Seasonal	P1S	700	800	750	56	7,47	3,86	12,51	34,31	16,94	7,71	5,63	15,02	67,63	13,34	15,02	10,14	7,9	224	0,16	0,28	100	0,25	1735,08	157,39	0,06	0,03	0,00	0,18	3,66	4,75	0,56	0,40	11,22	74,70	9,26	83,59	0,05	3,57
P1S 800-900	Phalaborwa	1	Seasonal	P1S	800	900	850	57	6,71	7,31	10,67	26,88	17,65	10,28	6,47	18,48	62,51	16,75	18,48	9,78	7,68	435	0,13	0,22	60	0,15	1972,72	139,14	0,07	0,04	0,00	0,10	4,66	6,07	1,69	0,39	14,78	80,01	12,62	86,62	0,04	2,65
P1S 900-1000	Phalaborwa	1	Seasonal	P1S	900	1000	950	58	6,11	9,11	12,57	35,38	10,44	8,41	5,40	16,89	67,50	13,81	16,89	9,57	7,72	580	0,10	0,17	60	0,08	2323,92	116,33	0,09	0,05	0,00	0,08	5,20	6,56	0,94	0,37	12,52	74,13	12,91	104,33	0,03	2,92
P1S 1000-1100	Phalaborwa	1	Seasonal	P1S	1000	1100	1050	59	5,62	18,97	20,53	26,36	10,32	5,12	2,68	12,49	76,17	7,80	12,49	9,4	7,52	710	0,05	0,09	3	0,13	2067,07	47,90	0,09	0,06	0,00	0,07	4,26	5,41	0,58	0,28	8,78	70,34	10,46	119,85	0,03	3,17
P1S 1100-1200	Phalaborwa	1	Seasonal	P1S	1100	1200	1150	60	5,22	26,71	24,82	20,59	6,55	2,46	2,93	13,19	78,67	5,39	13,19	9,07	7,04	670	0,05	0,09	50	0,19	1738,58	59,31	0,08	0,05	0,00	0,07	3,49	5,57	0,56	0,28	8,35	63,30	9,83	118,59	0,03	3,33
P2S 0-50	Phalaborwa	2	Seasonal	P2S	0	50	25	61	244,00	14,36	8,46	19,12	8,66	13,28	19,66	12,62	50,59	32,95	12,62	7,26	6,58	520	5,48	9,43	6410	0,71	3512,10	335,31	0,11	0,04	0,01	0,04	33,40	13,28	1,89	1,30	29,57	234,33	48,76	168,70	0,03	4,41
P2S 50-100	Phalaborwa	2	Seasonal	P2S	50	100	75	62	82,67	18,41	16,82	20,08	10,92	8,03	7,31	15,45	66,23	15,34	15,45	7,55	6,91	575	2,78	4,78	3890	0,30	2970,43	239,51	0,09	0,03	0,01	0,05	20,10	7,21	0,92	0,52	18,26	118,19	28,41	157,47	0,02	2,86
P2S 100-150	Phalaborwa	2	Seasonal	P2S	100	150	125	63	50,40	20,83	24,22	23,66	10,40	6,29	4,77	11,68	79,11	11,06	11,68	7,99	7,16	950	1,02	1,75	1820	0,23	1929,03	152,83	0,03	0,00	0,00	0,03	8,80	2,95	0,51	0,52	12,87	110,16	12,32	99,34	0,04	4,05
P2S 150-200	Phalaborwa	2	Seasonal	P2S	150	200	175	64	36,57	21,55	26,88	26,81	5,46	5,32	4,28	9,90	80,71	9,60	9,90	8,5	7,34	1270	0,67	1,15	1060	0,21	1850,40	136,86	0,00	0,00	0,00	0,02	7,60	2,79	0,36	0,61	8,96	90,48	10,77	126,76	0,06	6,80
P2S 200-250	Phalaborwa	2	Seasonal	P2S	200	250	225	65	28,89	20,71	27,75	22,93	8,08	5,90	4,76	14,72	79,46	10,66	14,72	8,56	7,06	1170	0,54	0,93	1060	0,16	2056,59	159,67	0,01	0,00	0,00	0,03	6,50	2,62	0,61	1,30	10,09	68,54	9,78	109,46	0,14	12,93
P2S 250-300	Phalaborwa	2	Seasonal	P2S	250	300	275	66	24,00	14,77	23,61	24,68	11,08	7,22	5,88	10,90	74,13	13,10	10,90	9,01	7,19	740	0,76	1,31	1060	0,11	2481,18	218,98	0,02	0,00	0,00	0,05	6,50	3,28	0,41	2,78	12,96	118,92	10,25	100,11	0,28	21,48
P2S 300-400	Phalaborwa	2	Seasonal	P2S	300	400	350	67	19,14	10,88	14,44	30,35	11,78	9,46	8,25	14,53	67,45	17,72	14,53	9,57	7,83	226	0,65	1,12	1010	0,13	2486,42	248,63	0,01	0,00	0,00	0,86	6,60	3,77	0,31	9,13	12,35	84,96	11,55	160,42	0,88	73,94
P2S 400-500	Phalaborwa	2	Seasonal	P2S	400	500	450	68	15,11	7,46	13,62	31,44	13,99	7,88	7,39	15,28	66,51	15,27	15,28	9,79	8,07	154	0,50	0,86	810	0,33	2255,78	207,57	0,00	0,00	0,00	1,23	4,90	3,61	0,72	14,61	15,30	100,16	10,46	155,72	1,72	95,45
P2S 500-600	Phalaborwa	2	Seasonal	P2S	500	600	550	69	12,55	5,56	13,98	37,94	16,21	8,87	5,19	11,69	73,69	14,07	11,69	10,14	8,24	161	0,32	0,55	610	0,29	1625,00	266,88	0,00	0,00	0,00	1,00	5,00	2,79	0,41	12,00	9,91	84,81	9,20	203,73	1,54	121,05
P2S 600-700	Phalaborwa	2	Seasonal	P2S	600	700	650	70	10,77	6,30	16,00	40,96	11,76	5,31	5,27	13,46	75,02	10,58	13,46	10,12	8,33	144	0,27	0,46	510	0,08	2051,34	184,76	0,00	0,00	0,00	0,97	5,20	2,95	0,46	12,26	13,83	102,69	9,58	150,96	1,50	88,68
P2S 700-800	Phalaborwa	2	Seasonal	P2S	700	800	750	71	9,47	4,60	14,44	39,72	12,15	5,54	6,54	19,34	70,91	12,08	19,34	10,13	8,28	158	0,24	0,41	460	0,14	1951,75	230,38	0,02	0,00	0,00	0,95	5,10	4,43	0,72	16,70	11,65	60,24	11,21	231,18	1,75	143,28
P2S 800-900	Phalaborwa	2	Seasonal	P2S	800	900	850	72	8,47	8,63	18,26	35,18	13,28	6,65	5,39	15,33	75,35	12,04	15,33	9,95	8,16	212	0,19	0,33	310	0,19	1651,21	209,85	0,01	0,00	0,00	0,19	7,40	4,26	0,41	10,78	9,30	60,67	12,27	245,63	0,92	115,89
P2S 900-1000	Phalaborwa	2	Seasonal	P2S	900	1000	950	73	7,68	12,45	22,28	34,74	10,49	5,13	2,84	8,39	79,96	7,97	8,39	9,76	8,18	252	0,16	0,28	310	0,12	1424,06	88,96	0,04	0,00	0,00	0,54	6,10	2,30	0,31	4,35	7,04	83,96	9,29	185,28	0,52	61,73
P2S 1000-1100	Phalaborwa	2	Seasonal	P2S	1000	1100	1050	74	7,05	16,10	25,63	31,22	10,52	5,01	2,20	5,73	83,48	7,20	5,73	9,73	8,12	340	0,13	0,22	260	0,23	1588,31	93,52	0,02	0,00	0,00	0,13	5,10	2,46	0,15	3,22	7,13	124,41	7,87	153,28	0,43	45,12
P2S 1100-1200	Phalaborwa	2	Seasonal	P2S	1100	1200	1150	75	6,52	16,24	30,86	35,40	8,77	3,30	1,61	4,43	91,27	4,91	4,43	9,77	8,1	375	0,17	0,29	250	0,21	1642,47	82,12	0,02	0,00	0,00	0,11	3,40	1,64	0,20	2,96	6,78	153,10	5,38	120,90	0,59	43,59
P3S 0-50	Phalaborwa	3	Seasonal	P3S	0	50	25	76	304,00	12,24	25,14	20,84	5,62	10,52	8,15	12,73	63,84	18,67	12,73	8,03	7,19	620	3,00	5,16	5190	1,09	2935,48	248,63	0,06	0,01	0,00	0,03	24,70	5,90	1,23	0,78	11,30	88,81	31,93	288,49	0,03	6,92
P3S 50-100	Phalaborwa	3	Seasonal	P3S	50	100	75	77	102,67	9,68	30,92	25,14	8,53	5,28	6,70	11,88	74,28	11,98	11,88	8,16	7,47	715	1,16	2,00	2220	0,47	2786,96	173,36	0,06	0,01	0,00	0,02	12,10	2,95	0,77	0,61	15,57	131,00	15,91	105,54	0,04	3,91
P3S 100-150	Phalaborwa	3	Seasonal	P3S	100	150	125	78	62,40	14,26	15,68	16,58	9,41	8,57	12,35	20,24	55,93	20,92	20,24	8,43	7,46	685	1,81	3,11	3280	0,22	3110,22	276,00	0,04	0,00	0,00	0,04	18,60	5,57	1,18	1,30	15,91	78,63	25,44	167,50	0,05	8,20
P3S 150-200	Phalaborwa	3	Seasonal	P3S	150	200	175	79	45,14	16,96	21,20	22,50	10,76	9,31	6,95	10,46	71,42	16,27	10,46	8,73	7,74	540	1,27	2,18	2560	0,17	2364,11	184,76	0,04	0,00	0,00	0,06	17,70	4,92	1,02	1,39	14,35	137,15	23,74	174,47	0,06	9,70
P3S 200-250	Phalaborwa	3	Seasonal	P3S	200	250	225	80	35,56	19,16	20,13	26,30	11,36	6,10	4,88	7,74	76,95	10,99	7,74	8,71	7,87	342,5	0,91	1,57	1620	0,21	1984,95	145,99	0,09	0,01	0,00	0,10	10,90	2,79	0,61	1,57	9,65	124,69	14,51	164,38	0,11	16,22
P3S 250-300	Phalaborwa	3	Seasonal	P3S	250	300	275	81	29,45	32,33	19,79	22,43	9,90	5,52	3,75	5,24	84,46	9,26	5,24	9,14	8,08	274	0,51	0,88	910	0,08	1864,38	127,74	0,13	0,02	0,00	0,90	8,60	2,30	0,56	2,87	10,17	194,20	12,51	140,82	0,26	28,21
P3S 300-400	Phalaborwa	3	Seasonal	P3S	300	400	350	82	23,43	35,59	18,94	20,57	8,49	4,54	4,51	6,07	83,58	9,05	6,07	9,72	8,26	234	0,30	0,52	810	0,07	2297,72	155,11	0,04	0,01	0,00	0,75	5,60	2,79	0,92	4,78	6,35	104,53	10,11	221,97	0,57	75,34
P3S 400-500	Phalaborwa	3	Seasonal	P3S	400	500	450	83	18,44	19,19	17,57	27,98	10,41	6,65	4,81	9,47	75,14	11,46	9,47	9,85	8,24	197	0,31	0,53	610	0,13	1969,22	175,64	0,04	0,01	0,00	0,87	6,40	3,44	0,51	6,17	7,39	78,03	11,27	223,61	0,63	83,53
P3S 500-600	Phalaborwa	3	Seasonal	P3S	500	600	550	84	15,27	18,51	19,81	27,28	11,69	6,79	4,29	9,51	77,29	11,08	9,51	9,94	8,32	216	0,22	0,38	370	0,12	2865,59	291,97	0,04	0,01	0,00	0,19	9,00	3,93	0,46	5,65	9,04	95,11	13,64	210,62	0,44	62,50
P3S 600-700	Phalaborwa	3	Seasonal	P3S	600	700	650	85	13,08	16,51	22,22	29,84	9,92	5,84	4,54	11,04	78,49	10,38	11,04	9,76	8,28	305	0,16	0,28	410	0,15	1661,69	111,77	0,03	0,00	0,00	0,15	9,40	4,43	0,61	5,13	7,91	71,66	14,62	247,32	0,37	64,84
P3S 700-800	Phalaborwa	3	Seasonal	P3S	700	800	750	86	11,47	27,37	19,46	25,39	11,21	4,18	2,95	6,65	83,44	7,14	6,65	9,61	8,35	305	0,15	0,26	300	0,19	1354,17	189,32	0,04	0,00	0,00	0,11	8,00	2,95	0,31	2,78	7,22	108,55	11,41	194,53	0,25	38,55
P3S 800-900	Phalaborwa	3	Seasonal	P3S	800	900	850	87	10,24	38,65	21,99	20,33	7,33	2,67	2,08	4,56	88,30	4,74	4,56	9,64	8,39	335	0,12	0,21	160	0,17	1134,01	111,77	0,05	0,00	0,00	0,14	5,60	2,62	0,61	3,39	4,78	104,92	9,03	255,68	0,41	70,91
P3S 900-1000	Phalaborwa	3	Seasonal	P3S	900	1000	950	88	9,26	39,99	25,00	18,33	7,67	3,08	1,77	2,52	90,99	4,85	2,52	9,54	8,46	350	0,11	0,19	260	0,16	1167,20	93,52	0,03	0,00	0,00	0,13	2,70	1,15	0,10	1,48	3,57	141,50	4,11	152,25	0,38	41,46
P3S 1000-1100	Phalaborwa	3	Seasonal	P3S	1000	1100	1050	89	8,48	36,95	29,36	20,12	5,61	2,19	1,44	2,67	92,04	3,63	2,67	9,24	8,08	375	0,10	0,17	260	0,15	1161,96	111,77	0,05	0,00	0,00	0,12	3,20	1,48	0,15	1,39	3,30	123,96	5,00	188,24	0,30	42,11
P3S 1100-1200	Phalaborwa	3	Seasonal	P3S	1100	1200	1150	90	7,83	43,30	30,08	16,53	3,97	2,34	1,12	3,09	93,87	3,46	3,09	8,9	7,49	475	0,22	0,38	110	0,35	2262,77	114,05	0,03	0,00	0,00	0,08	2,70	1,48	0,15	1,22	5,30	171,45	4,44	104,56	0,29	22,95

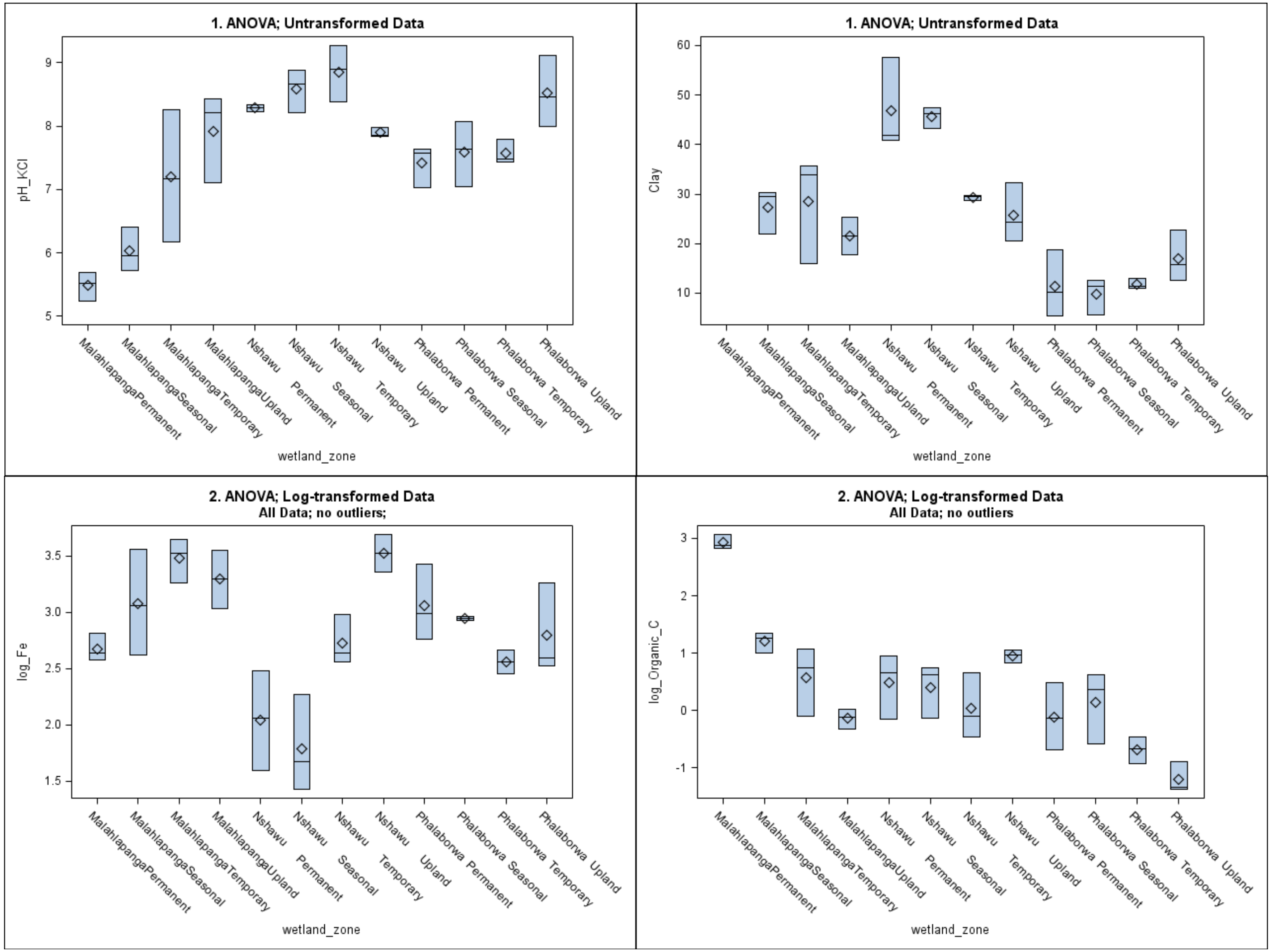
Table 34 Laboratory analyses for the temporary zones at the Tshutshi spruit

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
Sample description									Textures											pH		ER	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
P1T 0-50	Phalaborwa	1	Temporary	P1T	0	50	25	91	364,00	32,85	25,99	20,33	5,11	3,64	3,66	8,54	84,28	7,31	8,54	7,92	6,9	860	1,16	2,00	1670	0,27	1493,95	57,03	0,04	0,00	0,00	0,04	7,00	1,97	0,72	0,43	10,26	120,09	9,77	98,61	0,05	4,24
P1T 50-100	Phalaborwa	1	Temporary	P1T	50	100	75	92	122,67	39,42	26,45	20,39	4,96	1,53	1,09	6,91	91,22	2,62	6,91	8,12	7,08	1480	0,17	0,29	460	0,20	1306,99	50,18	0,03	0,00	0,00	0,02	2,80	0,66	0,51	0,52	4,00	57,88	4,01	112,22	0,15	13,04
P1T 100-150	Phalaborwa	1	Temporary	P1T	100	150	125	93	74,40	50,56	23,44	14,67	3,46	1,96	0,94	5,65	92,13	2,90	5,65	8,19	7,03	990	0,21	0,36	450	0,20	1446,77	52,46	0,04	0,00	0,00	0,02	3,10	0,66	0,31	0,43	3,04	53,90	4,12	147,77	0,12	14,29
P1T 150-200	Phalaborwa	1	Temporary	P1T	150	200	175	94	53,71	34,79	29,52	21,73	5,53	1,79	0,65	6,74	91,56	2,44	6,74	8,61	7,26	710	0,21	0,36	410	0,18	1340,19	52,46	0,04	0,00	0,00	0,04	3,50	0,98	0,31	0,78	4,52	67,11	4,87	123,25	0,17	17,31
P1T 200-250	Phalaborwa	1	Temporary	P1T	200	250	225	95	42,22	21,55	17,23	25,57	10,00	4,42	4,43	15,86	74,35	8,85	15,86	9,66	7,95	128	0,35	0,60	720	0,17	1766,53	98,08	0,07	0,01	0,00	1,35	5,60	2,13	0,82	10,09	10,96	69,07	9,98	170,10	1,30	92,06
P1T 250-300	Phalaborwa	1	Temporary	P1T	250	300	275	96	34,91	19,69	16,14	18,41	8,74	5,43	8,11	21,66	62,99	13,54	21,66	10,26	8,71	78	0,27	0,46	660	0,17	1740,32	79,84	0,06	0,00	0,00	2,17	14,70	3,77	0,82	23,22	17,48	80,70	21,53	243,20	1,26	132,84
P1T 300-400	Phalaborwa	1	Temporary	P1T	300	400	350	97	27,71	18,33	17,67	20,38	9,07	4,87	11,32	16,53	65,44	16,19	16,53	10,6	9,11	59	0,19	0,33	360	0,14	2074,06	70,71	0,05	0,00	0,00	3,48	13,00	3,93	0,82	29,04	14,78	89,43	21,28	316,56	1,72	196,47
P1T 400-500	Phalaborwa	1	Temporary	P1T	400	500	450	98	21,78	17,87	18,40	23,18	8,93	5,15	8,00	16,08	68,39	13,15	16,08	10,62	9,21	63	0,96	1,65	370	0,13	1862,63	75,27	0,04	0,00	0,00	2,09	16,00	3,11	0,41	23,48	15,48	96,29	21,66	277,82	1,23	151,69
P1T 500-600	Phalaborwa	1	Temporary	P1T	500	600	550	99	18,00	19,16	16,72	20,81	8,77	6,53	8,44	17,38	65,45	14,97	17,38	10,59	9,09	78	0,18	0,31	260	0,22	1516,67	70,71	0,04	0,00	0,00	1,57	16,00	3,11	0,51	22,78	11,04	63,56	21,23	384,02	1,19	206,30
P1T 600-700	Phalaborwa	1	Temporary	P1T	600	700	650	100	15,38	17,92	19,01	22,80	7,60	4,45	7,52	17,27	67,33	11,96	17,27	10,56	9,14	77,5	0,13	0,22	200	0,24	1296,51	79,84	0,02	0,00	0,00	1,48	16,90	3,61	0,41	21,57	10,35	59,91	22,41	410,53	1,05	208,40
P1T 700-800	Phalaborwa	1	Temporary	P1T	700	800	750	101	13,47	19,34	19,37	24,22	8,72	4,63	5,21	17,10	71,65	9,84	17,10	10,59	8,9	93	0,20	0,34	200	0,19	1541,13	66,15	0,04	0,00	0,00	1,30	10,50	3,77	0,26	18,35	12,87	75,27	15,87	255,44	1,29	142,57
P1T 800-900	Phalaborwa	1	Temporary	P1T	800	900	850	102	12,00	14,57	21,97	25,41	10,55	3,93	5,01	17,97	72,50	8,94	17,97	10,58	8,94	106	0,16	0,28	100	0,20	1459,01	63,87	0,02	0,00	0,00	1,77	9,20	3,28	0,20	16,00	12,52	69,69	14,48	229,07	1,28	127,78
P1T 900-1000	Phalaborwa	1	Temporary	P1T	900	1000	950	103	10,84	21,86	17,70	23,56	8,85	3,72	4,26	16,48	71,97	7,98	16,48	10,59	8,82	116	0,15	0,26	120	0,17	1485,22	36,50	0,04	0,00	0,00	1,70	9,60	4,10	0,36	18,52	12,35	74,94	15,80	263,84	1,35	150,00
P1T 1000-1100	Phalaborwa	1	Temporary	P1T	1000	1100	1050	104	9,90	21,39	16,59	22,44	8,31	2,96	5,52	20,31	68,74	8,48	20,31	10,49	8,72	122	0,15	0,26	60	0,18	1680,91	59,31	0,01	0,00	0,00	1,50	7,80	5,25	0,26	17,39	14,52	71,51	14,81	211,36	1,33	119,76
P1T 1100-1200	Phalaborwa	1	Temporary	P1T	1100	1200	1150	105	9,13	24,31	16,92	15,88	6,35	3,87	8,69	22,21	63,46	12,57	22,21	10,25	8,43	120	0,16	0,28	420	0,19	873,66	41,06	0,00	0,00	0,00	1,30	7,40	10,66	0,61	32,70	18,61	83,80	19,97	276,03	1,81	175,70
P2T 0-50	Phalaborwa	2	Temporary	P2T	0	50	25	106	424,00	37,77	23,18	15,37	5,12	3,00	4,53	10,48	81,43	7,52	10,48	8,21	7,35	395	1,05	1,81	2010	0,10	2088,04	107,21	0,14	0,01	0,00	0,08	8,40	2,62	1,02	0,61	12,61	120,34	12,27	100,36	0,06	4,83
P2T 50-100	Phalaborwa	2	Temporary	P2T	50	100	75	107	142,67	36,11	27,57	20,58	4,66	1,38	1,50	9,02	88,92	2,88	9,02	8,52	7,37	825	0,31	0,53	550	0,05	1417,07	54,74	0,05	0,00	0,00	0,03	4,70	1,31	0,46	0,26	7,39	81,94	6,55	91,09	0,04	3,53
P2T 100-150	Phalaborwa	2	Temporary	P2T	100	150	125	108	86,40	23,72	23,59	24,44	8,82	4,10	3,19	10,51	80,56	7,28	10,51	8,95	7,09	850	0,34	0,58	500	0,12	1645,97	68,43	0,01	0,00	0,00	0,03	5,50	1,97	0,51	0,78	6,78	64,56	8,02	129,17	0,10	11,54
P2T 150-200	Phalaborwa	2	Temporary	P2T	150	200	175	109	62,29	33,05	18,46	15,58	6,30	5,58	6,91	11,27	73,38	12,50	11,27	9,33	7,1	560	0,34	0,58	1780	0,12	2004,17	116,33	0,00	0,00	0,00	0,06	4,70	1,64	0,41	2,87	9,04	80,25	6,82	106,35	0,45	31,73
P2T 200-250	Phalaborwa	2	Temporary	P2T	200	250	225	110	48,89	30,76	18,00	16,22	6,23	6,08	5,83	12,87	71,20	11,92	12,87	9,88	7,36	395	0,66	1,14	650	0,29	1602,28	125,46	0,01	0,00	0,00	0,07	5,30	2,30	0,41	7,83	11,74	91,19	8,08	134,85	1,03	66,67
P2T 250-300	Phalaborwa	2	Temporary	P2T	250	300	275	111	40,36	25,23	18,58	18,77	8,17	6,16	6,62	14,03	70,76	12,78	14,03	10,53	8,35	196	0,38	0,65	460	0,23	1312,23	111,77	0,00	0,00	0,00	0,19	8,70	2,46	0,41	14,96	11,74	83,64	11,76	225,95	1,34	127,41
P2T 300-400	Phalaborwa	2	Temporary	P2T	300	400	350	112	32,00	22,00	16,86	17,29	7,72	4,26	8,37	20,14	63,87	12,63	20,14	10,7	8,99	96	0,29	0,50	460	0,33	1431,05	109,49	0,00	0,00	0,00	1,91	15,30	2,95	0,26	24,17	14,78	73,40	20,43	288,72	1,32	163,53
P2T 400-500	Phalaborwa	2	Temporary	P2T	400	500	450	113	25,11	19,83	12,03	20,42	9,05	6,99	8,18	19,00	61,33	15,18	19,00	10,8	9,21	83	0,27	0,46	410	0,20	1789,25	104,93	0,01	0,00	0,00	1,57	14,50	2,46	0,26	23,39	12,17	64,08	18,79	333,55	1,38	192,14
P2T 500-600	Phalaborwa	2	Temporary	P2T	500	600	550	114	20,73	22,89	18,46	22,37	3,64	3,53	6,51	18,43	67,36	10,03	18,43	10,84	9,35	77	0,20	0,34	200	0,20	1525,40	70,71	0,01	0,00	0,00	1,83	14,20	2,79	0,43	25,22	14,96	81,15	19,26	285,09	1,48	168,60
P2T 600-700	Phalaborwa	2	Temporary	P2T	600	700	650	115	17,69	20,22	17,29	21,22	9,08	4,56	7,11	19,44	67,81	11,67	19,44	10,8	9,23	83	0,21	0,36	250	0,21	1548,12	70,71	0,01	0,00	0,00	1,91	14,80	2,95	0,15	26,17	16,09	82,75	19,83	274,00	1,47	162,70
P2T 700-800	Phalaborwa	2	Temporary	P2T	700	800	750	116	15,47	19,36	14,31	22,69	10,33	5,07	4,39	22,22	66,69	9,46	22,22	10,78	9,17	97	0,16	0,28	200	0,25	1369,89	63,87	0,00	0,00	0,00	1,30	15,10	2,46	0,31	22,78	13,74	61,84	19,18	295,86	1,30	165,82
P2T 800-900	Phalaborwa	2	Temporary	P2T	800	900	850	117	13,76	22,59	19,86	21,55	8,81	5,44	4,90	16,92	72,82	10,34	16,92	10,8	8,98	136	0,16	0,28	110	0,26	1079,84	38,78	0,01	0,00	0,00	1,17	13,90	2,95	0,15	16,87	13,04	77,10	18,18	259,70	1,00	129,33
P2T 900-1000	Phalaborwa	2	Temporary	P2T	900	1000	950	118	12,42	18,20	19,45	26,32	7,43	4,74	4,94	14,89	71,40	9,69	14,89	10,67	8,71	160	0,17	0,29	110	0,27	1130,51	29,65	0,00	0,00	0,00	0,83	8,60	3,28	0,20	15,74	14,17	95,18	12,91	196,29	1,32	111,04
P2T 1000-1100	Phalaborwa	2	Temporary	P2T	1000	1100	1050	119	11,33	18,16	18,85	27,52	9,89	4,05	4,94	15,79	74,42	8,99	15,79	10,54	8,52	200	0,16	0,28	150	0,17	866,67	27,37	0,00	0,00	0,00	0,51	12,90	4,26	0,15	13,39	13,30	84,28	17,83	230,80	0,78	100,65
P2T 1100-1200	Phalaborwa	2	Temporary	P2T	1100	1200	1150	120	10,43	19,09	21,20	22,57	8,96	1,27	5,54	17,13	71,82	6,81	17,13	10,46	8,33	247	0,14	0,24	150	0,29	901,61	20,53	0,00	0,00	0,00	0,15	10,70	5,08	0,20	12,61	13,91	81,21	16,14	205,53	0,80	90,63
P3T 0-50	Phalaborwa	3	Temporary	P3T	0	50	25	121	484,00	31,29	20,68	22,26	9,48	3,92	1,78	9,74	83,71	5,70	9,74	8,61	7,37	1200	0,90	1,55	1570	0,15	2019,89	88,96	0,17	0,00	0,00	0,02	6,18	1,64	0,51	0,30	12,17	124,96	8,52	70,89	0,04	2,50
P3T 50-100	Phalaborwa	3	Temporary	P3T	50	100	75	122	162,67	22,27	23,67	28,96	11,38	5,11	1,93	7,77	86,28	7,04	7,77	8,71	7,45	1300	0,69	1,19	1410	0,05	1728,09	70,71	0,13	0,00	0,00	0,02	4,30	1,05	0,30	0,37	10,43	134,23	5,80	57,69	0,07	3,58
P3T 100-150	Phalaborwa	3	Temporary	P3T	100	150	125	123	98,40	20,48	22,43	22,75	13,55	6,00	3,46	9,35	79,22	9,46	9,35	9,09	7,72	695	0,51	0,88	1250	0,13	1885,35	77,55	0,09	0,00	0,00	0,06	6,70	1,61	0,36	0,41	26,96	288,34	8,83	33,68	0,05	1,52
P3T 150-200	Phalaborwa	3	Temporary	P3T	150	200	175	124	70,86	22,94	20,82	19,27	10,49	4,92	4,98	13,57	73,52	9,90	13,57	9,41	7,72	182	0,89	1,53	1590	0,05	2566,80	118,61	0,12	0,00	0,00	0,85	13,28	4,15	0,60	4,05	18,26	134,61	19,00	120,90	0,23	22,19
P3T 200-250	Phalaborwa	3	Temporary	P3T	200	250	225	125	55,56	25,40	19,22	15,78	7,42	3,84	6,49	17,78	67,82	10,34	17,78	9,76	8,12	140	0,45	0,77	870	0,32	1792,74	118,61	0,14	0,00	0,00	1,01	9,00	2,59	0,35	4,42	54,78	308,06	13,09	29,86	0,38	8,06
P3T 250-300	Phalaborwa	3	Temporary	P3T	250	300	275	126	45,82	17,55	19,13	20,93	8,68	4,75	6,90	19,19	66,28	11,65	19,19	10	8,36	80	0,36	0,62	890	0,17	1161,96	114,05	0,12	0,01	0,00	3,48	16,53	3,95	0,40	11,50	20,00	104,21	24,49	161,92	0,56	57,52
P3T 300-400	Phalaborwa	3	Temporary	P3T	300	400	350	127	36,29	21,23	16,40	15,62	6,06	3,64	9,98	25,02	59,32	13,63	25,02	10,3	8,81	57,5	0,33	0,57	650	0,27	924,33	98,08	0,10	0,01	0,00	6,00	19,85	4,41	0,40	23,04	27,83	111,20	30,77	171,43	0,95	82,81
P3T 400-500	Phalaborwa	3	Temporary	P3T	400	500	450	128	28,44	22,94	17,71	15,35	6,08	3,92	9,82	21,73	62,08	13,75	21,73	10,54	8,87	56	0,17	0,29	430	0,17	903,36	116,33	0,09	0,00	0,00	4,61	16,85	3,08	0,31	21,13	29,57	136,06	24,94	139,93	1,06	71,47
P3T 500-600	Phalaborwa	3	Temporary	P3T	500	600	550	129	23,45	24,04	17,94	13,76	6,07	4,25	10,24	21,20	61,81	14,49	21,20	10,6	8,89	69	0,19	0,33	510	0,18	655,24	86,68	0,07	0,00	0,00	3,83	16,59	2,64	0,31	22,26	40,00	188,71	23,44	104,51	1,16	55,65
P3T 600-700	Phalaborwa	3	Temporary	P3T	600	700	650	130	20,00	24,62	21,20	11,35	4,99	3,33	10,51	20,05	62,16	13,84	20,05	10,62	8,82	70	0,14	0,24	490	0,20	725,13	86,68	0,12	0,00	0,00	3,48	16,25	2,72	0,30	22,96	60,87	303,63	22,87	69,38	1,21	37,71
P3T 700-800	Phalaborwa	3	Temporary	P3T	700	800	750	131	17,47	25,54	18,60	13,98	4,66	3,46	10,96	21,78	62,78	14,42	21,78	10,61	8,83	78	0,16	0,28	230	0,31	679,70	66,15	0,09	0,00	0,00	2,78	16,06	3,61	0,33	23,04	30,43	139,73	22,87	141,41	1,17	75,71
P3T 800-900	Phalaborwa	3	Temporary	P3T	800	900	850	132	15,53	29,31	17,11	10,74	4,23	4,29	9,26	22,81	61,39	13,56	22,81	10,72	8,87	95	0,13	0,22	190	0,20	866,67	79,84	0,12	0,00	0,00	2,00	15,75	4,57	0,30	22,52	46,09	202,04	22,75	93,62	1,11	48,87
P3T 900-1000	Phalaborwa	3	Temporary	P3T	900	1000	950	133	14,00	25,60	18,79	15,17	1,94	3,07	12,54	19,61	61,50	15,61	19,61	10,67	8,71	109	0,19	0,33	320	0,27	1106,05	111,77	0,06	0,00	0,00	1,10	12,75	4,56	0,32	23,04	40,87	208,37	18,79	99,52	1,33	56,38
P3T 1000-1100	Phalaborwa	3	Temporary	P3T	1000	1100	1050	134	12,76	25,53	19,31	14,54	4,18	3,96	10,36	18,87	63,55	14,32	18,87	10,65	8,59	122	0,33	0,57	220	0,17	1441,53	130,02	0,04	0,00	0,00	0,79	11,97	5,54	0,32	24,26	26,96	142,86	18,67	156,16	1,39	90,00
P3T 1100-1200	Phalaborwa	3	Temporary	P3T	1100	1200	1150	135	11,74	19,81	20,04	14,45	6,20	4,35	12,43	21,06	60,50	16,78	21,06	10,59	8,44	136	0,15	0,25	210	0,26	1366,40	107,21	0,00	0,00	0,00	0,59	12,03	7,16	0,36	15,13	46,96	223,00	20,15	73,87	0,79	32,22

Table 35 Laboratory analyses for the upland zones at the Tshutshi spruit

Sample	Wetland	Transect/Repetition	Wetness Zone	Sample Summary	Upper depth (mm)	Lower depth (mm)	Avg. depth (mm)	Lab number	coarse size fraction (>2mm) %	Coarse sand %	Medium sand%	Fine sand %	Very fine sand %	Coarse silt %	Fine silt %	Clay %	Total Sand %	Total Silt %	Total Clay%	pH (H_2O)	pH (KCl)	Electrical Resistance (ohm)
Sample description									Textures											pH		ER
P1U 0-50	Phalaborwa	1	Upland	P1U	0	50	25	136	544,00	21,01	26,10	23,12	9,41	4,71	3,34	7,51	79,65	8,05	7,51	9	8	31
P1U 50-100	Phalaborwa	1	Upland	P1U	50	100	75	137	182,67	21,95	16,06	19,69	10,62	6,44	5,63	18,62	68,32	12,08	18,62	9,6	8,22	44
P1U 100-150	Phalaborwa	1	Upland	P1U	100	150	125	138	110,40	20,34	15,85	15,13	7,47	4,80	11,86	19,86	58,79	16,65	19,86	9,86	8,57	34
P1U 150-200	Phalaborwa	1	Upland	P1U	150	200	175	139	79,43	23,73	14,65	14,06	5,53	4,30	10,83	25,96	57,98	15,13	25,96	9,85	8,59	30,5
P1U 200-250	Phalaborwa	1	Upland	P1U	200	250	225	140	62,22	21,62	13,16	12,55	6,13	3,04	11,29	29,12	53,45	14,33	29,12	9,84	8,67	29
P1U 250-300	Phalaborwa	1	Upland	P1U	250	300	275	141	51,27	24,97	12,29	10,43	5,40	4,32	7,00	35,49	53,09	11,33	35,49	9,91	8,74	30
P1U 300-400	Phalaborwa	1	Upland	P1U	300	400	350	142	40,57	29,46	11,85	12,17	4,76	2,54	4,31	31,05	58,25	6,85	31,05	9,86	8,62	33
P1U 400-500	Phalaborwa	1	Upland	P1U	400	500	450	143	31,78	19,40	14,07	13,27	5,56	4,95	6,59	36,09	52,29	11,53	36,09	9,91	8,69	35,5
P1U 500-600	Phalaborwa	1	Upland	P1U	500	600	550	144	26,18	25,40	12,07	11,16	5,56	4,18	7,01	35,11	54,18	11,19	35,11	9,93	8,69	41,5
P1U 600-700	Phalaborwa	1	Upland	P1U	600	700	650	145	22,31	17,37	11,35	14,57	6,71	4,85	8,49	36,14	50,01	13,34	36,14	9,85	8,65	44,5
P1U 700-800	Phalaborwa	1	Upland	P1U	700	800	750	146	19,47	17,77	11,88	12,89	5,56	6,90	9,01	36,54	48,09	15,92	36,54	9,6	8,61	41,5
P1U 800-900	Phalaborwa	1	Upland	P1U	800	900	850	147	17,29	22,03	11,46	14,45	5,91	4,51	10,47	34,87	53,84	14,99	34,87	9,26	8,5	32
P1U 900-1000	Phalaborwa	1	Upland	P1U	900	1000	950	148	15,58	19,33	12,87	12,97	3,77	8,55	16,87	22,63	48,94	25,42	22,63	9,14	8,35	34
P1U 1000-1100	Phalaborwa	1	Upland	P1U	1000	1100	1050	149	14,19	16,63	12,88	14,95	6,31	7,99	17,72	23,62	50,78	25,71	23,62	9,08	8,19	40
P1U 1100-1200	Phalaborwa	1	Upland	P1U	1100	1200	1150	150	13,04	19,11	15,43	19,11	10,76	10,04	13,88	13,22	64,41	23,92	13,22	9,24	8,18	49
P2U 0-50	Phalaborwa	2	Upland	P2U	0	50	25	151	604,00	27,75	23,76	23,66	8,74	4,87	2,52	10,71	83,90	7,39	10,71	8,96	7,97	242
P2U 50-100	Phalaborwa	2	Upland	P2U	50	100	75	152	202,67	24,17	20,07	22,76	9,02	4,64	2,10	13,80	76,01	6,74	13,80	9,93	8,55	68
P2U 100-150	Phalaborwa	2	Upland	P2U	100	150	125	153	122,40	20,13	18,85	20,56	9,18	3,77	4,31	18,62	68,73	8,08	18,62	10,46	9,24	35,25
P2U 150-200	Phalaborwa	2	Upland	P2U	150	200	175	154	88,00	23,41	17,21	18,31	8,34	5,54	8,16	18,62	67,27	13,70	18,62	10,8	9,64	32
P2U 200-250	Phalaborwa	2	Upland	P2U	200	250	225	155	68,89	24,45	19,54	17,08	7,76	6,82	9,06	15,99	68,83	15,88	15,99	10,86	9,72	33,5
P2U 250-300	Phalaborwa	2	Upland	P2U	250	300	275	156	56,73	24,04	17,92	17,19	7,55	5,80	11,64	17,32	66,69	17,44	17,32	10,8	9,6	33
P2U 300-400	Phalaborwa	2	Upland	P2U	300	400	350	157	44,86	22,62	15,53	15,18	7,28	6,70	15,16	16,39	60,61	21,86	16,39	10,69	9,46	29,2
P2U 400-500	Phalaborwa	2	Upland	P2U	400	500	450	158	35,11	24,06	14,73	14,33	6,95	6,82	15,59	14,45	60,07	22,41	14,45	10,59	9,31	32
P2U 500-600	Phalaborwa	2	Upland	P2U	500	600	550	159	28,91	22,91	14,55	14,06	5,80	4,80	12,66	24,27	57,33	17,45	24,27	10,51	9,09	32,5
P2U 600-700	Phalaborwa	2	Upland	P2U	600	700	650	160	24,62	23,37	15,10	15,13	5,03	4,46	7,60	25,67	58,63	12,06	25,67	10,38	8,94	38
P2U 700-800	Phalaborwa	2	Upland	P2U	700	800	750	161	21,47	18,29	15,04	14,78	6,16	5,66	8,96	30,41	54,27	14,62	30,41	10,32	8,85	43
P2U 800-900	Phalaborwa	2	Upland	P2U	800	900	850	162	19,06	21,63	15,18	15,04	6,49	2,30	5,96	31,95	58,34	8,26	31,95	10,18	8,74	53
P2U 900-1000	Phalaborwa	2	Upland	P2U	900	1000	950	163	17,16	23,22	13,67	16,41	7,34	4,62	7,67	27,74	60,64	12,28	27,74	10,07	8,57	59
P2U 1000-1100	Phalaborwa	2	Upland	P2U	1000	1100	1050	164	15,62	25,71	16,09	13,00	6,06	2,38	5,99	26,13	60,86	8,37	26,13	10,02	8,48	64
P2U 1100-1200	Phalaborwa	2	Upland	P2U	1100	1200	1150	165	14,35	25,95	15,25	13,86	5,24	3,18	9,40	26,66	60,30	12,58	26,66	9,98	8,44	64
P3U 0-50	Phalaborwa	3	Upland	P3U	0	50	25	166	664,00	33,46	21,91	22,84	3,84	1,79	2,66	13,22	82,04	4,45	13,22	8,84	7,61	1340
P3U 50-100	Phalaborwa	3	Upland	P3U	50	100	75	167	222,67	15,85	29,54	33,13	9,39	4,32	1,48	9,62	87,91	5,80	9,62	9,12	7,84	1990
P3U 100-150	Phalaborwa	3	Upland	P3U	100	150	125	168	134,40	28,41	25,16	25,75	7,62	3,16	1,71	10,58	86,94	4,87	10,58	9,22	7,92	2010
P3U 150-200	Phalaborwa	3	Upland	P3U	150	200	175	169	96,57	36,42	24,84	22,96	3,99	1,86	1,74	11,24	88,22	3,60	11,24	9,6	8,23	1630
P3U 200-250	Phalaborwa	3	Upland	P3U	200	250	225	170	75,56	26,99	28,61	20,27	6,28	2,63	2,77	15,30	82,15	5,40	15,30	10,03	8,06	540
P3U 250-300	Phalaborwa	3	Upland	P3U	250	300	275	171	62,18	31,30	27,40	17,98	5,72	2,20	2,03	15,27	82,40	4,23	15,27	10,16	8,27	298
P3U 300-400	Phalaborwa	3	Upland	P3U	300	400	350	172	49,14	27,42	20,70	20,83	7,98	3,59	2,94	17,54	76,93	6,52	17,54	10,2	8,27	178
P3U 400-500	Phalaborwa	3	Upland	P3U	400	500	450	173	38,44	19,33	18,55	19,43	6,43	6,29	2,56	27,09	63,75	8,85	27,09	10,53	8,63	101
P3U 500-600	Phalaborwa	3	Upland	P3U	500	600	550	174	31,64	23,17	16,67	19,45	7,92	4,35	6,54	25,85	67,21	10,89	25,85	10,55	8,8	75
P3U 600-700	Phalaborwa	3	Upland	P3U	600	700	650	175	26,92	26,82	17,00	15,70	6,33	4,55	5,45	25,91	65,85	10,00	25,91	10,43	8,77	81
P3U 700-800	Phalaborwa	3	Upland	P3U	700	800	750	176	23,47	18,65	17,00	17,91	7,92	5,43	7,87	27,10	61,48	13,30	27,10	10,21	8,75	73,5
P3U 800-900	Phalaborwa	3	Upland	P3U	800	900	850	177	20,82	22,28	16,78	16,52	7,01	5,00	5,94	28,94	62,58	10,94	28,94	10,06	8,62	69
P3U 900-1000	Phalaborwa	3	Upland	P3U	900	1000	950	178	18,74	17,42	15,11	22,20	8,64	5,15	6,92	26,05	63,37	12,07	26,05	9,84	8,47	68
P3U 1000-1100	Phalaborwa	3	Upland	P3U	1000	1100	1050	179	17,05	21,93	16,33	16,82	5,96	5,67	8,15	27,31	61,04	13,82	27,31	9,85	8,42	69
P3U 1100-1200	Phalaborwa	3	Upland	P3U	1100	1200	1150	180	15,65	20,97	16,75	17,33	7,11	5,23	8,86	25,35	62,15	14,09	25,35	9,77	8,39	69

Sample	Organic Carbon (%)	Organic Matter	Nitrogen (mg/Kg)	Phosphorus ppm	Iron mg/Kg	Manganese mg/Kg	Ca sol. Cmolc/Kg	Mg sol. Cmolc/Kg	K sol. Cmolc/Kg	Na sol. Cmolc/Kg	Ca ex. Cmolc/Kg	Mg ex. Cmolc/Kg	K ex. Cmolc/Kg	Na ex. Cmolc/Kg	CEC Na Cmolc/Kg	CEC clay	Sum sol. & exch. Bases Cmolc/Kg	Base saturation %	Sodium Adsorption Ratio	Exchangeable Sodium %
	C		N	P	Fe	Mn	Soluble bases				Exchangeable bases				CEC		SUM	BaseSAT	SAR	ESP
P1U 0-50	0,33	0,57	530	0,14	2346,64	116,33	0,32	0,02	0,00	10,87	3,43	0,56	0,20	7,31	20,00	266,47	15,41	57,53	1,83	36,57
P1U 50-100	0,56	0,96	930	0,17	2820,16	130,02	0,16	0,02	0,00	7,91	2,94	1,31	0,23	12,30	47,83	256,90	12,57	35,07	2,89	25,71
P1U 100-150	0,60	1,03	870	0,20	3267,47	168,80	0,13	0,02	0,00	10,52	10,10	3,21	0,38	25,57	30,43	153,22	24,37	128,99	1,92	84,00
P1U 150-200	0,37	0,64	540	0,16	3896,51	145,99	0,10	0,02	0,00	12,70	7,43	3,93	0,45	29,57	42,61	164,11	24,63	97,10	2,60	69,39
P1U 200-250	0,30	0,52	470	0,21	3669,35	123,18	0,12	0,03	0,00	13,22	7,99	4,41	0,39	24,70	54,78	188,11	26,16	68,43	1,99	45,08
P1U 250-300	0,28	0,48	300	0,07	4263,44	104,93	0,11	0,02	0,00	12,70	8,93	5,13	0,48	31,39	34,78	98,02	27,37	132,06	2,23	90,25
P1U 300-400	0,63	1,08	300	0,19	3599,46	116,33	0,10	0,02	0,00	11,48	6,64	4,56	0,37	21,22	32,17	103,62	23,17	101,89	1,89	65,95
P1U 400-500	0,22	0,38	290	0,24	3564,52	139,14	0,18	0,02	0,00	9,57	7,89	6,52	0,45	26,00	40,87	113,23	24,63	99,99	1,80	63,62
P1U 500-600	0,16	0,28	220	0,10	2774,73	61,59	0,13	0,03	0,00	8,26	14,19	7,57	0,41	37,30	33,04	94,12	30,59	180,00	1,71	112,89
P1U 600-700	0,21	0,36	250	0,20	2152,69	43,34	0,13	0,06	0,00	8,00	17,43	9,10	0,37	19,30	30,43	84,21	35,09	151,80	0,73	63,43
P1U 700-800	0,18	0,31	240	0,22	1684,41	29,65	0,21	0,11	0,00	8,87	18,55	12,00	0,33	16,78	33,91	92,80	40,07	140,55	0,55	49,49
P1U 800-900	0,20	0,34	230	0,18	1558,60	29,65	0,38	0,25	0,00	10,87	18,18	13,31	0,30	14,52	43,48	124,69	43,30	106,52	0,46	33,40
P1U 900-1000	0,18	0,31	300	0,07	1535,89	38,78	0,44	1,20	0,00	10,61	16,34	14,52	0,27	14,12	40,00	176,74	43,38	113,14	0,46	35,30
P1U 1000-1100	0,18	0,31	200	0,34	1327,96	22,81	0,42	0,93	0,00	7,04	16,19	14,64	0,25	13,34	30,43	128,83	39,48	145,95	0,43	43,83
P1U 1100-1200	0,30	0,52	160	0,26	1347,18	20,53	0,46	0,84	0,00	6,00	13,33	14,21	0,22	13,26	30,43	230,14	35,06	134,79	0,48	43,57
P2U 0-50	0,38	0,65	1100	0,09	1848,66	77,55	0,15	0,05	0,00	0,57	3,03	0,89	0,34	0,74	15,65	146,19	5,02	31,89	0,19	4,72
P2U 50-100	0,39	0,67	1180	0,21	1799,73	82,12	0,12	0,02	0,00	2,96	3,48	0,77	0,39	4,11	10,43	75,59	7,74	83,88	0,97	39,42
P2U 100-150	0,37	0,64	1320	0,21	1715,86	107,21	0,08	0,01	0,00	10,17	11,81	1,85	0,55	13,29	24,35	130,76	24,48	112,93	0,97	54,57
P2U 150-200	0,21	0,36	700	0,10	1541,13	118,61	0,06	0,00	0,00	11,91	9,92	1,25	2,90	15,04	24,35	130,77	26,04	119,56	1,35	61,79
P2U 200-250	0,13	0,22	560	0,18	1446,77	111,77	0,04	0,00	0,00	11,65	8,68	1,00	0,59	19,57	23,48	146,80	21,97	127,09	2,02	83,33
P2U 250-300	0,09	0,15	410	0,21	1382,12	116,33	0,05	0,00	0,00	11,48	8,47	0,97	0,52	20,43	20,87	120,50	21,49	145,64	2,17	97,92
P2U 300-400	0,11	0,19	460	0,09	1483,47	139,14	0,07	0,00	0,00	11,48	4,75	0,70	0,68	32,87	23,48	143,24	17,68	166,11	6,03	140,00
P2U 400-500	0,08	0,14	460	0,23	1630,24	127,74	0,07	0,00	0,00	12,43	8,00	1,03	0,71	32,00	29,57	204,65	22,25	141,19	3,54	108,24
P2U 500-600	0,06	0,10	400	0,30	2606,99	166,51	0,07	0,00	0,00	9,83	9,01	1,36	0,53	25,39	27,83	114,64	20,79	130,41	2,45	91,25
P2U 600-700	0,08	0,14	280	0,10	2612,23	139,14	0,05	0,00	0,00	10,09	10,95	2,26	0,54	28,61	43,48	169,35	23,89	97,44	2,17	65,80
P2U 700-800	0,08	0,14	300	0,14	2170,16	86,68	0,10	0,03	0,01	0,99	20,10	3,77	0,64	25,39	21,74	71,48	25,65	229,55	1,06	116,80
P2U 800-900	0,07	0,12	250	0,17	1527,15	77,55	0,10	0,05	0,01	0,59	11,02	3,11	0,65	25,04	23,48	73,49	15,54	169,66	1,77	106,67
P2U 900-1000	0,06	0,10	360	0,11	1390,86	75,27	0,10	0,07	0,01	0,41	11,03	4,43	0,68	22,09	20,00	72,09	16,72	191,09	1,43	110,43
P2U 1000-1100	0,09	0,15	270	0,09	1296,51	63,87	0,11	0,07	0,00	0,42	13,17	4,59	0,49	14,43	28,70	109,82	18,85	113,89	0,81	50,30
P2U 1100-1200	0,10	0,17	200	0,13	1319,22	66,15	0,11	0,10	0,00	0,43	13,43	5,57	0,55	14,87	20,87	78,28	20,20	164,93	0,78	71,25
P3U 0-50	0,62	1,07	1970	0,22	2587,77	116,33	0,04	0,01	0,01	0,09	7,45	1,69	0,65	0,23	7,22	54,59	9,93	138,87	0,03	3,25
P3U 50-100	0,32	0,55	690	0,07	1815,46	70,71	0,02	0,00	0,00	0,04	6,55	1,51	0,45	0,26	4,43	46,10	8,57	197,74	0,03	5,88
P3U 100-150	0,16	0,28	590	0,12	1866,13	77,55	0,02	0,00	0,00	0,06	6,27	1,23	0,29	0,12	4,35	41,10	7,88	181,99	0,02	2,80
P3U 150-200	0,14	0,24	390	0,07	1350,67	47,90	0,03	0,00	0,00	0,16	11,59	2,51	0,33	0,58	6,78	60,35	14,62	221,27	0,04	8,59
P3U 200-250	0,14	0,24	380	0,07	1535,89	57,03	0,06	0,01	0,00	0,17	15,83	3,93	0,32	1,83	9,04	59,09	20,32	242,25	0,09	20,19
P3U 250-300	0,13	0,22	470	0,07	1308,74	59,31	0,05	0,00	0,00	0,16	14,15	4,26	0,33	3,57	7,48	48,97	18,95	298,33	0,19	47,67
P3U 300-400	0,16	0,28	570	0,06	1362,90	72,99	0,05	0,01	0,00	0,41	13,48	4,26	0,37	6,26	11,57	65,95	18,58	210,73	0,35	54,14
P3U 400-500	0,11	0,19	410	0,03	1502,69	70,71	0,04	0,01	0,00	0,26	11,94	2,62	0,44	10,26	10,61	39,16	15,32	238,14	0,70	96,72
P3U 500-600	0,07	0,12	300	0,13	2168,41	86,68	0,05	0,01	0,00	0,49	11,47	2,41	0,43	10,78	22,61	87,45	14,86	110,98	0,78	47,69
P3U 600-700	0,10	0,17	310	0,07	1392,61	52,46	0,05	0,01	0,00	0,36	14,16	3,77	0,41	10,35	10,09	38,93	18,76	284,40	0,58	102,59
P3U 700-800	0,08	0,14	280	0,07	1198,66	45,62	0,06	0,03	0,00	0,22	14,82	4,43	0,38	10,52	9,65	35,61	19,94	312,38	0,55	109,01
P3U 800-900	0,07	0,12	270	0,08	1055,38	34,22	0,08	0,06	0,00	0,48	17,80	6,07	0,36	8,96	16,52	57,09	24,85	200,86	0,38	54,21
P3U 900-1000	0,09	0,15	260	0,09	1036,16	29,65	0,11	0,11	0,00	0,23	15,95	7,87	0,34	8,87	16,43	63,10	24,61	200,98	0,37	53,97
P3U 1000-1100	0,07	0,12	220	0,14	864,92	25,09	0,12	0,10	0,00	0,42	16,10	8,69	0,27	8,78	16,52	60,49	25,70	204,83	0,35	53,16
P3U 1100-1200	0,06	0,10	250	0,04	842,20	25,09	0,13	0,10	0,00	0,41	13,71	8,52	0,26	7,91	18,26	72,04	23,14	166,52	0,36	43,33


1. ANOVA; Untransformed Data
pH_KCl
wetland_zone
MalahlapangaPermanent
MalahlapangaSeasonal
MalahlapangaTemporary
MalahlapangaUpland
Nshawu Permanent
Nshawu Seasonal
Nshawu Temporary
Nshawu Upland
Phalaborwa Permanent
Phalaborwa Seasonal
Phalaborwa Temporary
Phalaborwa Upland
1. ANOVA; Untransformed Data
Clay
wetland_zone
2. ANOVA; Log-transformed Data
All Data; no outliers;
log_Fe
wetland_zone
2. ANOVA; Log-transformed Data
All Data; no outliers
log_Organic_C
wetland_zone

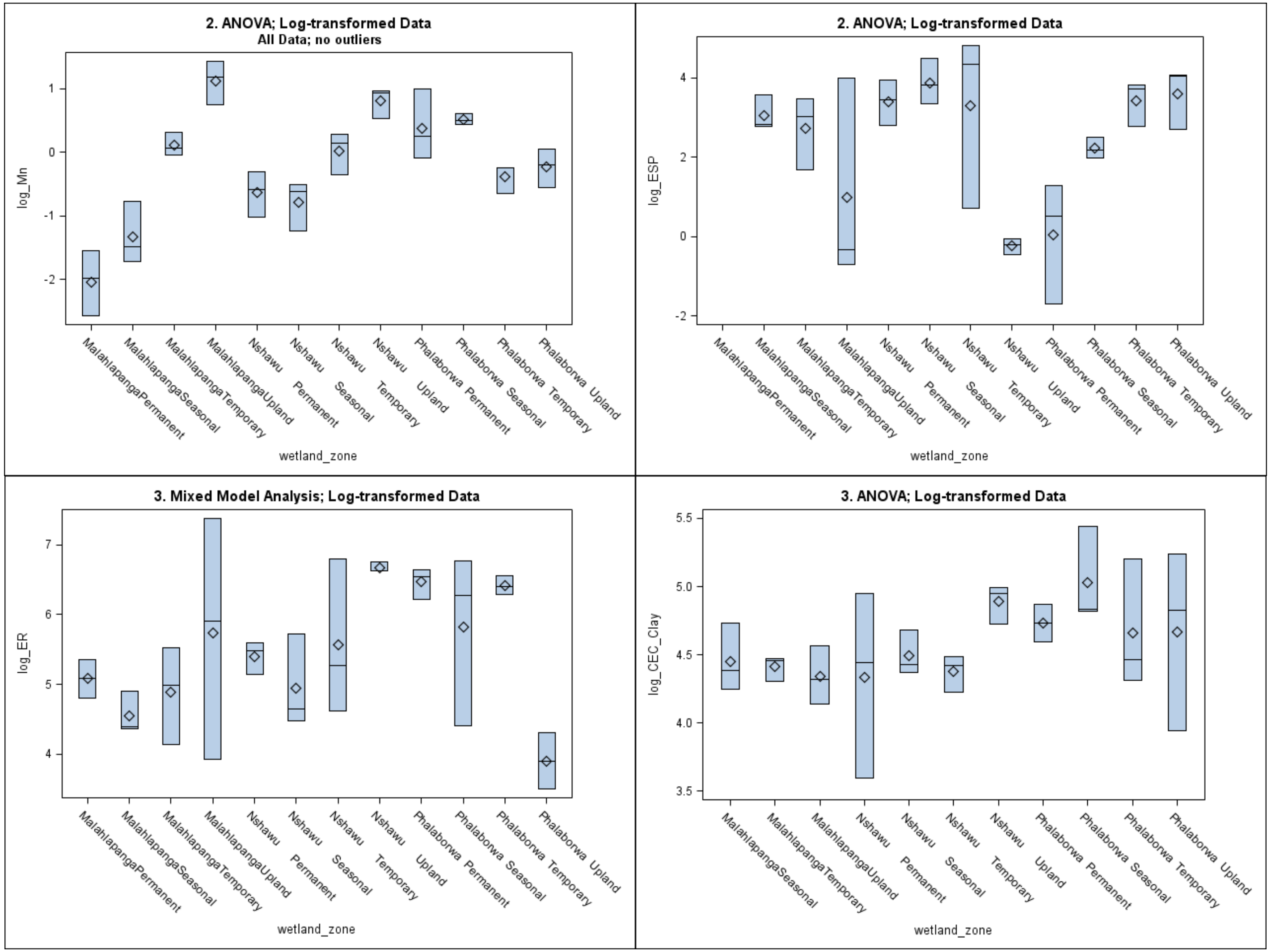


Figure 42 Statistical analyses comparing soil data from all three wetlands

Appendix B

Results for 12 profiles which were selected from the 36 points sampled. The data is presented in the following order for each profile:

- Profile descriptions
- Photographs of the profiles
- WRB classification

Profile No: M2P

Map/photo: No photo

Latitude & Longitude: 22.88726°S; 31.03985°E

Surface stoniness: NA

Altitude: 443m

Terrain unit: 4 Footslope

Slope: 1%

Slope shape: Concave

Aspect: Level

Microrelief: Other mounds

Parent material solum: Solid rock

Underlying material: Goudplaats Gneiss

Soil form: Champagne

Soil family: 1200

Surface rockiness: NA

Occurrence of flooding: Frequent

Wind erosion: Slight

Water erosion: Moderate

Vegetation / Land use: Grassveld, open

Water table: 600 mm

Described by: CW Van Huyssteen

Date described: July 2013

Weathering of underlying material: Strong physical and strong chemical

Alteration of underlying material: Ferruginised

Horizon	Depth(mm)	Description	Diagnostic horizons
O	0 – 1100	**Moisture status:** wet; **moist colour:** G1 2.5/N; fine sand; few, coarse, faint grey mottles; apedal, massive structure; hard, friable, non-sticky, plastic consistence; many, bleached pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 1 second; many roots; clear, smooth transition.	Organic O horizon
G	1100 – 1200	**Moisture status:** wet; **dry colour:** G1 3/N; fine sand; few, coarse, faint grey mottles; apedal, massive structure; very hard, firm, sticky, very plastic consistence; few, blached pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 1 second; few roots; transition not reached.	G horizon

<u>Profile No: M1S</u>

Map/photo: Figure 43

Latitude & Longitude: 22.88863°S; 31.04001°E

Surface stoniness: NA

Altitude: 443m

Terrain unit: 5 Valley bottom

Slope: 0.5%

Slope shape: Straight

Aspect: North

Microrelief: Other mounds

Parent material solum: Alluvium

Underlying material: Goudplaats Gneiss

Soil form: Kroonstad

Soil family: 1000

Surface rockiness: NA

Occurrence of flooding: Occasional

Wind erosion: Slight/moderate

Water erosion: Moderate gully

Vegetation / Land use: Barren

Water table: Not encountered

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical and strong chemical

Alteration of underlying material: Ferruginesed

Horizon	Depth(mm)	Description	Diagnostic horizons
A1	0 – 50	**Moisture status:** dry; **dry colour:** 10YR 3/2; **moist colour:** 10YR 2/1; 10% clay; fine, loamy sand; no mottles; weak, coarse, platy structure; apedal, single grain secondary structure; loose, loose, very sticky, very plastic consistence; few, normal, very fine and fine pores; fine cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 3 seconds; no roots; clear, smooth transition.	Melanic A horizon/ Orthic A horizon
A2	50 – 300	**Moisture status:** dry; **dry colour:** 10YR 6/1; **moist colour:** 10YR 4/1; 25% clay; fine, sandy clay loam; few, fine, distinct white reduced iron oxide mottles; strong, coarse prismatic structure; strong, medium, angular blocky secondary structure; very hard, firm, sticky, plastic; few, normal fine and very fine pores; fine cracks; no cementation; slight free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 2 seconds; no roots, clear, smooth transition.	Orthic A horizon
E	300 – 450	**Moisture status:** dry; **dry colour:** 10YR 8/1; **moist colour:** 10YR 7/1; 20% clay; fine, sandy loam; common, fine, prominent yellow, brown and red oxidised iron oxide mottles; apedal massive structure; strong, coarse, angular blocky secondary structure; very hard, firm, sticky, plastic consistence; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 1 second; no roots; gradual smooth transition.	E horizon
G1	450 – 850	**Moisture status:** moist; **dry colour:** 5Y 6/1; **moist colour:** 5Y 3/2; 30% clay; fine, sandyclay loam; common, fine, prominent red oxidised iron oxide; few, fine, faint yellow oxidised iron oxide secondary mottles; apedal, massive structure; strong, coarse angular blocky secondary structure; very hard, friable, slightly sticky,very plastic consistence; fewvery fine and fine pores with rusty streaking; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial deositional stratification; water absorption 4 seconds; no roots; gradual smooth transition.	G horizon
G2	850 –1200	**Moisture status:** moist; **dry colour:** G1 7/10Y; **moist colour:** G1 4/10Y; 35% clay; fine, sandy clay loam; common, medium, prominent red oxidised iron oxide mottles; few, coarse, distinct yellow, olive and brown oxidised iron oxide secondary mottles; apedal massive structure; strong, coarse angular blocky secondary structure; very hard, friable, sticky, very plastic consistence; few rusty streaky very fine and fine pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 3 seconds; no roots; gradual smooth transition.	G horizon
G3	1200 –1350+	**Moisture status:** wet; **moist colour:** G1 2.5/5G; 40% clay; coarse, sandy clay; common, medium, prominent reddish brown oxidised iron oxide mottles; commo, medium, distinct grey reduced iron oxide secondary mottles; apedal massive structure; strong, coarse angular blocky secondary structure; very hard, friable, sticky, very plastic consistence; few normal very fine and fine pores; alluvial depositional stratification; water absorption 3 seconds; transition not reached.	G horozon

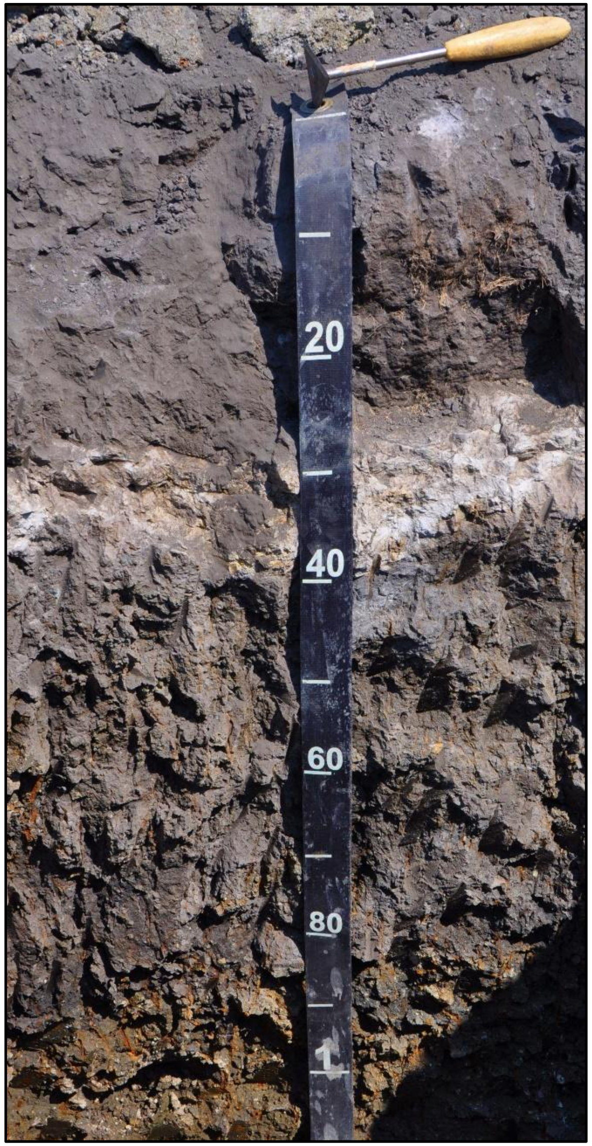


Figure 43 Profile M1S

FAO horizons

0-50 mm A1

50-250 mm A2

250-400 mm 2Cl

400-850 mm 3 Br

850-1100 mm 4 Cr

1100 mm 5 Cr

WRB Diagnostics:

Fluvic material, gleyic colour patterns from 250 mm, reducing condition from 400 mm.

Epigleyic Fluvisol (Siltic, Eutric)

M Fuchs and E Micheli

Profile No: M1T

Map/photo: Figure 44

Latitude & Longitude: 22.88845°S; 31.04052°E

Surface stoniness: None

Altitude: 552m

Terrain unit: 5 Valley bottom

Slope: 0.5%

Slope shape: Straight

Aspect: North

Microrelief: NA

Parent material solum: Binary, alluvium and solid rock

Underlying material: Goudplaats Gneiss

Soil form: Katspruit

Soil family: 1000

Surface rockiness: None

Occurrence of flooding: Occasional

Wind erosion: Slight

Water erosion: Moderate gully

Vegetation / Land use: Barren

Water table: Not encountered

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Weak physical and weak chemical

Alteration of underlying material: Ferriginised

Horizon	Depth(mm)	Description	Diagnostic horizons
A1	0 – 100	**Moisture status:** dry; **dry colour:** 2.5Y 4/1; **moist colour:** 2.5Y 3/1; 10% clay; coarse loamy sand; few, fine, faint red oxidised iron oxide mottles; weak, coarse, platy structure; weak, fine, angular blocky secondary structure; hard, friable, sticky, plastic consistence; few normal very fine and fine pores; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 5 seconds; common roots; clear, smooth transition.	Orthic A horizon
A2	100 – 300	**Moisture status:** dry; **dry colour:** 2.5Y 4/1; **moist colour:** 2.5Y 3/1; 20% clay; medium, sandy loam; few, fine, faint red oxidised iron oxide mottles; few, fine, faint grey mottles; strong, coarse, angular blocky structure; hard, friable, sticky, plastic consistence; few, normal very fine and fine pores; fine cracks; no cementation; no free lime; no slickenslides; few organic cutans; no coarse fragments; alluvial depositional stratification; water absorption 7 seconds; common roots; clear smooth transition.	Orthic A horizon
E	300 – 400	**Moisture status:** dry; **dry colour:** 10YR 8/1; **moist colour:** 10YR 7/1; 20% clay; coarse, sandy loam; few, fine, distinct yellow oxidised iron oxide mottles; strong, coarse, angular blocky structure; very hard, friable, slightly sticky plastic consistence; common very fine and fine normal pores; fine cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 2 seconds; few roots; clear smooth transition.	E horizon
G1	400 – 800	**Moisture status:** dry; **dry colour:** 10YR 5/1; **moist colour:** 10YR 3/1; 10% clay; coarse, loamy sand; common, medium, prominent grey and yellow reduced iron oxide mottles; few, fine faint red oidized iron oxide mottles; strong, coarse, angular blocky structure; very hard, friable, slightly sticky, plastic consistence; few very fine and fine normal pores; cementation of horizon; no free lime; no slickenslides; no cutans; no coarse fragments; alluvial depositional stratification; water absorption 6 seconds; clear smooth transition.	G horizon
G2	800 – 1100+	**Mositure status:** dry; **dry colour:** 5Y 6/4; **moist colour:** 5Y 4/4; many, medium, prominent, red oxidised iron oxide mottles; many, medium, prominent black manganese, magnetite mottles; fine cracks; no cementation of horizon; no free lime; no slickenslides; no cutans; very many, angular, coarse gravel fragments; no depositonal stratification; water absorption 2 seconds; transition not reached.	Saprolite

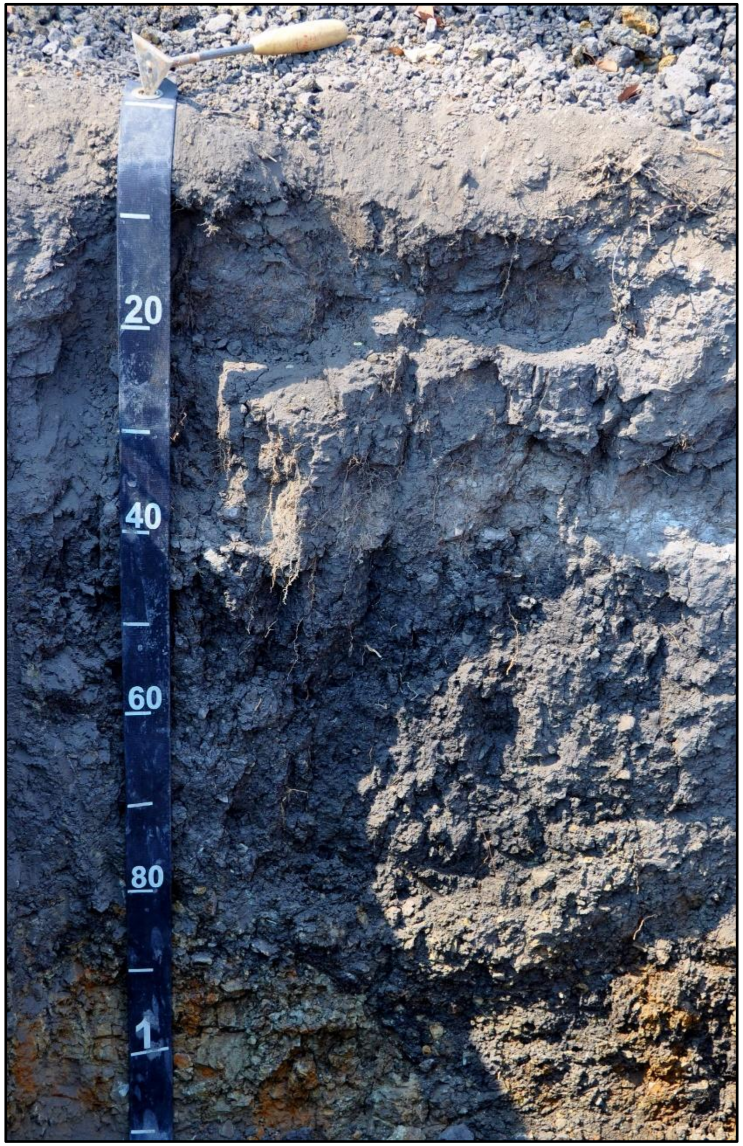


Figure 44 Profile M1T

FAO horizons

0-100 mm A1

100-300 mm A2

300-400 mm 2 C

400-800 mm 3 Bl

800-1100 mm 4 C/D

WRB Diagnostics:

Fluvic material, mollic horizon (0-300 mm), gleyic colour patterns from 400 mm, lithological discontinuity.

Mollic Gleyic Fluvisol (Endoruptic)

M Fuchs and E Micheli

<u>Profile No: M1U</u>

Map/photo: Figure 45

Latitude & Longitude: 22.8885°S; 31.04084°E

Surface stoniness: 2-10% angular gravel

Altitude: 521m

Terrain unit: 4L Lower footslope

Slope: 2%

Slope shape: Straight

Aspect: North

Microrelief: Termite mounds

Parent material solum: Single origin, local colluvium

Underlying material: Quartzite, Goudplaats Gneiss

Soil form: Glenrosa

Soil family: 1111

Surface rockiness: <2% extent

Occurrence of flooding: None/occasional

Wind erosion: Moderate

Water erosion: Slight sheet erosion

Vegetation / Land use: Thicket

Water table: Not encountered

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical and weak chemical

Alteration of underlying material: Ferruginised

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 400	**Moisture status:** dry; **dry colour:** 10YR 5/3; **moist colour:** 10YR 4/2; 10 % clay; coarse loamy sand; few fine faint white, fungi mottles; weak, fine, granular structure; hard, loose, slightly sticky, plastic consistence; no fine and very fine pores; common normal medium and coarse pores; no cracks; no cementation; no free lime; no slickensides; no cutans; few, angular, gravel rock fragments; water absorption 1 second; common fine and coarse roots; clear smooth transition.	Orthic A horizon
B	400 – 600	**Moisture status:** dry; **dry colour:** 10YR 5/5; **moist colour:** 10YR 4/3; 15% clay; coarse loamy sand; common, medium, prominent white fingi mottles; moderate, medium, angular blocky structure; slightly hard, loose, sticky, plastic consistence; no fine and very fine pores; common normal medium and coarse pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; common, angular, gravel rock fragments; water absorption 1 second; few fine and coarse roots; clear and smooth transition.	Lithocutanic B horizon
C	600 – 700	**Moisture status:** dry; very many angular gravel rock fragments and coarse gravel; water absorption 2 seconds; few fine and coarse roots.	Saprolite/ Hard rock

Figure 45 Profile M1U

FAO horizons

0-400 mm A

400-600 mm B

600 mm C/D

WRB Diagnostics:

Cambic horizon (400-600 mm).

Haplic Cambisol (Endoskeletic)

M Fuchs and E Micheli

Profile No: N1P

Map/photo: Figure 46

Latitude & Longitude: 23.52278°S; 31.48729°E

Surface stoniness: NA

Altitude: 391m

Terrain unit: 5 Valley bottom

Slope: 1%

Slope shape: Concave

Aspect: East

Microrelief: Other mounds

Parent material solum: Alluvium

Underlying material: Basalt

Soil form: Katspruit

Soil family: 2000

Surface rockiness: NA

Occurrence of flooding: Frequent

Wind erosion: None

Water erosion: None

Vegetation / Land use: Grassveld, open

Water table: 1000 mm

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical and strong chemical

Alteration of underlying material: Calcified

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 200	**Moisture status:** moist; **dry colour:** G1 6/10Y; **moist colour:** G1 3/10Y; 40% clay, fine sand, sandy clay; common, fine, distinct white lime mottles; strong, coarse, angular blocky structure; very hard, very firm, slightly sticky, very plastic consistence; many very fine and fine rusty pores; few medium and coarse pores; fine cracks; no cementation of horizon; moderate free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 2 seconds; many roots; clear, smooth transition.	Orthic A horizon
G1	200 – 1100	**Moisture status:** moist; **dry colour:** G1; **moist colour:**; G1 4/5GY; 40% clay, fine sand, sandy clay; common, fine, distinct white lime mottles; few, fine, faint, red and yellow oxidised iron oxide; strong, coarse angular blocky structure; very hard, friable, slightly sticky, plastic consistence; many very fine and fine rusty pores; few medium and coarse pores; fine cracks; no cementation; slight free lime; few slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 2 seconds; many roots; gradual smooth transition.	G horizon
G2	1100 – 1400	**Moisture status:** wet; **moist colour:** G1 4/N; 30% clay, fine sand, sandy clay loam; common, medium, distinct, blue and green reduced iron oxide; few, fine, faint white lime mottles; strong, medium, angular blocky structure; very hard, friable, slightly sticky and slightly plastic consistence; common, very fine and fine rusty pores; few medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 3 seconds; few roots; transition not reached.	

Figure 46 Profile N1P

FAO horizons

0-200 mm Al

200-500 mm Bssrk

500-1100 mm Crk

WRB Diagnostics:

Gleyic colour patterns from surface, reducing conditions, secondary carbonates, vertic properties (200-550 mm).

Calcic Gleysol (Eutric, Vertic)

M Fuchs and E Micheli

<u>Profile No: N1S</u>

Map/photo: Figure 47

Latitude & Longitude: 23.52272°S; 31.48693°E

Surface stoniness: NA

Altitude: 392m

Terrain unit: 5 Valley bottom

Slope: 1%

Slope shape: Concave

Aspect: East

Microrelief: None

Parent material solum: Alluvium

Underlying material: Basalt

Soil form: Katspruit

Soil family: 2000

Surface rockiness: NA

Occurrence of flooding: Frequent

Wind erosion: None

Water erosion: None

Vegetation / Land use: Grassveld, open

Water table: 1000 mm

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical and strong chemical

Alteration of underlying material: Calcified

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 250	**Moisture status:** moist; **dry colour:** 10YR 4/2; **moist colour:** 10YR 2/2; 40% clay, fine sand, clay loam; no mottles; strong, coarse angular blocky structure; very hard, firm, slightly sticky, very plastic consistence; few very fine and fine pores; few medium and coarse pores; fine cracks;no cementation; slight free lime; no slickenslides; no cutans; very few, round gravel rock fragments; no depositional stratification; water absorption 2 seconds; many roots; clear smooth transition.	Orthic A horizon
B	250 – 600	**Moisture status:** moist; **dry colour:** G1 5/5GY; **moist colour:** G1 4/5GY; 45% clay, fine sand, silty clay; common, fine, prominent; white lime mottles; strong, coarse, angular blocky structure; hard,friable, sticky, very plastic consistence; few fine and very fine pores; few medium and coarse pores; fine cracks; no cementation; slight free lime; few slickenslides; no cutans; very few round gravel rock fragments; no depositional stratification; water absorption 1 second; common roots; gradual smooth transition.	G horizon
C	600 – 1200	**Moisture status:** wet; **dry colour:** G1 7/10Y; **moist colour:** G1 6/5GY; 35% clay, coarse sand, sandy clay loam; common, medium, faint, black and brown mottles; strong, coarse angular blocky structure; very hard, friable, very sticky, very plastic consistence; few very fine and fine pores; few medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; very few, round gravel rockfragments; common, fine, lime concretions/nodules; no depositional stratification; water absorption 1 second; few roots; trsnsition not reached.	

Figure 47 Profile N1S

FAO horizons

0-200 mm A

200-600 mm Blssk

600 mm Crk

WRB Diagnostics:

Mollic horizon (0-200 mm, gleyic colour patterns 200 mm and below, vertic properties 200-600 mm, secondary carbonates.

Calcic Mollic Gleysol (Eutric, Vertic)

M Fuchs and E Micheli

Profile No: N1T

Map/photo: Figure 48

Latitude & Longitude: 23.52281°S; 31.48668°E

Surface stoniness: NA

Altitude: 393m

Terrain unit: 5 Valley botom

Slope: 3%

Slope shape: Straight

Aspect: East

Microrelief: None

Parent material solum: Alluvium

Underlying material: Basalt

Soil form: Steendal

Soil family: 2000

Surface rockiness: NA

Occurrence of flooding: Frequent

Wind erosion: None

Water erosion: None

Vegetation / Land use: Grassveld, open

Water table: Not encountered

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Moderate physical and chemical

Alteration of underlying material: Calcified

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 150	**Moisture status:** dry; **dry colour:** 7.5YR 3/2; **moist colour:** 7.5YR 2.5/1; 8% clay, fine sand, sand; no mottles; moderate, medium, granular structure; apedal, single grain secondary structure; loose, loose, non-sticky, non-plastic consistence; many very fine and fine pores; few medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; very few, angular stones; common, medium lime concretions; no depositional stratification; water absorption 1 second; many roots; clear, smooth transition.	Melanic A horizon
C1	150 – 400	**Moisture status:** dry; **dry colour:** 7.5YR 5/2; **moist colour:** 7.5YR 3/2; 10% clay, coarse sand, sandy loam; no mottles; moderate, fine, angular blocky structure; loose, loose, slightly sticky, slightly plastic consistence; common very fine and fine pores; few medium and coarse pores; no cracks; nodular pan, moderate, easily broken with hammer, discontinuous carbonates; moderate free lime; no slickenslides; no cutans; very few, angular stones; common, medium lime concretions; no depositional stratification; water absorption 1 second; common roots; gradual, smooth transition.	Soft carbonate
C2	400 – 1100	**Moisture status:** dry; **dry colour:** 7.5YR 8/1; **moist colour:** ;7.5YR 7/2; 15% clay, coarse sand, sandy loam; no mottles; moderate, fine, subangular blocky structure; hard, firm, slightly sticky, slightly plastic consistence; few very fine and fine pores; no cracks; nodular pan, moderate, easily broken with hammer, discontinuous carbonates; moderate free lime; no slickenslides; no cutans; very few, angular stones; common, medium lime concretions; no depositional stratification; water absorption 1 second; few roots; gradual, smooth transition.	
C3	1100 – 1400	**Moisture status:** moist; **dry colour:** 10YR 6/4; **moist colour:** 10YR 6/4; 5% clay, coarse sand, sand; common, coarse, distinct yellow, olive and brown oxidised and reduced iron oxide and manganese/magnetite mottles; moderate, medium, subangular blocky structure; slightly hard, friable, non-sticky, non-plastic; no cracks; no cementation; moderate free lime; no slickenslides; no cutans; very few, angular stones; few, medium lime concretions; no depositional stratification; water absorption 1 second; few roots; transition not reached	

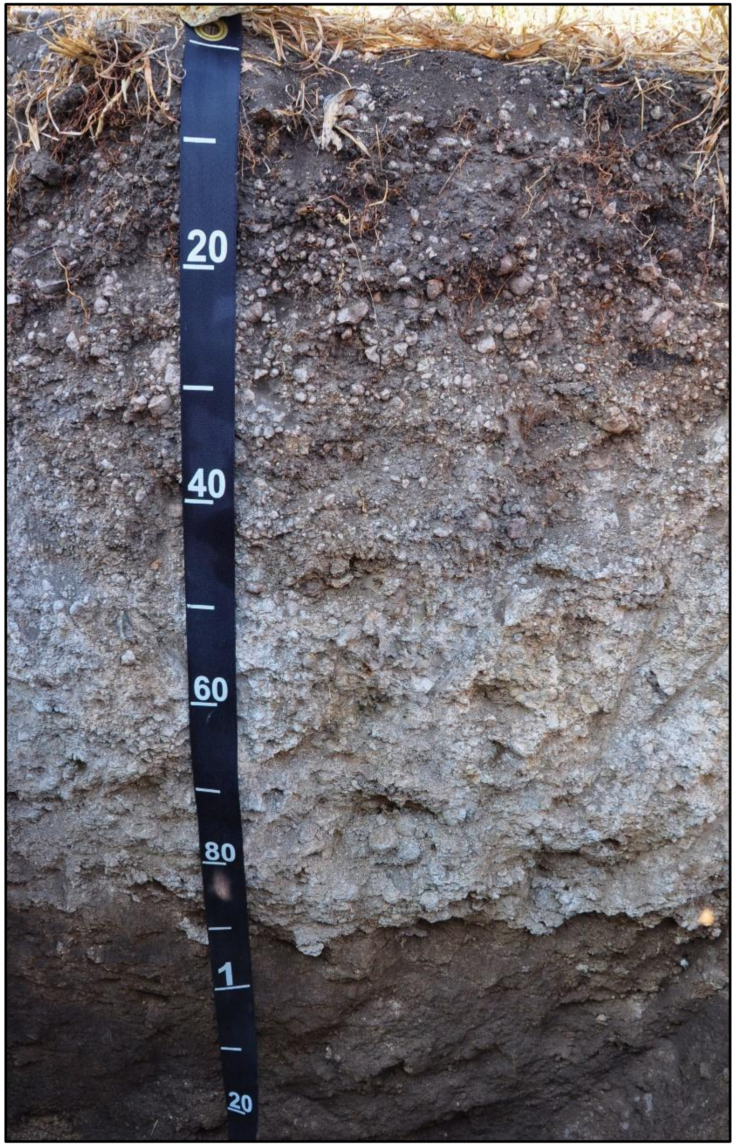


Figure 48 Profile N1T

FAO horizons

0-150 mm Ak

150-400 mm CAk

400-800 mm Ck

800-1100 mm 2Ckl*

1100 mm 3Ckl *

WRB Diagnostics:

Calcic horizon, petrocalcic horizon, gleyic colour pattern (800 mm and below).

Bathypetric Endogleyic Hypercalcic Calcisol (Endoruptic)

M Fuchs and E Micheli

Profile No: N1U

Map/photo: No photo

Latitude & Longitude: 23.52295°S; 31.48621°E

Surface stoniness: NA

Altitude: 395m

Terrain unit: 3U Upper Midslope

Slope: 3%

Slope shape: Convex

Aspect: East

Microrelief: None

Parent material solum: Solid rock

Underlying material: Basalt

Soil form: Milkwod

Soil family: 2000

Surface rockiness: NA

Occurrence of flooding: None

Wind erosion: None

Water erosion: None

Vegetation / Land use: Grassveld, open

Water table: Not encountered

Described by: CW Van Huyssteen

Date described: July 2013

Weathering of underlying material: Moderate physical and chemical

Alteration of underlying material: Ferruginised and calcified

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 100	**Moisture status:** dry; **dry colour:** 5Y 2.5/1; fine sand; many, medium, prominent, white, lime mottles; strong, medium, subangular blocky structure; loose, friable, non-sticky, non-plastic consistence; few fine and very fine pores; common medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; few, round, gravel rock fragments; no depositional stratification; water absorption 1 second; many roots; clear, smooth transition.	Melanic A horizon
B	100 – 240	**Moisture status:** dry; **dry colour:** 2.5Y 3/2; fine sand; many, medium, prominent, white, lime mottles; strong, medium, subangular blocky structure; loose, friable, non-sticky, non-plastic consistence; few fine and very fine pores; common medium and coarse pores; no cracks; no cementation; strong free lime; no slickenslides; no cutans; common, round, coarse gravel; no depositional stratification; water absorption 1 second; common roots; clear, wavy transition.	Hard rock/ Neocarbonate B
C	240 – 500	**Moisture status:** dry; **dry colour:** 2.5Y 5/2; fine sand; many, medium, prominent, white, lime mottles; apedal, single grain structure; very hard, very firm, non-sticky, non-plastic consistence; few fine and very fine pores; few medium and coarse pores; no cracks; no cementation; strong free lime; no slickenslides; common, carbonate cutans; very many, angular and flat stones; no depositional stratification; water absorption 1 second; few roots.	Hard rock/ Soft carbonate

Profile No: P1P

Map/photo: Figure 49

Latitude & Longitude: 23.95354°S; 31.16802°E

Surface stoniness: NA

Altitude: 443m

Terrain unit: 4L Lower Footslope/ 5 Valley bottom

Slope: 0%

Slope shape: Straight

Aspect: South

Microrelief: Other mounds

Parent material solum: Alluvium and unconsolidated mineral sediment

Underlying material: Granite

Soil form: Dundee

Soil family: 1210

Surface rockiness: NA

Occurrence of flooding: Occasional

Wind erosion: None

Water erosion: None

Vegetation / Land use: Thicket

Water table: 1000 mm

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical

Alteration of underlying material: NA

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 100	**Moisture status:** dry; **dry colour:** 10YR 4/3; **moist colour:** 10YR 3/3; 15% clay, fine sand, sandy loam; no mottles; strong, medium, subangular blocky structure; slightly hard, firm, non-sticky, plastic consistence; few very fine, fine, medium and large pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 4 seconds; many roots; clear, smooth transition.	Orthic A horizon
C1	100 – 550	**Moisture status:** dry; **dry colour:** 10YR 3/4; **moist colour:** 10YR 3/3; 20% clay, fine sand, loam; many, medium, distinct, grey and yellow reduced iron oxide; common, fine, distinct, yellow, olive and brown, oxidised iron oxide; strong, coarse, prismatic structure; very hard, slightly firm, slightly sticky, plastic contistence; few very fine, fine, medium and large pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; no coarse fragments; alluvial stratification; water absorption 3 seconds; common roots; clear, smooth transition.	Stratified alluvium
C2	550 – 800	**Moisture status:** moist; **moist colour:** Gley2 2.5BG; 5% clay, coarse sand, sand; many, medium, distinct, red and yellow, oxidised iron oxide; apedal, single grain structure; friable, non-sticky, non-plastic; few very fine, fine, medium and large pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 2 seconds; few roots; clear, smooth transition.	Unconsolidated material, with signs of wetness
C3	800 – 1000	**Moisture status:** moist; **moist colour:** Gley2 4/10B; 8% clay, coarse sand, sand; few, fine, distinct, yellow oxidised iron oxide; apedal, single grain structure; friable, non-sticky, non-plastic; few very fine, fine, medium and large pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; many, mixed shaped stones; no depositional stratification; water absorption 1 second; few roots; transition not reached.	

Figure 49 Profile P1P

FAO horizons

0-100 mm A

100-550 mm 2Cl (stratified)

550-800 mm 3Cl

800 mm 4Cr

WRB Diagnostics:

Fluvic soil material, gleyic colour pattern (100 mm and below), reducing conditions 800 mm and below.

Epigleyic Fluvisol (Eutric)

M Fuchs and E Micheli

Profile No: P1S

Map/photo: Figure 50

Latitude & Longitude: 23.95342°S; 31.16802°E

Surface stoniness: NA

Altitude: 444m

Terrain unit: 4L Lower Footslope

Slope: 1%

Slope shape: Straight

Aspect: South

Microrelief: None

Parent material solum: Alluvium and unconsolidated mineral sediment

Underlying material: Granite

Soil form: Sterkspruit

Soil family: 2100

Surface rockiness: NA

Occurrence of flooding: Occasional

Wind erosion: None

Water erosion: None

Vegetation / Land use: Thicket

Water table: 1140 mm

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical and strong chemical

Alteration of underlying material: Ferruginised

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 20	**Moisture status:** dry; **dry colour:** 10YR 5/2; **moist colour:** 10YR 3/2; 20% clay, coarse sand; no mottles; apedal, single grain structure; loose, non-sticky consistence; few very fine, fine, medium, and coarse pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 3 seconds; common roots; abrupt, smooth transition.	Orthic A horizon
B1	20 – 100	**Moisture status:** dry; **dry colour:** 10YR 5/3; **moist colour:** 10YR 3/3; 20% clay, coarse sand; no mottles; strong, coarse, columnar structure; very hard, slightly-sticky, plastic consistence; common very fine and fine pores; few medium and coarse pores; fine cracks; no cementation; slight free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 2 seconds; common roots; clear, smooth transition.	Prismacutanic B horizon
B2	100 – 180	**Moisture status:** dry; **dry colour:** 10YR 5/3; **moist colour:** 10YR 3/3; 20% clay, coarse sand; no mottles; apedal, single grain structure; loose, slightly sticky, slightly plastic; few very fine, fine, medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 1 second; few roots; abrupt, smooth transition.	
B3	180 – 700	**Moisture status:** moist; **moist colour:** 10YR 3/4; 30% clay, fine sand; common, coarse, faint, red oxidised iron oxide mottles; many, coarse, prominent, black manganese, magnetite mottles; strong, coarse, angular blocky structure; friable, sticky, plastic; common very fine and fine pores; few medium and coarse pores; no cracks; no cementation; no free lime; no slickenslides; few cutans; no coarse fragments; no depositional stratification; water absorption 1 second; few roots; clear, smooth transition.	
B4	700 – 1000	**Moisture status:** wet; **moist colour:** 10YR 3/2; 30% clay; fine sand; common, coarse, faint, grey, yellow and olive oxidised iron oxide; weak, coarse, angular blocky structure; friable, sticky, plastic consistence; common very fine and fine pores; few medium and coarse pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 3 seconds; few roots; clear, smooth transition.	
B5	1000 – 1200	**Moisture status:** wet; **moist colour:** 10YR 4/2; 10% clay, coarse sand; common, medium, distinct, yellow, brown and red oxidised iron oxide; common, medium, distinct, grey and white reduced iron oxide mottles; weak, coarse, angular blocky structure; friable, sticky, plastic consistence; few very fine, fine, medium, and coarse pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; common coarse stones and stones with mixed shapes; no depositional stratification; water absorption 3 seconds; few roots; transition not reached.	

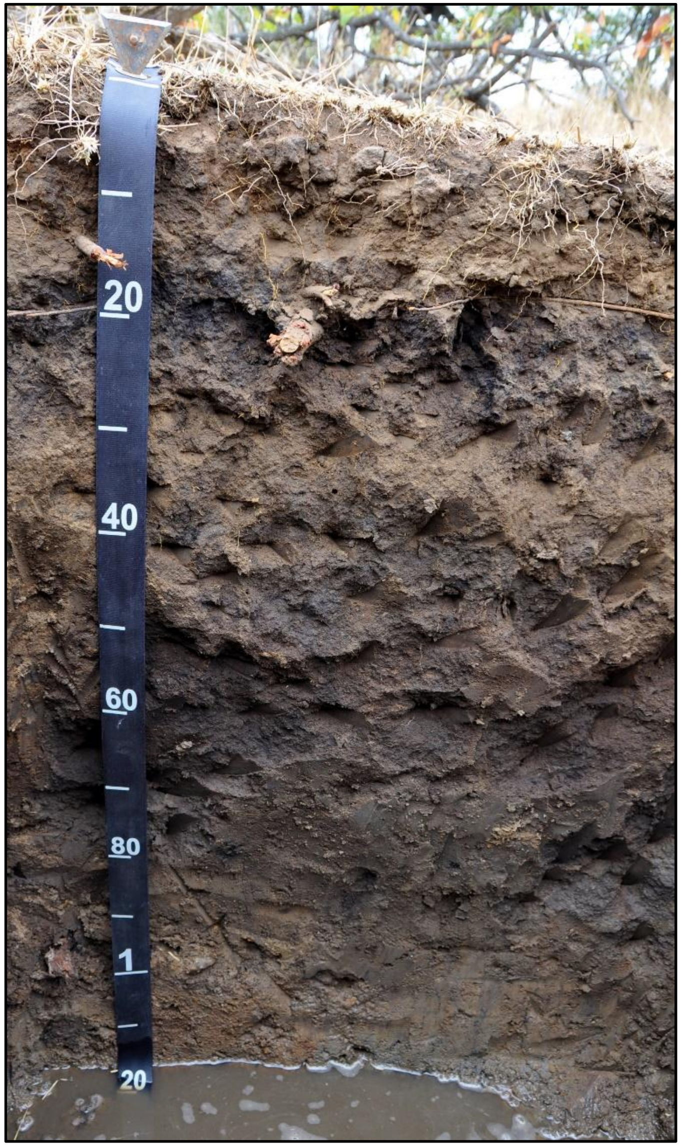


Figure 50 Profile P1S

FAO horizons

0-20 mm A

20-100 mm Bn1

100-180 mm Bn2

180-300 mm 2Bl

300-400 mm 3 Bl

400-800 mm 4 Bl

800 mm 5Cr

WRB Diagnostics:

Fluvic soil material, gleyic colour pattern (180 mm and below), reducing conditions 800 mm and below.

Epigleic Fluvisol (Sodic)

M Fuchs and Erika Micheli

<u>Profile No: P1T</u>

Map/photo: Figure 51

Latitude & Longitude: 23.95325°S; 31.1681°E

Surface stoniness: NA

Altitude: 236m

Terrain unit: 4U Upper Footslope/ 4L Lower Footslope

Slope: 1%

Slope shape: Straight

Aspect: South

Microrelief: None

Parent material solum: Alluvium and unconsolidated mineral sediment

Underlying material: Granite

Soil form: Sterkspruit

Soil family: 2100

Surface rockiness: NA

Occurrence of flooding: Occasional

Wind erosion: None

Water erosion: Slight sheet

Vegetation / Land use: Thicket

Water table: Not encontered

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical

Alteration of underlying material: Calcified

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 160	**Moisture status:** dry; **dry colour:** 2.5YR 7/4; **moist colour:** 2.5YR 5/6; 3% clay, coarse sand, sand; no mottles; apedal, single grain structure; loose, loose, non-sticky, non-plastic consistence; few very fine, fine, medium, and coarse pores; no cracks; no cementation; no free lime; no slickenslides; no cutans; no depositional stratification; water absorption 1 second; many roots; abrupt, smooth transition.	Orthic A horizon
B1	160 – 300	**Moisture status:** dry; **dry colour:** 10YR 4/2; **moist colour:** 10YR 4/1; 30% clay, coarse sand, sandly clay loam; few, fine, faint, red oxidised iron oxide mottles; strong, coarse, prismatic structure; very hard, very firm, sticky, slightly plastic consistence; few very fine, fine, medium, and coarse pores; fine cracks; no cementation; slight free lime; no slickenslides; common clay cutans; no depositional stratification; water absorption 2 seconds; common roots; gradual, smooth transition.	Prismacutanic B horizon
B2	300 – 550	**Moisture status:** moist; **dry colour:** 10YR 6/2; **moist colour:** 10YR 3/1; 35% clay, coarse sand, sandy clay loam; common, medium, white lime mottles; few, fine, faint, grey, yellow and olive oxidised iron oxide; strong, coarse, angular blocky structure; very hard, friable, slighty sticky, slightly plastic consistence; few very fine, fine, medium, and coarse pores; no cracks; no cementation; moderate free lime; no slickenslides; few clay cutans; no depositional stratification; water absorption 2 seconds; few roots; gradual, smooth transition.	
B3	550 – 800	**Moisture status:** moist; **dry colour:** 10YR 6/3; **moist colour:** 10YR 5/4; 30% clay, coarse sand, sandy clay loam; few, medium, distinct, white lime mottles; common, medium, prominent, red and yellow oxidised iron oxide; strong, coarse, angular blocky structure; very hard, friable, slightly sticky, slightly plastic consistence; many very fine and fine pores; few medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; few clay cutans; no depositional stratification; water absorption 2 seconds; few roots; gradual, smooth transition.	
B4	800 – 1180	**Moisture status:** moist; **moist colour:** 10YR 6/3; 30% clay, coarse sand, sandy clay loam; common, medium, distinct, red and yellow, oxidised iron oxide; common, medium, distinct, black and brown, illuvial iron and humus mottles; strong, coarse, angular blocky structure; friable, slightly sticky, slightly plastic consistence; many very fine and fine pores; few medium and coarse pores; no cracks; no cementation; slight free lime; no cutans; no depositional stratification; water absorption 2 seconds; few roots; gradual, smooth transition.	
B5	1180 – 1300	**Moisture status:** moist; **moist colour:** 10YR 6/2; 30% clay, coarse sand, sandy clay loam; few, medium, faint, red, oxidised iron oxide; strong, coarse, angular blocky structure; friable, slightly sticky, slightly plastic consistence; many very fine and fine pores; few medium and coarse pores; no cracks; no cementation; slight free lime; no slickenslides; no cutans; no depositional stratification; water absorption 2 seconds; few roots; transition not reached.	

Figure 51 Profile P1T

FAO horizons

0-150 mm A

150-300 mm 2Btn

300-550 mm 2Bkn

550-800 mm 2Bkl

800-1100 mm 3Cl

1100 mm 4Cr

WRB Diagnostics:

Natric horizon (150-300 mm), calcic horizon (300-800 mm), secondary carbonate (300-800 mm), gleyic colour pattern 550 mm and below, reducing conditions 1100 mm and below, fluvic soil material.

Calcic Endogleyic Solonetz (Novic, Endofluvic)

M Fuchs and E Micheli

Profile No: P1U

Map/photo: Figure 52

Latitude & Longitude: 23.95309°S; 31.16813°E

Surface stoniness: NA

Altitude: 236m

Terrain unit: 4U Upper Footslope

Slope: 1-2%

Slope shape: Straight

Aspect: South

Microrelief: Terracettes

Parent material solum: Alluvium and unconsolidated mineral sediment

Underlying material: Granite

Soil form: Brandvlei

Soil family: 2000

Surface rockiness: NA

Occurrence of flooding: None

Wind erosion: None

Water erosion: Slight sheet

Vegetation / Land use: Thicket (Mopani)

Water table: Not encontered

Described by: T Johnson & CW Van Huyssteen

Date described: August 2012

Weathering of underlying material: Advanced physical and strong chemical

Alteration of underlying material: Calcified

Horizon	Depth(mm)	Description	Diagnostic horizons
A	0 – 180	**Moisture status:** dry; **dry colour:** 2.5Y 4/2; **moist colour:** 2.5Y 3/1; 25% clay, coarse sand, sandy clay loam; many, fine, prominent, white lime mottles; few, fine, faint, red, oxidised iron oxide mottles; strong, medium, prismatic structure; strong, coarse angular blocky secondary structure; very hard, firm, non-sticky, non-plastic consistence; common very fine and fine pores; few medium and coarse pores; fine cracks; no cementation; slight free lime; no slickenslides; few clay cutans; no coarse fragments; no depositional stratification; water absorption 2 seconds; few roots; clear, smooth transition.	Orthic A horizon
B1	180 – 450	**Moisture status:** dry; **dry colour:** 2.5Y 4/1; **moist colour:** 2.5Y 4/3; 35% clay, coarse sand, sandy clay; many, medium, prominent, grey, yellow and olive lime mottles; common, medium, faint red oxidised iron oxide mottles; moderate, coarse, subangular blocky structure; hard, slightly firm, slightly sticky, non-plastic consistence; common very fine and fine pores; no cracks; no cementation; moderate free lime; no slickenslides; no cutans; no coarse fragments; no depositional stratification; water absorption 1 second; few roots; clear, smooth transition.	Soft carbonate
B2	450 – 850	**Moisture status:** dry; **dry colour:** 2.5Y 4/3; **moist colour:** 2.5Y 4/3; 35% clay, coarse sand, sandy clay; many, coarse, prominent, grey, yellow and olive lime mottles; common, medium, distinct, red oxidised iron oxide mottles; moderate, coarse, subangular blocky structure; slightly hard, friable, sticky, non-plastic consistence; few very fine and fine pores; no cracks; moderate, easily broken with a hammer, discontinuous carbonate cementation; strong free lime; no slickenslides; few clay cutans; no coarse fragments; few medium lime concretions/nodules; no depositional stratification; water absorption 1 second; few roots; clear, smooth transition.	
B3	850 – 1300	**Moisture status:** moist; **dry colour:** 2.5Y 5/3; **moist colour:** 2.5Y 4/4; 18% clay, coarse sand, sandy loam; many, coarse, prominent grey, yellow and olive lime mottles; many, coarse, prominent, red oxidised iron oxide mottles; strong, coarse, angular blocky structure; hard, friable, slightly sticky, non-plastic; few very fine and fine pores; no cracks; strong, breaks with hammer, rings, discontinuous, carbonate cementation; strong free lime; no slickenslides; few clay cutans; no coarse fragments; common, coarse lime concretions/nodules; no depositional stratification; water absorption 1 second; few roots; transition not reached.	

Figure 52 Profile P1U

FAO horizons

0-20 mm Ak

20-180 mm 2Ank

180-450 mm 3ABkl

450-900 mm 4BCkl

900 mm 5Ckl

WRB Diagnostics:

Fluvic soil material, calcic horizon (450-900 mm), secondary carbonate, gleyic colour patterns 450 mm and below.

Calcic Endogleyic Fluvisol (Sodic, Eutric)

M Fuchs and E Micheli

Appendix C

- Water table data (measured monthly from September 2012- September 2013)
- pH data
- Eh data
- Calculated rH values

Table 36 Water table data for Malahlapanga measured monthly from September 2012- September 2013

		05-Sep-12	26-Sep-12	27-Sep-12	26-Oct-12	19-Nov-12	13-Dec-12	14-Jan-13	12-Mar-13	10-Apr-13	08-May-13	06-Jun-13	01-Jul-13	29-Jul-13	28-Aug-13
M1	P	8	14		15	20	9	FLOODS	20	14	7	5	4	8	4
	S	133	126		104	117	110	FLOODS	107	106	111	121	120	119	115
	T	NR	NR		D	D	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR
	U	NR	NR		NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR
M2	P	5,5	6		2	0	0	FLOODS	L	L	L	36	30	32	33
	S	67	60		60	64	60	FLOODS	53	91	L	L	L	L	L
	T	NR	NR		NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR
	U	NI		I-NR	NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR
M3	P	7,5	12		10	25	19	FLOODS	24	24	13	15	12	14	10
	S	Nrec	NR		NR	D	NR	FLOODS	NR	D	NR	NR	NR	NR	NR
	T	NR	NR		NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR
	U	Nrec	NR		NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR

Table 37 Water table data for Nshawu measured monthly from September 2012- September 2013

		19-Sep-12	20-Sep-12	23-Oct-12	20-Nov-12	11-Dec-12	15-Jan-13	25-Jan-13	12-Feb-13	11-Mar-13	09-Apr-13	07-May-13	05-Jun-13	02-Jul-13	30-Jul-13	27-Aug-13
N1	P	19		20	20	28	FLOODS	12 ABL	12	8	14	12	4	0	0	0
	S	83		100	104	87	FLOODS	1 AGL	26	30	34	46	48	54	52	51
	T	I		NR	D	NR	NR	64	97	108	D	NR	NR	NR	NR	NR
	U	I		NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR	NR	NR
N2	P	61		66	75	70	FLOODS	0	8	9	8	10	16	11	7	16
	S	116		125	126	126	FLOODS	14	47	54	54	64	70	70	71	74
	T	I		NR	NR	D	FLOODS	47	89	97	87	113	117	116	119	116
	U		I	NR	NR	NR	FLOODS	NR	NR	NR	NR	NR	NR	NR	NR	NR
N3	P	75		74	85	83	FLOODS	24	31	37	35	38	38	42	35	37
	S	110		112	118	118	FLOODS	3	38	47	46	55	60	63	61	64
	T	I		NR	NR	D	FLOODS	47	83	92	95	107	111	114	117	115
	U		I	NR	NR	D	FLOODS	NR	NR	NR	NR	NR	NR	NR	NR	NR

Table 38 Water table data for the Tshutshi spruit measured monthly from September 2012- September 2013

		06-Sep-12	07-Sep-12	21-Sep-12	25-Oct-12	21-Nov-12	12-Dec-12	16-Jan-13	13-Feb-13	13-Mar-13	08-Apr-13	06-May-13	04-Jun-13	30-Jun-13	31-Jul-13
P1	P	80,5		81	73	87	67	10 AGL	66	78	D-82	79	D	NR	NR
	S	136,5		112	100	116	98	14	90	107	113	106	123	D	120
	T	NR		D-148	148	D	D	120	139	NR	D	NR	D	122	NR
	U	NR		NR	NR	NR	D	150	NR	NR	D	NR	NR	NR	NR
P2	P		I	88	89	102	79	30	77	85	96	90	D	97	101
	S	NI		I-104	102	D	95	29	87	100	D	95	D	NR	D
	T	NI		I-91	100	D	D	28	90	103	106	103	D	NR	D
	U	NI		I-NR	NR	NR	D	NR	NR	NR	NR	NR	NR	NR	NR
P3	P	90		90	93	106	83	37	83	98	106	94	112	93	106
	S	90		95	89	99	80	21	76	88	107	89	106	101	103
	T	NR		NR	NR	NR	D	17	122	NR	D	NR	NR	NR	NR
	U	NR		NR	NR	NR	D	NR	NR	NR	NR	NR	NR	NR	NR

NR= Not reached
NI= Not installed
Nrec= Not recorded
I= Installed
NI= Not installed
L= Lost
AGL= Above ground level

Table 39   pH and Eh data for Malahlapanga measured monthly from September 2012- September 2013

		26-Sep-12		26-Oct-12		19-Nov-12		13-Dec-12			12-Mar-13		10-Apr-13		08-May-13		06-Jun-13		01-Jul-13		29-Jul-13		28-Aug-13	
		pH	Eh	pH	Eh	pH	Eh	pH	Eh	FLOODS	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh
M1	P	7,1	93	6,73	47	6,71	41	6,67	24		7,58	149	6,97	-112	7,73	9	6,83	120	8,02	162	8,02	9	7,04	71
M1	S	6,88	98	7	-58	6,64	-36	6,57	-62		6,47	183	6,68	36	6,53	?111	6,12	7	6,36	162	6,51	-5	6,2	80
M1	T																							
M1	U																							
M2	P	6,61	-222	7,88	-222	7,64	-221	7,13	-153				6,44	-217	7,13	101	6,37	131	6,7	-185	6,42	134	7,22	90
M2	S	6,59	24	6,86	78	6,57	24	6,28	4						missing	missing	missing	missing	missing	missing	missing	missing	missing	missing
M2	T																							
M2	U																							
M3	P	7	73	5,98	109	6,93	11	6,95	31		7,3	103	7,36	108	7,16	6	6,33	181	6,81	85	6,73	110	7,38	116
M3	S																							
M3	T																							
M3	U																							
Cal			*no Cal		230		230		229			220		221		216		208		208		214		219

Table 40   pH and Eh data for Nshawu measured monthly from September 2012- September 2013

		19-Sep-12		23-Oct-12		20-Nov-12		11-Dec-12		15-Jan-13		25-Jan-13		12-Feb-13		11-Mar-13		09-Apr-13		07-May-13		05-Jun-13		02-Jul-13		30-Jul-13		27-Aug-13	
		pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh
N1	P	7,17	-163	7,33	130	7,31	-88	7,14	25		FLOODS	7,91	74	7,18	-149	6,96	-118	7,17	-192	7,25	-145	7,31	-122	7,2	-134	7,21	-79	7,44	-80
N1	S	7,53	187	7,51	145	7,41	-174	7,19	-89		FLOODS	8,14	-145	7,49	-147	7,51	-73	7,67	-181	7,56	-58	7,61	-86	7,65	153	7,81	170	7,87	-16
N1	T										FLOODS	7,26	98	7,1	-126														
N1	U										FLOODS																		
N2	P	7,65	50	7,49	104	7,39	126	7,25	91		FLOODS	7,62	0	7,59	0	7,42	93	7,44	36	7,58	149	7,49	139	7,42	90	7,37	122	7,46	101
N2	S	7,62	72	7,41	-116	7,38	-10	7,2	-25		FLOODS	7,46	88	7,34	-140	7,3	-128	7,3	93	7,42	133	7,26	164	7,35	83	7,2	114	7,46	76
N2	T										FLOODS	7,78	117	7,65	-112	7,62	-96	5,5	-18	7,79	121	7,7	144	7,74	-28	7,67	70	7,73	55
N2	U										FLOODS																		
N3	P	7,46	53	7,26	-127	7,19	-108	7,2	-91		FLOODS	7,38	33	7,35	-122	7,3	-71	7,23	40	7,44	135	7,39	169	7,28	132	7,11	101	7,31	-91
N3	S	7,47	-152	7,53	-121	7,4	-105	7,39	61		FLOODS	8,2	111	7,93	106	7,52	121	7,51	71	7,62	121	7,51	149	7,52	123	7,34	-229	7,49	-190
N3	T										FLOODS	7,8	131	7,82	82	7,64	123	7,54	104	7,76	127	7,7	166	7,65	134	7,66	39	7,66	65
N3	U										FLOODS																		
Cal			*no Cal.		230		225		227		235		229		226		220		192		216		212		220		205		237

Table 41   pH and Eh data for the Tshutshi spruit measured monthly from September 2012- September 2013

		21-Sep-12		25-Oct-12		21-Nov-12		12-Dec-12		16-Jan-13		13-Feb-13		13-Mar-13		08-Apr-13		06-May-13		04-Jun-13		30-Jun-13		31-Jul-13		26-Aug-13	
		pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh	pH	Eh
P1	P	7,36	110	7,41	-94	7,19	-110	7,19	-96	7,76	153	7,47	-124	7,4	-103												
P1	S	7,77	47	7,81	45	7,52	-150	7,37	-85	8,13	155	7,83	-155	7,53	-99	7,45	-211	7,87	-12	7,63	-105	7,18	-134	7,76	-54	7,34	-86
P1	T									8,02	205	8,04	96														
P1	U																										
P2	P	7,21	105	5,85	-9	6,98	-138	6,95	-33	7,84	137	7,13	-94	7,28	-112	7,22	0	7,2	20			7,05	-122	7,38	-193	6,98	-146
P2	S	8,24	93	7,53	-133			7,44	54	8,13	134	7,78	-53	7,45	-131			7,6	-22								
P2	T	8,02	91	8,3	69					7,87	23	7,78	37	7,74	-163	7,64	-259	7,82	-137								
P2	U																										
P3	P	7,41	57	6,13	79	7,27	101	7,27	158	7,8	52	7,29	55	7,19	169	7,03	264	7,12	182	7,07	74	7,49	-22	7,45	129	7,3	107
P3	S	7,37	72	7,42	102	7,25	60	7,06	184	7,4	-77	7,32	-21	7,25	147	7,16	212	7,26	186	7,24	17	7,27	-64	7,42	8	7,48	1
P3	T									8,22	-120	7,91	-207														
P3	U																										
Cal			*no Cal.		232		204		237		231		232		231		240		219		210		211		203		227

Appendix D

- XRD analysis of paint
- IRIS tube data

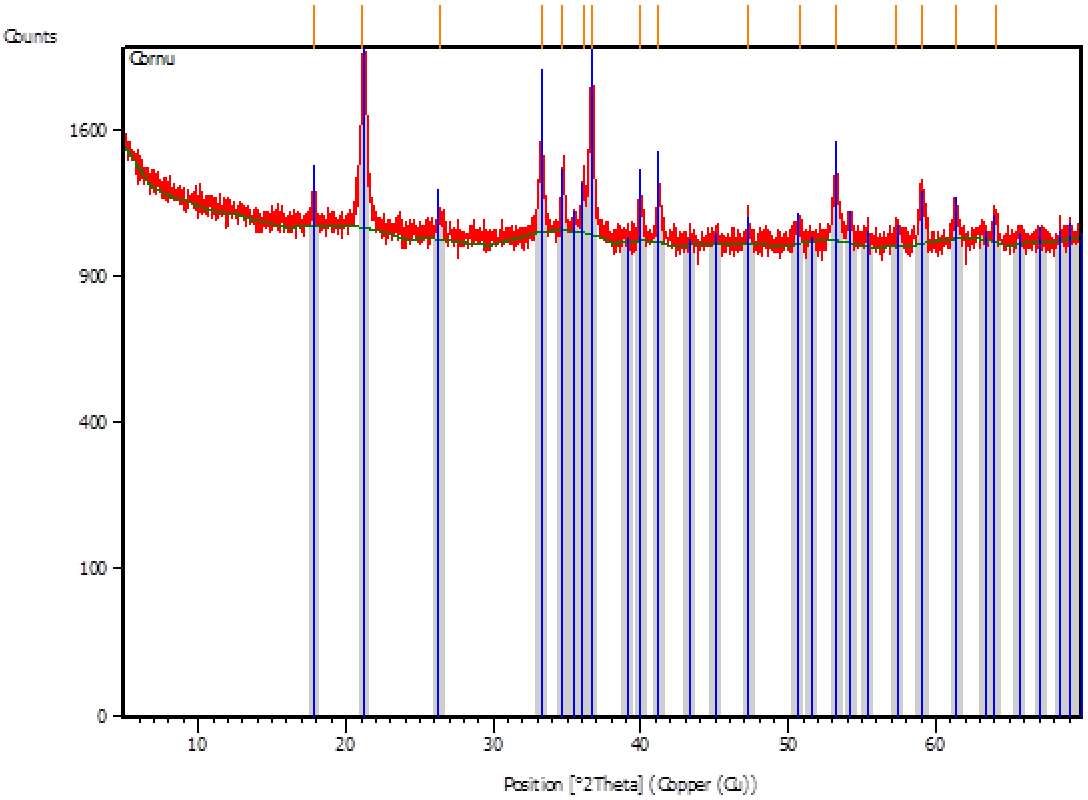


Figure 53 XRD analysis of IRIS paint

Table 42 Identified patterns list for XRD analysis

Ref. Code	Score	Mineral Name	Chemical Formula
00-029-0713	68	Goethite	Fe +3 O (O H)

Table 43 Peak list for XRD analysis

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]	Tip Width	Matched by
17.8230	195.43	0.1338	4.97673	21.22	0.1606	00-029-0713
21.1548	920.84	0.3346	4.19984	100.00	0.4015	00-029-0713
26.3719	121.68	0.4015	3.37965	13.21	0.4818	00-029-0713
33.2155	420.42	0.1673	2.69730	45.66	0.2007	00-029-0713
34.7216	316.97	0.1673	2.58367	34.42	0.2007	00-029-0713
36.1024	302.80	0.1004	2.48796	32.88	0.1204	00-029-0713
36.6592	783.56	0.2342	2.45145	85.09	0.2810	00-029-0713
39.9959	178.43	0.2676	2.25429	19.38	0.3212	00-029-0713
41.2192	261.66	0.2676	2.19017	28.42	0.3212	00-029-0713
47.3116	72.63	0.4015	1.92138	7.89	0.4818	00-029-0713
50.7071	77.50	0.4015	1.80040	8.42	0.4818	00-029-0713
53.2176	308.22	0.3346	1.72124	33.47	0.4015	00-029-0713
57.3512	72.55	0.8029	1.60662	7.88	0.9635	00-029-0713
59.0461	261.03	0.3346	1.56449	28.35	0.4015	00-029-0713
61.3575	156.53	0.2676	1.51098	17.00	0.3212	00-029-0713
64.0288	126.62	0.2007	1.45423	13.75	0.2409	00-029-0713

Table 44 Paint removal for IRIS tubes at Malahlapanga

	Area % paint removal from top 30cm of IRIS tube												
Month	**Sep-12**	**Oct-12**	**Nov-12**	**Dec-12**	**Jan-13**	**Feb-13**	**Mar-13**	**Apr-13**	**May-13**	**Jun-13**	**Jul-13**	**Jul-13**	**Aug-13**
Tube code	**Batch 1**	**Batch 2**	**Batch 3**	**Batch 4**	**Batch 5**	**Batch 6**	**Batch 7**	**Batch 8**	**Batch 9**	**Batch 10**	**Batch 11**	**Batch 12**	**Batch 13**
M1Pa	66,67	0,00	56,67	48,67	Floods	Floods	0,00	53,33	74,48	93,33	53,33	6,67	83,33
M1Pb	73,33	59,95	48,33	50,00			0,00	20,00	38,33	60,00	56,67	60,00	43,33
M1Pc	63,33	53,33	58,33	48,33			46,67	20,00	25,00	33,33	45,00	35,00	93,33
M1Pd	66,67	61,67	50,00	93,33			20,00	13,33	33,33	20,00	48,33	36,67	51,67
M1Pe	60,00	68,33	45,30	86,67			50,00	31,67	13,33	16,67	53,33	40,00	66,67
Average	66,00	48,66	51,73	65,40			23,33	27,67	36,90	44,67	51,33	35,67	67,67
M2Pa	17,16	86,67	83,33	70,00			Lost	Lost	0,00	0,00	0,00	0,00	0,00
M2Pb	86,67	100,00	73,33	86,67					0,00	0,00	0,00	0,00	0,00
M2Pc	52,13	100,00	46,67	68,33					0,00	0,00	0,00	0,67	0,00
M2Pd	50,28	0,00	73,33	71,67					0,00	3,33	0,00	0,00	0,00
M2Pe	100,00	0,00	91,67	50,00					0,00	13,33	0,00	0,00	0,00
Average	61,25	57,33	73,67	69,33					0,00	3,33	0,00	0,13	0,00
M3Pa	76,11	26,67	57,16	63,87			66,67	50,00	60,00	100,00	86,67	93,33	40,00
M3Pb	53,11	64,68	88,33	93,33			71,17		40,00	86,67	46,67	66,67	53,33
M3Pc	65,00	61,67	61,06	61,27			63,16	13,33	13,33	75,00	26,67	96,67	46,67
M3Pd	66,67	58,33	25,92	28,33			70,00	76,67	35,00	66,67	45,00	66,67	28,33
M3Pe	73,82	63,33	45,00	30,00			81,49	53,33	60,00	83,33	60,00	96,67	33,33
Average	66,94	54,94	55,49	55,36			70,50	48,33	41,67	82,33	53,00	84,00	40,33
M1Sa	2,03	0,00	0,00	0,00			0,00	0,00	0,00	0,00	17,03	0,00	0,00
M1Sb	3,48	0,00	0,00	0,00			0,00	0,00	0,00	0,00	17,66	0,00	0,00
M1Sc	5,55	0,00	0,00	0,00			0,00	0,00	0,00	0,00	18,60	0,00	0,00
M1Sd	1,18	0,00	0,00	0,00			0,00	0,00	0,00	0,00	22,84	0,00	0,00
M1Se	7,19	0,00	0,00	0,00			0,00	0,00	0,00	0,00	19,60	0,00	0,00
Average	3,88	0,00	0,00	0,00			0,00	0,00	0,00	0,00	19,15	0,00	0,00
M2Sa	0,37	0,00	3,68	0,00			30,21	0,00	28,45	0,00	0,00	0,00	0,00
M2Sb	0,83	0,00	0,00	0,00			16,50	0,00	15,61	0,00	0,00	0,00	0,00
M2Sc	0,64	5,44	0,00	19,91			25,46	0,00	28,36	0,00	0,00	0,00	0,00
M2Sd	1,35	0,00	0,00	35,63			37,39	0,00	9,99	0,00	0,00	0,00	0,00
M2Se	24,34	3,83	14,39	26,01			28,23	0,00	13,57	0,00	0,00	0,00	0,00
Average	5,51	1,85	3,61	16,31			27,56	0,00	19,20	0,00	0,00	0,00	0,00
M3Sa	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Sb	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Sc	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Sd	0,00	0,00	0,00	19,46			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Se	0,00	0,00	0,00	11,10			0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	6,11			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Ta	13,15	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Tb	10,99	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Tc	9,14	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Td	0,65	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Te	9,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	8,59	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M2Ta	17,67	0,00	0,00	0,00			21,26	7,92	0,00	0,00	0,00	0,00	0,00
M2Tb	11,71	0,00	0,00	0,00			33,16	6,57	0,00	0,00	0,00	0,00	0,00
M2Tc	6,50	0,00	0,00	0,00			15,87	8,69	0,00	0,00	0,00	0,00	0,00
M2Td	10,85	0,00	0,00	0,00			1,71	3,53	0,00	0,00	0,00	0,00	0,00
M2Te	5,29	0,00	0,00	0,00			8,44	10,96	0,00	0,00	0,00	0,00	0,00
Average	10,40	0,00	0,00	0,00			16,09	7,54	0,00	0,00	0,00	0,00	0,00
M3Ta	6,70	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Tb	7,21	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Tc	7,41	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Td	1,58	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Te	5,51	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	5,68	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Ua	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Ub	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Uc	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Ud	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M1Ue	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M2Ua	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M2Ub	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M2Uc	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M2Ud	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M2Ue	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Ua	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Ub	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Uc	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Ud	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,00	0,00
M3Ue	0,00	0,00	0,00	0,00			0,00	0,00	11,93	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00			0,00	0,00	2,39	0,00	0,00	0,00	0,00

Table 45 Paint removal for IRIS tubes at Nshawu

	Area % paint removal from top 30cm of IRIS tube												
Month	**Sep-12**	**Oct-12**	**Nov-12**	**Dec-12**	**Jan-13**	**Feb-13**	**Mar-13**	**Apr-13**	**May-13**	**Jun-13**	**Jul-13**	**Jul-13**	**Aug-13**
Tube code	**Batch 1**	**Batch 2**	**Batch 3**	**Batch 4**	**Batch 5**	**Batch 6**	**Batch 7**	**Batch 8**	**Batch 9**	**Batch 10**	**Batch 11**	**Batch 12**	**Batch 13**
N1Pa	55,95	43,10	13,70	23,86	10,49	15,11	8,47	4,43	8,03	5,86	5,61	27,75	6,39
N1Pb	38,07	61,06	4,55	25,45	4,55	16,19	3,73	9,09	9,64	10,19	43,93	29,67	9,89
N1Pc	19,63	68,71	14,93	37,07	3,59	18,26	17,21	0,00	50,19	8,23	23,36	37,90	19,25
N1Pd	18,40	78,11	17,15	0,00	8,84	12,50	22,47	0,00	48,82	6,92	6,00	18,11	16,65
N1Pe	10,58	0,00	17,84	0,00	3,77	22,67	22,87	20,56	25,08	17,61	7,42	7,42	37,12
Average	28,53	50,20	13,63	17,28	6,25	16,95	14,95	6,82	28,35	9,76	17,26	24,17	17,86
N2Pa	0,00	0,00	0,00	0,00	19,23	21,58	18,47	37,90	30,80	17,28	32,56	23,66	24,43
N2Pb	0,00	0,00	0,00	37,94	0,00	14,68	36,00	35,50	26,46	20,33	11,32	31,71	38,81
N2Pc	0,00	0,00	0,00	0,00	0,00	16,30	23,21	30,37	16,46	29,02	12,59		42,66
N2Pd	0,00	0,00	0,00	0,00	21,07	31,36	14,12	39,07		18,52	11,50	34,26	34,26
N2Pe	0,00	0,00	0,00	18,95	0,00	35,16	41,55	19,28	21,89	18,44	13,72	19,58	31,69
Average	0,00	0,00	0,00	11,38	8,06	23,82	26,67	32,42	23,90	20,72	16,34	27,30	34,37
N3Pa	0,00	0,00	0,00	0,00	19,09	24,35	44,45	41,37	41,07		17,18	17,98	30,77
N3Pb	0,00	29,73	0,00	0,00	20,78	24,29	6,58	0,00	0,00	18,93	21,44	29,67	30,55
N3Pc	0,00	0,00	0,00	0,00	16,11	21,68	3,78	33,10	31,52	17,39	12,04	20,23	21,04
N3Pd	0,00	0,00	0,00	0,00	63,53	15,62	25,45	28,98	24,14	16,57	32,39	19,21	16,54
N3Pe	0,00	32,25	0,00	0,00	22,94	30,97	25,57	31,39		23,31	21,52	33,77	18,34
Average	0,00	12,40	0,00	0,00	28,49	23,38	21,17	26,97	24,18	19,05	20,91	24,17	23,45
N1Sa	5,76	0,00	0,00	0,00	1,62	13,95	32,25	29,16	32,02	26,76	30,99	22,11	29,30
N1Sb	13,26	0,00	0,00	0,00	2,55	52,30	43,86	16,63	34,11	28,05	13,74	23,01	15,98
N1Sc	6,81	0,00	0,00	0,00	6,33	3,15	49,02	18,69	19,22	29,75	22,88	22,86	28,82
N1Sd	6,36	0,00	0,00	0,00	9,43	11,71	35,90	31,14	27,68	18,80	13,51	34,71	0,00
N1Se	4,39	0,00	0,00	0,00	43,19	24,87	43,44	25,88	28,32	7,60	39,68	25,77	20,20
Average	7,32	0,00	0,00	0,00	12,62	21,20	40,89	24,30	28,27	22,19	24,16	25,69	18,86
N2Sa	0,00	0,00	0,00	0,00	23,87	20,61	49,65	32,67	0,00	22,31	12,17	25,02	18,85
N2Sb	0,00	0,00	0,00	0,00	5,26	31,53	30,82	67,94	28,57	23,81	7,22	29,07	0,00
N2Sc	0,00	0,00	0,00	0,00	17,58	26,57	42,67	13,57	0,00	16,64	6,58	14,41	0,00
N2Sd	0,00	0,00	0,00	0,00	0,00	14,07	58,22	29,07	0,00	16,89	2,45	0,00	0,00
N2Se	0,00	0,00	0,00	0,00	21,85	8,14	49,65	15,88	0,00	21,14	9,83	0,00	0,00
Average	0,00	0,00	0,00	0,00	13,71	20,19	46,20	31,83	5,71	20,16	7,65	13,70	3,77
N3Sa	0,00	0,00	11,96	0,00	15,48	14,68	25,96	7,26	0,00	0,00	17,30	39,15	25,73
N3Sb	0,00	0,00	4,42	0,00	18,48	20,91	16,43	10,40	0,00	0,00	9,89	29,47	0,00
N3Sc	0,00	0,00	0,00	0,00	3,07	5,76	20,09	27,17	34,38	0,00	10,36	37,83	0,00
N3Sd	0,00	0,00	5,25	0,00	7,44	11,90	39,41	27,54	18,40	0,00	22,92	41,92	0,00
N3Se	0,00	0,00	0,00	0,00	17,20	32,31	19,98	33,68	0,00	0,00	8,79	34,77	10,79
Average	0,00	0,00	4,33	0,00	12,33	17,11	24,38	21,21	10,56	0,00	13,85	36,63	7,30
N1Ta	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Tb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Tc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Td	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Ta	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Tb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Tc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	25,45	0,00	0,00	0,00	0,00	0,00
N2Td	0,00	0,00	0,00	0,00	0,00	0,00	22,97	0,00	0,00	0,00	0,00	0,00	0,00
N2Te	0,00	0,00	0,00	0,00	0,00	0,00	41,46	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	12,89	5,09	0,00	0,00	0,00	0,00	0,00
N3Ta	0,00	0,00	0,00	0,00	0,00	2,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Tb	0,00	0,00	0,00	0,00	0,00	62,87	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Tc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Td	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Te	0,00	0,00	0,00	0,00	0,00	7,89	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	14,68	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Ua	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Ub	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Uc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Ud	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N1Ue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Ua	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Ub	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Uc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Ud	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N2Ue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Ua	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Ub	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Uc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Ud	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
N3Ue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 46 Paint removal for IRIS tubes at Tshutshi spruit

	Area % paint removal from top 30cm of IRIS tube												
Month	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Jul-13	Aug-13
Tube code	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8	Batch 9	Batch 10	Batch 11	Batch 12	Batch 13
P1Pa	4,78	0,00	0,00	0,00	0,00	11,70	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Pb	1,95	0,00	0,00	0,00	0,00	9,15	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Pc	2,38	0,00	0,00	0,00	0,00	11,96	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Pd	12,53	0,00	0,00	0,00	0,00	19,30	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Pe	2,66	0,00	0,00	0,00	0,00	12,31	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	4,86	0,00	0,00	0,00	0,00	12,88	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Pa	3,16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	35,22	0,00
P2Pb	2,10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	33,86	0,00
P2Pc	1,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	35,80	0,00
P2Pd	1,97	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	28,07	0,00
P2Pe	5,56	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	21,18	0,00
Average	2,88	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	30,82	0,00
P3Pa	8,75	0,00	0,00	0,00	10,11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Pb	0,00	0,00	0,00	0,00	15,85	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Pc	0,00	0,00	0,00	0,00	11,14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Pd	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Pe	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	1,75	0,00	0,00	0,00	7,42	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Sa	0,00	74,04	72,80	0,00	0,00	9,54	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Sb	0,00	2,78	0,00	0,00	0,00	11,97	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Sc	0,00	11,11	0,00	0,00	0,00	10,34	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Sd	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Se	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	17,59	14,56	0,00	0,00	6,37	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Sa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Sb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Sc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Sd	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Se	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Sa	0,00	0,00	0,00	0,00	0,00	5,18	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Sb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Sc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Sd	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Se	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	1,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Ta	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Tb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Tc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Td	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Ta	0,00	0,00	0,00	0,00	0,00	6,57	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Tb	0,00	9,22	0,00	0,00	0,00	4,84	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Tc	0,00	0,00	0,00	0,00	0,00	6,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Td	0,00	0,00	0,00	0,00	0,00	33,97	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Te	0,00	0,00	0,00	0,00	0,00	4,95	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	1,84	0,00	0,00	0,00	11,28	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Ta	8,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Tb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Tc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Td	11,81	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	4,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Ua	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	47,44	0,00	0,00	0,00	0,00
P1Ub	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Uc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Ud	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P1Ue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	30,69	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	15,62	0,00	0,00	0,00	0,00
P2Ua	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Ub	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Uc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Ud	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P2Ue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Ua	0,00	0,00	0,00	0,00	13,21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Ub	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Uc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Ud	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
P3Ue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average	0,00	0,00	0,00	0,00	2,64	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00