# WETLAND ASSESSMENT REPORT:

## ZAALKLAPSPRUIT WETLAND (B20G-01)

**Date: February 2013**

**Report No: EP60-03**

**Province:** Mpumulanga
**Project:** Zaalklapspruit Wetland
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**Wetland Name:** Zaalklapspruit
**Wetland No:** B20G-01
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# 1. INTRODUCTION

Rehabilitation refers to re-instating the driving ecological forces that underlie a wetland, so as to improve the wetland's health and the ecological services that it delivers. Effective rehabilitation planning therefore requires an assessment of how the following three processes have been threatened/impacted upon:

- Hydrological;
- Geomorphological; and
- Ecological.

Furthermore, it requires an assessment of the predicted contribution that wetland rehabilitation will make to improving wetland health and ecosystem delivery through addressing the identified impacts/threats. Without these assessments, a wetland rehabilitation programme is unlikely to have a well-informed basis on which to improve the rehabilitation's "return on investment" (with return being measured in terms of wetland health and ecosystem services delivery).



# 2. PROJECT DESCRIPTION

## 2.1. General Approach for Specific Category of Project

This wetland assessment forms part of phase 2 of Zaalklapspruit wetland rehabilitation project, which is classified as a Category 2 wetland rehabilitation project. This involves planning of rehabilitation within prioritized wetlands of a catchment where priority wetland have been identified for rehabilitation action.

## 2.2. Project Description, Location, Category and Catchment Information

This wetland system is located in quaternary catchment B20G in the Upper Olifant's catchment, Mpumalanga and has been identified as a suitable site for rehabilitation in consultation with Coaltech and the CSIR. The Zaalklapspruit wetland (B20G-01) forms part of a larger wetland system along the Grootspruit, a tributary of the Zaalklapspruit (Saalklapspruit) River which then flows into the Wilge River approximately 35km northwest of Witbank Town. The wetland is situated directly below areas subject to coal mining and as such, is likely to be subject to significant water quality impacts.

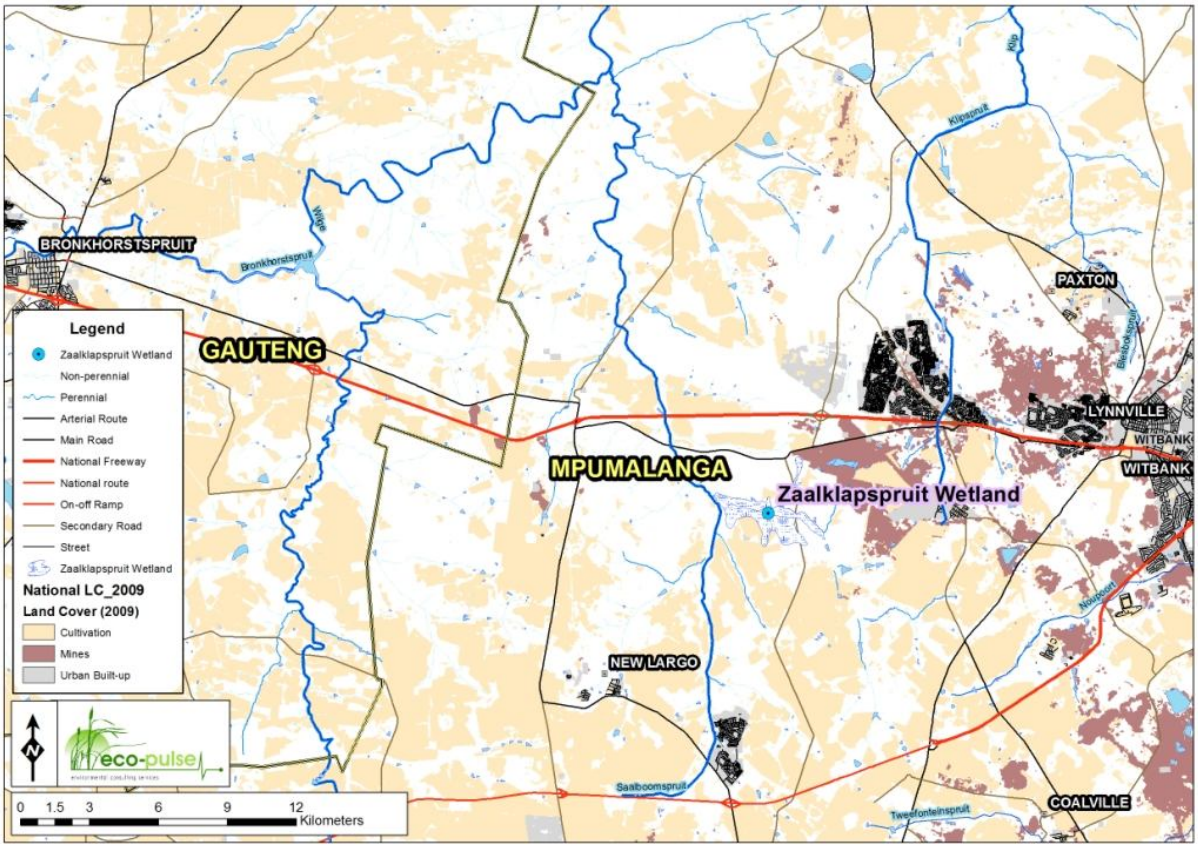


**Figure 1.** Map showing the location of the Zaalklapspruit wetland system (B20G-01) in relation to nearby towns.

# 3. METHODOLOGY

## 3.1. Wetland delineation

The approximate boundary of the wetland was mapped at a desktop level from available Google Earth and 2010 colour imagery. This was then refined during field visits to the area which was informed primarily by visual observations of topography and vegetation characteristics. While soil sampling was undertaken at selected points, no detailed wetland delineation was undertaken due to time and budget constraints.

## 3.2. Assessing the Present Ecological Status of the wetland

WET-Health (Macfarlane *et al*, 2007) provides an appropriate framework for assessing the Present Ecological State (PES) of wetland systems. The assessment also helps to identify specific impacts which can be addressed through rehabilitation activities.

For the purposes of this study, where a good understanding of the Present Ecological State (PES) of the wetland is required, a Level 2 assessment was undertaken. This approach relies on a combination of desktop and on-site indicators to assess various aspects of wetland condition, including:

- ***Hydrology***: defined as the distribution and movement of water through a wetland and its soils.
- ***Geomorphology***: defined as the distribution and retention patterns of sediment within the wetland.
- ***Vegetation***: defined as the vegetation structural and compositional state.

Each of these modules follows a broadly similar approach and is used to evaluate the extent to which anthropogenic changes have impacted upon wetland functioning or condition. While the impacts considered vary considerably across each module, a standardized scoring system is applied to facilitate the interpretation of results (Table 1). Scores range from 0 indicating no impact to a maximum of 10 which would imply that impacts had totally destroyed the functioning of a particular component. The reader is encouraged to refer back to the tables below to help interpret the results of the assessment (Section 4.3).

**Table 1.** Guideline for interpreting the magnitude of impacts on wetland integrity

| IMPACT CATEGORY | DESCRIPTION | SCORE |
|---|---|---|
| None | No discernible modification or the modification is such that it has no impact on this component of wetland integrity. | 0 – 0.9 |
| Small | Although identifiable, the impact of this modification on this component of wetland integrity is small. | 1 – 1.9 |
| Moderate | The impact of this modification on this component of wetland integrity is clearly identifiable, but limited. | 2 – 3.9 |
| Large | The modification has a clearly detrimental impact on this component of wetland integrity. Approximately 50% of wetland integrity has been lost. | 4 – 5.9 |
| Serious | The modification has a highly detrimental effect on this component of wetland integrity. Much of the wetland integrity has been lost but remaining integrity is still clearly identifiable. | 6 – 7.9 |
| Critical | The modification is so great that the ecosystem processes of this component of wetland integrity are almost totally destroyed, and 80% or more of the integrity has been lost. | 8 – 10 |

Impact scores obtained for each of the modules reflect the degree of change from natural reference conditions. These scores are subtracted from 10 to obtain an intactness or health score for the wetland system evaluated. Resultant health scores fall into one of six health categories (A-F) on a gradient from "unmodified/natural" (Category A) to "severe/complete deviation from natural" (Category F) as depicted in Table 6. This classification is consistent with DWAF categories used to evaluate the present ecological state of aquatic systems.

**Table 2.** Health categories used by WET-Health for describing the integrity of wetlands

| HEALTH CATEGORY | DESCRIPTION | RANGE |
|---|---|---|
| A | Unmodified, natural. | 0 – 0.9 |
| B | Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place. | 1 – 1.9 |
| C | Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact | 2 – 3.9 |
| D | Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred. | 4 – 5.9 |
| E | The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable. | 6 – 7.9 |
| F | Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota. | 8 – 10 |

An overall wetland health score was calculated by weighting the scores obtained for each module and combining them to give an overall combined score using the following formula:

**Overall health rating = [(Hydrology*3) + (Geomorphology*2) + (Vegetation*2)] / 7**

This overall score assists in providing an indication of wetland health/condition which can in turn be used for recommending appropriate management measures.

**Note: Supplementary vegetation monitoring**

In order to improve the accuracy of the Wet-Health assessment and to establish baseline information for future monitoring, additional information was collected on plant species occurring within area of targeted rehabilitation. This information was collected using standard 1m x 1m quadrats at various locations around prioritized disturbance units (See Annexure 2 for further details). Species composition in each plot was assessed based on the aerial cover of plants within sampled quadrats. Appropriate references were then consulted to determine the hydric status of each species. Differentiation was also made between indigenous and alien species. This information was then summarised and used to refine the vegetation assessment.

Based on the wetland assessment, specific impacts and/or threats to be addressed by structural rehabilitation were then identified for rehabilitation planning.

## 3.3. Assess the importance and sensitivity of the wetland

The supply of ecosystem goods and services of the wetland was assessed using and approach based on the WET-Ecoservices assessment tool Kotze *et al.* (2007). This approach relies on a combination of desktop and on-site indicators to assess the importance of a range of common wetland ecosystem services. A level 2 (detailed) assessment was conducted that assessed a host of benefits by assigning a score to each benefit based on a rating system that rates a range of pre-defined variables affecting the importance of benefits provided by the wetland system.

The results are captured in tabular form as a list of benefits/goods with the level of supply and demand rated on a scale of 0 - 4. The following rating shown in Table 7 is used to describe the level of importance of supply and demand:

**Table 3.** Rating table used to rate supply and demand scores

| Score | Importance or level of supply/demand |
|---|---|
| <2 | Low |
| 2 – 3 | Moderate |
| >3 | High |

Since the importance of wetland goods and benefits is dictated not only by the supply (benefit availability) of a particular good/benefit but also on the need or demand (user requirement) for such a benefit, the overall importance of the ecosystem service or benefit is ultimately derived from a combination of supply and demand scores. For example, a wetland may supply a particular service relatively freely; however this service may not be in great demand, limiting the importance of the benefit to society. *Wet-Ecoservices datasheets are available on request.*

The outcomes of the Wet-Ecoservices assessment were then used to inform an assessment of the importance and sensitivity of wetland systems using the Wetland EIS assessment tool (Rountree, in prep). The tool includes an assessment of three components:

- Biodiversity support
- Landscape scale importance
- Sensitivity of the wetland to floods and water quality changes

The maximum score for these components was taken as the importance rating for the wetland which is rated using Table 8, below.

**Table 4.** Rating table used to rate EIS (Rountree, in prep).

| Rating | Explanation |
|---|---|
| None, Rating = 0 | Rarely sensitive to changes in water quality/hydrological regime |
| Low, Rating =1 | One or a few elements sensitive to changes in water quality/hydrological regime |
| Moderate, Rating =2 | Some elements sensitive to changes in water quality/hydrological regime |
| High, Rating =3 | Many elements sensitive to changes in water quality/ hydrological regime |
| Very high, Rating =4 | Very many elements sensitive to changes in water quality/ hydrological regime |

## 3.4. Set rehabilitation objectives and design an appropriate rehabilitation strategy

Objectives for wetland rehabilitation were informed by the above assessments (e.g., if the primary threat to the wetland was identified as an erosion headcut threatening to propagate through the wetland then an appropriate rehabilitation objective would be to halt propagation of the erosion headcut). This was used to inform the development of a rehabilitation strategy for the wetland. This includes the identification and prioritization of appropriate interventions to achieve objectives identified.

## 3.5. Assess the likely impact of wetland rehabilitation on wetland health and ecosystem delivery

The following steps were followed to assess the anticipated contribution of rehabilitation on the wetland system and associated functioning:

- Assessment of the anticipated future state of the wetland if the proposed rehabilitation strategy is effectively implemented (using Wet-Health).
- Assess the benefits that are likely to result from achievement of the rehabilitation objective/s in terms of the integrity of the affected area of the wetland (using WET-Health).
    - Impact scores with and without rehabilitation were calculated for the hydrology, geomorphology and vegetation components of health.

- Hectare equivalents were then calculated by comparing Impact scores with and without rehabilitation for the wetland area under investigation (Cowden & Kotze. 2009).

- Assessment of the benefits that are likely to result from achievement of the rehabilitation objective/s in terms of the ecosystem services that the area delivers (using WET-Ecoservices: Kotze *et al.,* 2007). This assessment was applied subjectively to indicate where changes in goods and services are anticipated rather than undertaking a detailed assessment.

## 3.6. Assumptions and Limitations

It is important to note that this assessment was undertaken in a short period of time, with limited field verification. There are therefore a number of limitations to this assessment as outlined below:

- Wetland boundaries are estimated, based primarily on desktop information and limited field verification[1];
- Assessment of impacts and potential rehabilitation outcomes is informed by a structured process, but is based on opinion rather than exact science;
- The assessment of importance and sensitivity is based on available desktop information and limited interactions with local stakeholders.

[1] Note that in this case, the wetland boundary effectively represents the wetland boundary of the HGM unit assessed. A number of seepage zones enter this wetland at various points such that the actual extent of wetlands in the area are significantly larger that the area assessed.

# 4. WETLAND DETAILS FOR ZAALKLAPSPRUIT WETLAND

## 4.1. Wetland Description

The Zaalklapspruit Wetland is a moderate sized (~135 ha) naturally unchannelled valley bottom wetland system located along the Grootspruit River (Figure 1). It occurs in a landscape of quite low topographic relief and is located in a shallow valley bottom location. The local climate is characterized by a low mean annual precipitation of 668.4 mm and a high mean annual potential evapotranspiration of 2104.6 mm. This gives a MAP to PET ratio of 0.3 (vulnerability index of 1.05), which means that the wetland has a relatively high sensitivity to hydrological impacts (changes in water input volumes and patterns).

The control on the formation and dynamics of the system is linked to the base level of the Zaalklapspruit stream into which this wetland system flows. This prevents down-cutting of the valley and encourages alluvial deposition in the valley upstream of this junction. Water inputs into the wetland are primarily from the upstream catchment although the presence of significant areas of seasonal and temporay seepage areas leading into the wetland suggests that lateral sub-surface seepage is also an important input.

As with other wetlands in the region, the lower, more permanently saturated sections of the wetland appear to be naturally characterized by extensive beds of *Phragmites australis* (common reed) and *Typha capensis* (bulrush). Seasonal and temporary zones along the edge of the wetland are naturally much more diverse and characterized by a mix of hygrophilous grasses, sedges and forbs. Typical sedges species include *Bulboschoenus glaucus*, *Bulbostylis hispidula*, *Choenoplectus corymbosus*, *Cyperus congestus*, *Cyperus fastigiatus* and species of *Juncus* and *Schoenoplectus*. Typical grass species include *Imperata cylindricl*, *Agrostis lachnantha*, *Harpochloa Falx* and *Pennisetum Sphacelatum*. Herbs such as *Kniphoffia* spp. are also common along the edges of the wetland.

Some transformation of wetland areas has taken place in response to historic agricultural activities which have included ridge and furrow cultivation, drainage and construction of small impoundments for livestock watering. Poplars (*Populus spp.*) has also impacted part of the wetland.

**Table 5.** Summary details of the wetland assessed

| | |
|---|---|
| **Project Name** | Zaalklapspruit |
| **Quaternary catchment** | B20G |
| **Wetland Name** | Zaalklapspruit 1 |
| **Wetland Number** | B20G-01 |
| **Wetland Size** | 135.3 ha |
| **Catchment Size** | 9603 Ha |
| **River System Name** | Grootspruit |
| **Landuse in catchment** | Commercial agriculture, livestock grazing, mining. |
| **Landuse in wetland** | Livestock grazing, dams, historic cultivation. Mining extends into the wetland upstream of this assessment unit. |
| **Date of wetland assessment** | 20 – 21 November 2012 |
| **Wetland Assessor(s)** | Douglas Macfarlane |

## 4.2. Catchment description

The catchment landuse was historically characterized by livestock grazing and dryland cultivation. While large areas are still managed for these purposes, mining (primarily coal[2]) has resulted in considerable changes to the landscape in the catchment (Figure 2[3]). Other impacts are limited, with small areas affected by alien invasive species (principally wattle and gum) and limited road infrastructure.

[2] A large steel manufacturing plant is also located in the lower catchment area with water from this area draining into a small wetland arm that joins the mid reaches of this wetland system.

[3] Note that the national Landcover significantly under-estimated the actual extent of areas impacted by mining.

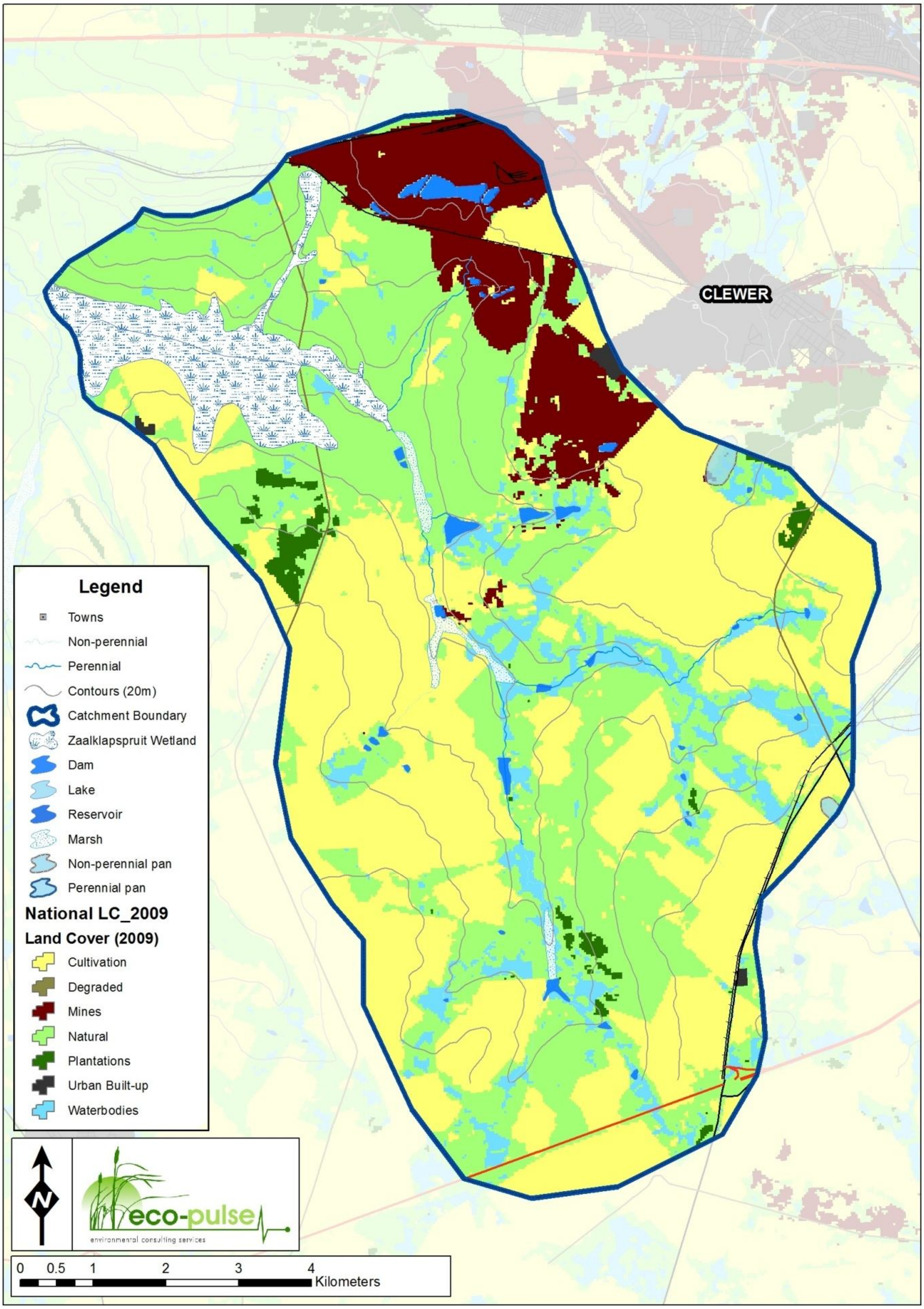


**Figure 2.** Map of the catchment of the wetland showing landcover within the catchment area.

## 4.3. Assessment of ecological status (Wet-Health)

Wetland ecological status is assessed by considering impacts to wetland hydrology, geomorphology and vegetation. A summary of the findings is outlined here, with additional information captured in the associated excel spreadsheets which are available on request.

### Hydrology

The assessment of hydrology is based on an assessment of changes to (i) water inputs (Table 6) and (ii) changes in water distribution and retention patterns within the wetland and is based on a combination of desktop information and field-based observations.

While it is difficult to assess changes to water inputs, the following information and observations were used to inform the assessment:

- Approximately 40% of the catchment area is classified as cultivated land. Presence of a number of small farm dams and a few centre-pivots, suggests that irrigation is used to supplement crop water requirements. Given the lack of information, we have assumed that half of the areas under cultivation would receive seasonal irrigation.
- Coal mines occupy an estimated 5-6% of the wetlands catchment. Coal mines source the bulk of their water from their underground operations and from own dams (Department of Water Affairs, 2011), suggesting that water use from mining is likely to be quite low. Mines are however known to act as a collector of groundwater. The catchment surface is fractured from mining, runoff decreases and water is drained into underground aquifers, and then seeps into streams (Lodewijks, 2006). Based on this information, a minor reduction in water inputs is attributed to mining activities in the catchment.
- The extent of alien plant encroachment in the catchment is limited (estimated at approximately 1% of the catchment).
- Approximately 51 dams occur in the catchment covering an area of approximately 93ha (1% of the catchment). Some water losses are anticipated as a result of evaporative losses and agricultural abstractions.

Based on this information, a minor reduction in water inputs is anticipated (Table 6).

A minor reduction in flood peaks is also anticipated in response to activities in the catchment (Table 6). This reduction is linked with the large number of dams in the wetlands catchment, which with the low runoff are likely to store in the region of 40% of mean annual runoff. A moderate level of extraction is anticipated from most of these dams, which combined with limited allowance for natural floods suggests that these are likely to result in a moderate reduction in flood peaks. This is likely to be offset to some degree by hardened surfaces (roads and other infrastructure) and quite large areas of bare soil in the catchment (principally associated with mines) that is likely to result in increased storm flows from affected areas.

When considered together, catchment impacts are likely to have resulted in a clearly identifiable but limited impact on the hydrological integrity of the Zaalklapspruit wetland (Table 3).

**Table 6.** Assessment of impacts of reduced water inputs (volume and patterns) on wetland hydrological integrity

| Nature of Alteration | Alteration Class Score | Land-use factors contributing to impacts, and any additional notes |
|---|---|---|
| 1. Reduction in flows (water inputs) | -2.0 | Irrigation, mining, alien plants. |
| 2. Increase in flows (water inputs) | 0 | None anticipated |
| **Combined impact Score** | **-2.0** | |
| 3. Change in flood patterns (peaks) | -3.2 | Farm dams (decrease); areas of infrastructure and bare soil (increase). |
| **Magnitude of impact Score** | **2.5 (Moderate)** | |

Apart from catchment-related impacts, there are a range of impacts within the wetland itself that have impacted on the hydrological functioning of the system. These are summarized in Table 7 and displayed spatially in Figure 3. The primary impacts are associated with historic drainage. These impacts are most evident in the mid and lower reaches of the wetland and includes area affected by drainage (e.g. Photos[4] 11, 22, 47 & 54); ridge and furrow cultivation (e.g. Photo 24) and channel incision (e.g. Photos 14, 25 & 50). This has resulted in flows being canalized, preventing diffuse flows important for maximizing the water quality enhancement functions of the wetland. Poplars (*Populus spp.*) also have a significant localized

[4] Photos are included in Annexure 1 of this report.

impact, causing a significant trying out of localized wetland areas (e.g. Photo 42). Other minor impacts are associated with deposition/ infilling and associated modifications below the district road where a number of small dams (largely ineffective) have been created (e.g. Photo 12).

**Table 7.** Assessment of impacts of changes in water distribution and retention on wetland hydrological integrity

| Impact Type | Magnitude of impact |
|---|---|
| 1. Canalization and stream channel modification | 3.08 |
| 2. Impeding features (e.g. dams/roads) – downstream effects | 0.00 |
| 3. Altered surface roughness | 0.00 |
| 4. Increased on-site water use (e.g. from alien plants, plantations and/or sugarcane) | 0.16 |
| 5. Deposition/infilling or excavation | 0.01 |
| **Combined impact Score** | **3.24** |

Based on the assessment undertaken, the state of wetland hydrology prior to rehabilitation was categorized as Moderately Modified (**"C" PES Category**), with a moderate-large change in ecological processes having taken place (Table 8).

**Table 8.** Calculation of combined hydrology impact score based on joint consideration of catchment and wetland impacts.

| | |
|---|---|
| Changes to water distribution & retention patterns | **3.2** |
| Changes to Water Input characteristics | **2.5** |
| **Combined Hydrology Impact Score** | **3.9** |
| **PES Category** | **C** |

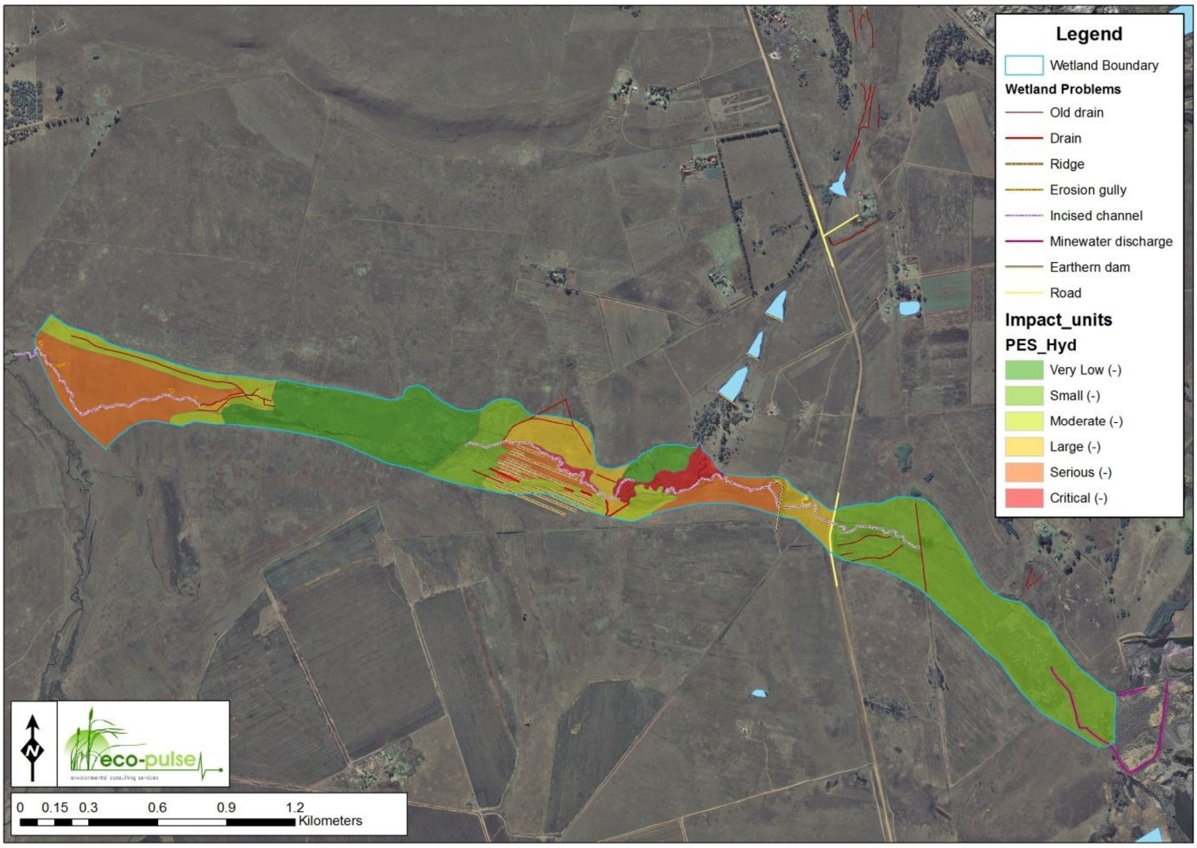


**Figure 3.** A map of Zaaklap wetland showing impacts to water distribution and retention patterns within assessment unit.

**B. Assessment of threats and opportunities**

While there is a risk of further channel erosion and headcut-advancement, a number of drains are showing signs of de-activation as a result of sedimentation and plant establishment. As a consequence, the hydrological state of the wetland is likely to remain stable in the absence of rehabilitation. Considerable opportunities exist to address on-site impacts.

## Geomorphology

The levels of impacts and threats to the geomorphological integrity of the wetland are presented in Table 9 below. While upstream dams would have reduced the volumes of sediment moving through this wetland, this has not been assessed as such impacts are typically not regarded as being of particularly high significance in naturally Unchannelled valley bottom wetlands. The geomorphological template of the wetland remains largely unaffected apart from localized areas of sediment loss (associated with incision of artificial drains and head-cut advancement) which have either been deposited within wetland areas further downstream or have been exported from the wetland (lower reaches). Based on this assessment, the current geomorphic integrity is regarded as largely natural with few modifications as reflected by a **"B" PES Category.**

### A. Assessment of impacts

**Table 9.** Assessment of impacts on the geomorphology of the wetland.

| Impact type | Applicability to HGM type | Magnitude of impact |
|---|---|---|
| **Daignostic component** | | |
| 1. Upstream dams | Floodplain | Not assessed |
| 2. Stream diversion/shortening | Floodplain, Channeled VB | Not assessed |
| 3. Infilling | Floodplain, Channeled VB | Not assessed |
| 4. Increased runoff | Non-floodplain HGMs | 0 |
| **Indicator-based component** | | |
| 5. Erosional features | All non-floodplain HGMs | 0.56 |
| 6. Depositional features | All non-floodplain HGMs | 0.50 |
| 7. Loss of organic matter | All non-floodplain HGMs with peat | 0.00 |
| **Combined Impact Score based on a sum of the three highest scores** | | **1.06** |
| **PES Category** | | **B** |

### B. Assessment of threats and opportunities

Most erosion features appear to be relatively stable and are unlikely to deteriorate significantly in the next 5 years. Rehabilitation options aimed at addressing the impacts drainage and channel incision help to improve the geomorphic integrity of the system.

## Vegetation

Livestock grazing is the dominant form of landuse in the Zaalklapspruit wetland. While there is evidence that this may have some impact on wetland vegetation (e.g. at drinking and crossing points), this use appears to be reasonably well managed. Historic agricultural practices have however had a significant localized negative and long-term impact on wetland vegetation. The current state of vegetation is regarded as moderately modified as described by a **"C" Category**.

### A. Assessment of impacts

Table 10 summarizes the impacts to wetland vegetation disturbance units mapped as part of this assessment (Mapped in Figure 4). These ratings were informed by a walk through affected areas and vegetation sampling undertaken in selected units (See Annexure 2 for further details). Areas of highest impact are associated with an area of heavy Poplar infestation that has resulted in an almost total loss of indigenous species in affected areas. The most common impacts are associated with drained areas used previously for cultivation. This has not only resulted in localized effects but has resulted in the creation of a permanent incised channel through affected sections of the wetland. This has resulted in considerable drying out of wetland areas with a loss of characteristic wetland species and an increase in terrestrial grasses and ruderal weeds.

**Table 10.** Assessment of impacts on wetland vegetation.

| Disturbance Unit | | Extent (%) | Intensity (0 - 10) | Magnitude of impact |
|---|---|---|---|---|
| 1 | Largely untransformed Phragmites and Typha dominated marsh with narrow zone of seasonal habitat occupied by a diverse plant community along the periphery of the wetland. | 28.8 | 2.0 | 0.4 |
| 2 | Central Phragmites dominated zone along weakly defined stream channel. | 2.3 | 0.0 | 0.0 |
| 3 | Diverse seasonally inundated zone along northern edge of wetland above road. | 3.8 | 2.0 | 0.1 |
| 4 | Diverse seasonal and temporary grass and sedge dominated zone along southern edge of wetland above road crossing point. | 5.3 | 1.0 | 0.0 |
| 5 | Highly disturbed zone below road characterised by small dams and dominated by terrestrial grass species. | 3.7 | 7.0 | 0.2 |
| 6 | Short-grass dominated area characterised by terrestrial grass species such as *E. Racemosa*, *E. Curvula*, *T. Triandra* and *S. Palidefusca*. A range of ruderal species are also present and account for a moderate proportion of cover. | 5.6 | 7.0 | 0.3 |
| 7 | Area dominated by dense stand of Poplars. Under-canopy vegetation cover very limited. | 3.8 | 9.0 | 0.3 |
| 8 | Largely untransformed temporary / seasonal wetland area dominated by a mix of grasses and sedges. | 1.7 | 1.0 | 0.0 |

| Disturbance Unit | | Extent (%) | Intensity (0 - 10) | Magnitude of impact |
|---|---|---|---|---|
| 9 | *Typha* and *Phragmites* dominated marsh. | 1.4 | 0.0 | 0.0 |
| 10 | Narrow zone alongside incised channel dominated by a mix of hydrophilic grasses and sedge species. Expected obligate wetland species are lacking in this area. | 0.4 | 4.0 | 0.0 |
| 11 | Diverse assortment of obligate wetland species including Typha, *Choenoplectus* & *Cyperus fastigiatus.* | 2.0 | 3.0 | 0.0 |
| 12 | Area dominated by terrestrial grass species and lacking characteristic obligate wetland species expected in this area. | 0.4 | 6.0 | 0.0 |
| 13 | Zone dominated by terrestrial grass species and lacking the diversity of species anticipated in seasonal and temporary zones. Lower lying areas are lacking characteristic obligate wetland species anticipated in this area. | 1.4 | 5.0 | 0.1 |
| 14 | Area impacted by historic ridge and furrow cultivation and receiving little water inputs as a result of drainage and incision. Area dominated by terrestrial grass species such as *H. Hirta* and *E. Curvula.* Sedges and other typical wetland species are lacking in this area. | 2.0 | 5.0 | 0.1 |
| 15 | Section of historically cultivated area which receives higher water inputs that adjacent areas and supports a higher abundance of wetland species. | 1.8 | 3.0 | 0.0 |
| 16 | Area impacted by historic ridge and furrow cultivation and receiving little water inputs as a result of drainage and incision. Area dominated by terrestrial grass species such as *H. Hirta* and *E. Curvula*. Ruderal species are common in this area. | 4.3 | 6.0 | 0.2 |
| 17 | Elevated berm along edge of main drain. Dominated by terrestrial grass species. | 0.8 | 7.0 | 0.0 |
| 18 | Area dominated by a range of species typical of seasonal wetland areas. Ruderal species also common. Characteristic obligate wetland species (particularly *Typha* and *Phragmites*) are absent from this zone. | 5.6 | 5.0 | 0.2 |
| 19 | Area dominated by characteristic seasonal wetland but not dominated by *Typha* and *Phragmites* as anticipated. | 3.3 | 3.0 | 0.1 |
| 20 | Area dominated by a range of typical seasonal wetland species but lacking species typical of permanent wetland areas. | 4.0 | 2.0 | 0.1 |
| 21 | *Typha* and *Phragmites* dominated marsh. | 24.2 | 0.0 | 0.0 |
| 22 | Area still dominated by characteristic obligate wetland species but no longer dominated by *Typha* and *Phragmites* as would be expected in the absence of drainage. | 1.4 | 2.0 | 0.0 |
| 23 | Area dominated by characteristic seasonal wetland vegetation but lacking a range of | 1.0 | 2.0 | 0.0 |

| Disturbance Unit | | Extent (%) | Intensity (0 - 10) | Magnitude of impact |
|---|---|---|---|---|
| | obligate wetland species anticipated (particularly in areas towards the central sections of the wetland) | | | |
| 24 | Central area dominated by terrestrial vegetation with limited wetland species present. | 0.5 | 6.0 | 0.0 |
| 25 | Edge of wetland still supporting characteristic obligate wetland species but at lower abundance than would be anticipated under natural conditions. | 1.1 | 2.0 | 0.0 |
| 26 | Area dominated by terrestrial grass species, particularly *E. Curvila* and largely lacking characteristic facultative and obligate wetland species. | 19.5 | 7.0 | 1.0 |
| 27 | Peripheral wetland area still dominated by seasonal wetland species (fed by lateral seepage). | 5.2 | 4.0 | 0.2 |
| | | | **Overall weighted impact score** | **3.3** |

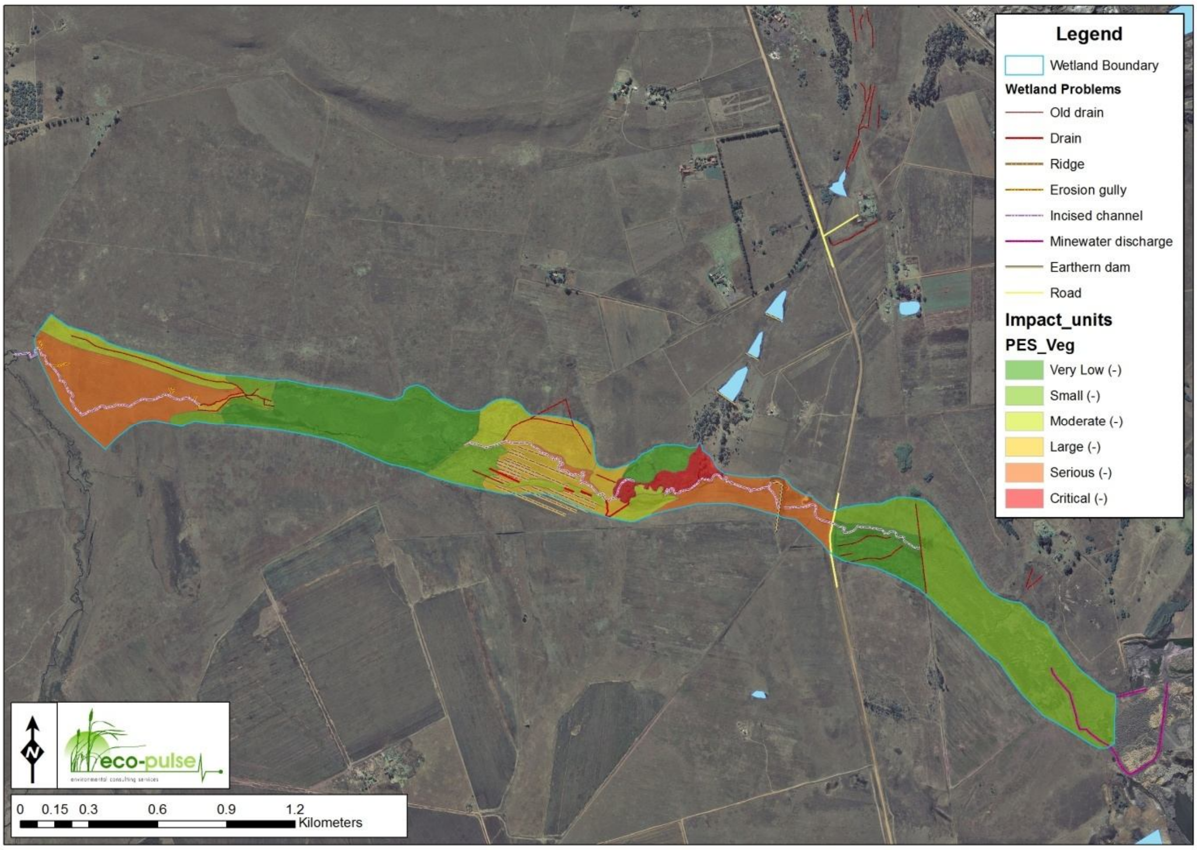


**Figure 4.** A map of Zaalklapspruit wetland showing key current levels of impacts on wetland vegetation.

**B. Assessment of threats and opportunities**

Potential threats to wetland vegetation include deteriorating water quality, head-cut advancement and spread of Poplars into areas of intact wetland vegetation. Despite these threats, little change in the overall state of the wetland vegetation is anticipated over the next 5 years under current management.

## Summary

The catchment of the Zaalklapspruit wetland has been significantly modified through cultivation and the construction of numerous farm dams that are likely to have a moderate impact on water inputs into the wetland. Mining has also transformed large areas of the catchment and whilst impacts are difficult to assess, it is likely that this has resulted in water quality deterioration and increased stormwater runoff. A range of impacts have also taken place within the wetland HGM unit itself, with historical cultivation and drainage having caused the most notable changes to the three components of wetland health assessed. The assessment suggest that wetland hydrology is most severely impacted followed by wetland vegetation and wetland geomorphology (Table 11). Given these changes, the current state of the wetland can be described as moderately modified as reflected by a **"C" PES Category** . Despite a range of threats, it is unlikely that there will be a noticeable deterioration or improvement in wetland condition over the next 5 years under the current management regime.

**Table 11.** Summary of present wetland health based on the Wet-Health assessment.

| Wetland No | Ha | Hydrology | | Geomorphology | | Vegetation | |
|---|---|---|---|---|---|---|---|
| | | Impact Score | Change Score | Impact Score | Change Score | Impact Score | Change Score |
| B20G-01 | 139 | 3.9 | 0 | 1.1 | 0 | 3.3 | 0 |
| PES Categories | | C | → | B | → | C | → |
| Wetland Impact Score | | 2.92 | | | | | |
| Wetland PES | | C | | | | | |

# 5. ASSESSMENT OF IMPORTANCE AND SENSITIVITY

A breakdown of the current levels of benefit provision (supply) and demand for a range of ecosystem goods and services associated with the Zaalklapspruit wetland is presented in graphically in Figure 5 and in more detail in Table 12. This suggests toxicant removal, stream flow regulation and sediment trapping are the most important regulating services provided by the wetland. Given the suitability of the wetland for research into the ability of wetlands to address acid mine drainage, education and research opportunities are regarded as high. While sections of the wetland are used by livestock, the value of direct provisioning services is limited.

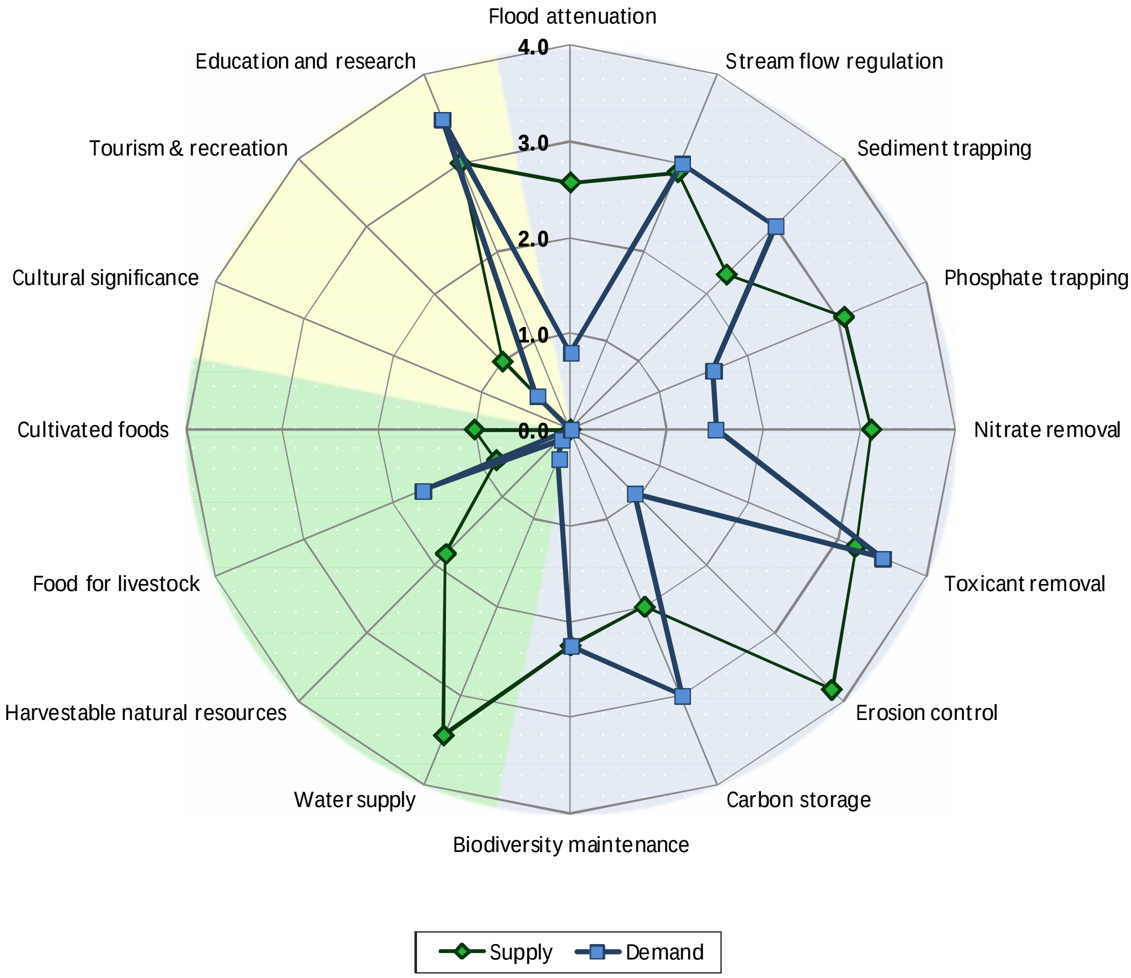


**Figure 5.** Spider diagram illustrating the relative demand and supply of ecosystem goods and services provided by the Zaalklapspruit wetland.

**Table 12.** Summary of the importance of ecosystem services currently provided by the wetland.

| | Benefit | Supply | Comment | Demand | Comment | Importance |
|---|---|---|---|---|---|---|
| REGULATING AND SUPPORTING SERVICES | Flood attenuation | 2.6 | The low slope of the wetland and high surface roughness suggests that the wetland is likely to be moderately effective in attenuating floods. | 0.8 | The average slope of the catchment is low with moderate runoff rates anticipated during storm events. There is also very limited floodable property in the downstream area. As a result, demand for flood attenuation is regarded as low. | Low |
| | Stream flow regulation | 2.9 | The occurrence of large areas of reed beds and water inputs from adjacent slopes and drainage lines suggests that the wetland is likely to assist in streamflow regulation. | 3.0 | While downstream use is limited to livestock grazing, the Ezemvelo-Telperion Nature Reserve is located a short distance downstream of the wetland. As such, the demand for streamflow regulation for grazing and downstream ecological requirements is regarded as moderately high. | Medium |
| | Sediment trapping | 2.3 | While there is little evidence of sediment deposition, wetland characteristics suggest that it will be very effective in trapping sediments from the upstream catchment and adjoining slopes. | 3.0 | Mines and agricultural activities pose a moderate risk of increased sediment inputs. The importance of this service is heightened however due to the presence of the Nature Reserve a little distance downstream. | Medium |
| | Phosphate trapping | 3.1 | The ability of the wetland to effectively trap sediments together with good vegetation cover and diffuse flows suggests that the wetland is well suited for Phosphate rapping. | 1.6 | While agricultural activities in the upstream catchment may contribute to elevated Phosphorous levels, other point sources are lacking and there is little use for domestic or recreational purposes in the downstream area. As such, the demand for this service is regarded as moderately low. | Low |
| | Nitrate removal | 3.1 | Wetland characteristics also make much of the wetland well suited to remove nitrates. | 1.5 | The risk of nitrate enrichment from catchment activities is limited. As such, the demand for this service is regarded as low. | Low |

| Benefit | | Supply | Comment | Demand | Comment | Importance |
|---|---|---|---|---|---|---|
| | Toxicant removal | 3.2 | Wetland characteristics make this wetland well suited to remove toxicants from influent water. While the ability of sections of the wetland to provide this service have been compromised by anthropogenic activities, the overall ability of the wetland to provide this service is regarded as high, particularly during low-flow periods. | 3.5 | Previous studies have indicated that the water quality in the Zaalklapspruit is extremely poor with surveys undertaken in 2008 indicating that toxicity posed an "acute hazard" (Deacon, 2009). Continued mining activities and acid mine drainage is a significant concern in this catchment. While domestic and recreational activities are limited in the immediate downstream area, improved water quality is important for the environment and broader catchment users. | High |
| | Erosion control | 3.8 | Good vegetation cover and surface roughness make the wetland well suited to slow flows and reduce erosion. | 0.9 | The low slope of the wetland and low erodibility suggest that risks of erosion are limited. | Low |
| | Carbon storage | 2.0 | The wetland is likely to store moderate levels of carbon but lacks areas of peat accumulation. | 3.0 | Due to climate change, the global demand for Carbon storage is growing. Current demand is regarded as high. | Medium |
| | Biodiversity maintenance | 2.3 | While wetland vegetation remains largely intact, water quality impacts are likely to have had a significant impact on wetland-dependant biota. Species such as the vulnerable Grass owl (Tyto capensis) do however occur in the wetland area. | 2.3 | The wetland falls within a critically endangered wetland type and has been identified as a National Freshwater Ecosystem Area. Thus, although the wetland is not currently under any form of conservation, the need to improve conservation of the wetland has been identified. | Medium |

| | | | | | | |
|---|---|---|---|---|---|---|
| PROVISIONING SERVICES | Water supply | 3.5 | A perennial stream flows through this wetland and is maintained by recharge from the wetland and surrounding catchment area. | 0.3 | The demand for water supply by adjoining communities is negligible, with the only current use being for livestock watering. | Low |
| | Harvestable natural resources | 1.8 | While reeds are available for harvesting, the availability of other materials is not well understood. | 0.1 | The wetland is located away from any communal areas with no known demand for wetland products. | Low |
| | Food for livestock | 0.8 | While some palatable species occur along the edge of the wetland and in impacted areas, much of the wetland is dominated by reeds and bulrushes which are not favoured by livestock. The overall grazing value of the wetland is therefore regarded as low. | 1.7 | Sections of the wetland are used for livestock grazing. The extent of the wetland relative to other grazing resources is limited however, detracting from the value of this area as a grazing resource. | Low |
| | Cultivated foods | 1.0 | While there is evidence of historic use, wetland soils have a high clay content and areas would be subject to regular inundation. The wetland is therefore poorly suited to cultivation. | 0.0 | The lack of cultivation of adjacent areas by property owners suggests that the current demand for cultivated foods is limited. | Low |
| CULTURAL SERVICES | Cultural significance | 0.0 | The wetland is located away from any communal areas with no known cultural significance. | 0.0 | The demand for cultural services is regarded as very low. | Low |
| | Tourism & recreation | 1.0 | The proximity of the wetland to mines, lack of charismatic species and lack of accessibility to the general public detracts from the suitability of the site for tourism and recreational activities. | 0.5 | There is currently no known use of the area for recreation or tourism. | Low |
| | Education and research | 3.0 | While the wetland is not an ideal reference site, it is located in a context that lends itself to research on the effects of wetlands on water quality improvement. The degraded nature of sections of the wetland also provides an opportunity to assess the effects of rehabilitation on water quality enhancement functions. | 3.5 | While there is little evidence of historic research on the site, the site has been specifically selected as part of the Coaltech project to investigate the ability of wetlands in ameliorating some of the impacts that mining has on water quality. As such, the demand for research at this site is regarded as high. | High |

Based on an understanding of the goods and services provided by the wetland, the EIS assessment indicates that this wetland has a "Moderate to "High" importance and sensitivity (Table 13). This is attributed primarily to the ecological importance and sensitivity value which is regarded as high due to aspects such as the high threat status of the wetland and sensitivity to hydrological changes, particularly low flows. The hydrological importance is moderate while direct benefits are limited as discussed previously.

**Table 13.** Results of the importance assessment for the wetland

| Component assessed | Score |
|---|---|
| Ecological Importance & sensitivity | 2.67 |
| Hydrological / Functional Importance | 1.75 |
| Importance of Direct Human Benefits | 0.83 |
| **Overall Importance Score** | **2.67** |
| **Importance & Sensitivity Class** | **Moderate-High** |

# 6. REHABILITATION PLANNING

## 6.1. Summary of Wetland Problems

Apart from changes in catchment hydrology and sediment dynamics, the ecological integrity of Zaalklapspruit wetland has been impacted by several site-based factors including:

- Drainage and associated channel incision;
- Ridge and furrow cultivation;
- Introduction of pasture grass species;
- Construction of a gravel roads across the wetland;
- Alien invasive plants (particularly Poplars);
- Construction of small "dams" in the central reaches of the wetland.

## 6.2. Potential of wetlands in addressing acid mine drainage

Much work has been done internationally to develop approaches to treat acid mine water (particularly that associated with coal mining activities). The principal contaminants of concern are typically excessive acidity, iron, manganese and aluminium (Kleinman, 2006). These are certainly some of the primary elements of concern in the Upper Olifants catchment although other chemical parameters such as sulphate, calcium and magnesium are also highly elevated (Hobbs, et al., 2008). Efforts to address water quality concerns have focussed strongly on biological water treatment systems, particularly in the form of constructed wetlands which can reportedly play an important role in improving water quality. The most common goal of these systems is to remove iron from the water column, although sulphate reduction and the alleviation of extremely acid conditions are also appropriate goals (Mitch & Gosselink, 2007). Wetland (natural or artificial) potentially provide the long-term solution to AMD, although their success has been limited in cases where excessive volumes, high iron loadings or excessively low pH values are encountered (pers. comm. P Younger in Council for Geoscience , 2010).

Findings suggest that wetland characteristics play an important role in the effectiveness of providing water quality functions. While design criteria are not universal and generally accepted, findings suggest that the following wetland features may promote desired water quality enhancement functions (Mitch & Gosselink, 2007; Kleinman, 2006; Stark & Williams, 1995):

- Broad drainage basins;
- Non-channelized, diffuse patterns of flow;
- Large surface area to volume ratio (large wetlands with low flow volumes);
- Shallow surface water depths;
- High plant diversity (e.g. Sheoran, 2006);
- Vigorous plant growth (high biomass) - Typha-dominated wetlands are reportedly effective at accumulating metals (e.g.. Yadav et al. 2012, Yang et al., 2006).

This provides useful insights into what wetland attributes rehabilitation activities should aim to enhance in order to maximize the water quality enhancement functions of the system.
It is important to note however that the efficiency of wetlands in improving water quality is also highly dependent on the quality of the influent water (Sobolewski, 2012). As long as water is frankly acidic (pH < 4-5), there is very little wetlands can do, short of removing suspended solids. It is for this reason that limestone is typically

used in artificial wetlands since the acid dissolves the calcium carbonate, which neutralizes water pH. At a pH above 6, bacteria within wetlands will oxidize iron and cause it to precipitate. At a pH above 7, other bacteria will oxidize manganese and cause it to precipitate.

The ability of wetlands to continually improve water quality over the long term has also been questioned and it is suggested that they are unlikely to be able to continue to function effectively over the long term (MEND, 1996). Concentration of large amounts of contaminants in wetlands, while addressing current water quality concerns may be remobilized and pose a hazard to downstream users (Coetzee, Et al., 2002). It is for this reason that wetland rehabilitation is being undertaken on a trial basis, with monitoring being planned to evaluate the outcomes of rehabilitation activities.

## 6.3. Rehabilitation objectives and strategy for wetland rehabilitation

The focus of rehabilitation of this particular wetland is to assess the ability of wetlands to address water quality impacts associated with upstream coal mining activities. As such, the primary objective is to enhance the water quality enhancement functions of the wetland.

While a number of problems and threats have been identified, channel incision, resulting in concentration of flows and a reduction in plant growth is regarded as having the most significant impact on the ability of the wetland to improve water quality. Rehabilitation is therefore focused on addressing the impacts associated with artificial drainage and ridge and furrow cultivation in the central reaches of the wetland at this stage (Figure 6). Details of the current rehabilitation objectives, together with the planned strategy for achieving this objective are summarized in Table 14 below:

**Table 14.** Summary of rehabilitation objective and proposed rehabilitation strategies to achieve these.

| Rehabilitation objective | Rehabilitation strategy |
|---|---|
| To improve the water quality enhancement functions of the wetland in addressing impacts associated with upstream coal mining activities. | • Prevent further channel incision by de-activating head-cut upstream of main channel;<br>• De-activate central incised channel, encouraging water to flow diffusely across the wetland.<br>• Re-activate areas affected by ridge and furrow cultivation. |

## 6.4. Interventions proposed to meet rehabilitation objectives

In order to achieve the rehabilitation objectives defined, a number of wetland interventions have been proposed. These have been prioritized from a wetland rehabilitation perspective and with input from the CSIR who will be undertaking monitoring at the site. These priorities may need to be re-ordered due to practical or financial constraints. Details of these new interventions, together with the associated rehabilitation objectives are summarized in Table 15, below.

**Table 15.** Details of interventions planned in line with the rehabilitation strategy for the wetland.

| Intervention Number | Structure Type | Priority | Rehabilitation objective | Cost Estimate |
|---|---|---|---|---|
| B20G-01-201-00 | Concrete weir | 1 | • Deactivate head-cut upstream of main drain. | R158 400,00 |
| B20G-01-202-00 | Concrete weir | 2 | • Raise the water level in the main channel and promote distribution into adjacent wetland areas. | R195 700,00 |
| B20G-01-203-00 | Low concrete wall and removal of berms | 4 | • Promote diffuse flows and encourage establishment of wetland vegetation. | R126 000,00 |
| B20G-01-204-00 | Earthworks - levelling | 5 | • Promote diffuse flows and encourage establishment of wetland vegetation. | R51 750,00 |
| B20G-01-205-00 | Low concrete wall | 6 | • Promote diffuse flows and encourage establishment of wetland vegetation. | R65 250,00 |
| B20G-01-206-00 | Concrete weir | 12 | • De-activate main channel and deflect water into adjacent wetland areas. | R208 525,00 |
| B20G-01-207-00 | Concrete weir | 13 | • De-activate main channel and deflect water into adjacent wetland areas. | R237 925,00 |
| B20G-01-208- | Earthworks - | 10 | • De-activate areas of ridge and furrow | **R153 750.00** |

| Intervention Number | Structure Type | Priority | Rehabilitation objective | Cost Estimate |
|---|---|---|---|---|
| 00 | distribution berm | | cultivation and promote diffuse flows accross the wetland. | |
| B20G-01-209-00 | Earthworks - berm | 9 | • De-activate secondary drain and promote distribution of flows into adjacent wetland. Flows to downstream area to be maintained through use of pipes through the berm. | R162 785,00 |
| B20G-01-210-00 | Earthworks - berm | 8 | • Promote diffuse flows and encourage establishment of wetland vegetation. | R63 275,00 |
| B20G-01-211-00 | Earthworks - berm | 7 | • Promote diffuse flows and encourage establishment of wetland vegetation. | R40 875,00 |
| B20G-01-212-00 | Earthworks - distribution berm | 11 | • De-activate areas of ridge and furrow cultivation and promote diffuse flows across the wetland. | **R 108 375.00** |
| B20G-01-213-00 | Concrete weir | 3 | • De-activate secondary channel in order to deflect flows into downstream wetland area. | R154 000,00 |
| | | | **Overall Estimated Cost** | **R 1 172 6610.00** |

A map indicating the proposed location of interventions identified at the time of the assessment is shown in Figure 6, below.

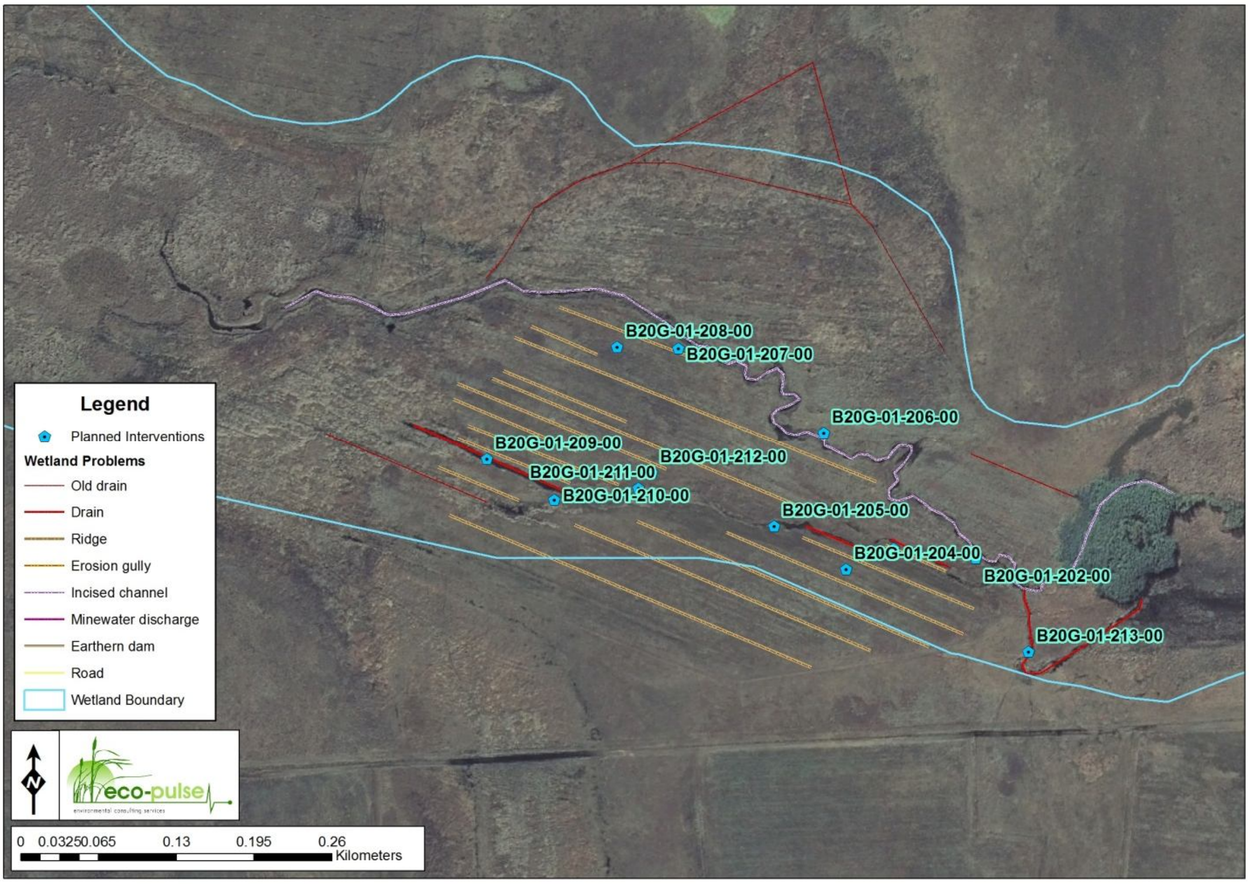


**Figure 6.** Map indicating the location of planned interventions as identified during the first year of planning.

# 7. ANTICIPATED REHABILITATION OUTCOMES

## 7.1. Effect on wetland integrity

The effects of implementation of the rehabilitation strategy and proposed interventions on the Zaalklapspruit wetland have been assessed by predicting the anticipated future state of the wetland with and without rehabilitation[5] (Table 16). This was used to estimate hectare equivalents achieved through wetland rehabilitation activities. Based on the Wet-Health assessments undertaken, it is predicted that **4.2** hectare equivalents with be rehabilitated or secured through the interventions identified.

**Table 16.** Summary of anticipated outcomes from implementation of the rehabilitation strategy

| | | Status Quo | With Rehabilitation | Without Rehabilitation |
|---|---|---|---|---|
| Size of wetland (Ha) | | 135.3 | | |
| Impact Scores | Hydrology | 3.9 | 3.7 | 4.0 |
| | Geomorphology | 1.1 | 0.8 | 1.2 |
| | Vegetation | 3.3 | 3.0 | 3.3 |
| | Overall | 2.9 | 2.7 | 3.0 |
| | Ecological Category | C | C | C |
| | Hectare equivalents | 95.8 | 99.1 | 94.9 |

## 7.2. Effect on supply of goods and services

The proposed rehabilitation interventions will not only affect the ecological integrity of the wetland but will also have a number of positive impacts on the supply of goods and services provided by the wetland. Details of anticipated change in the delivery of wetland services is summarized in Table 17, below. Guidelines for interpreting these scores are detailed in Table 18.

This suggests that improvements to a range of regulating and supporting services can be anticipated, including toxicant removal services, which is the focus of rehabilitation planning. A slight decrease in grazing value is anticipated while data

[5] *Refer to Appendix 3 for maps indicating the predicted improvements in wetland hydrology and vegetation integrity within the focal area. Additional information is also available in the Wet-Health datasheet.*

collected as part of this project will contribute meaningfully towards education and research.

**Table 17.** Anticipated change scores for ecosystem services post-rehabilitation based on the rehabilitation strategy defined.

| Ecosystem Service | | Change Score | Comments |
|---|---|---|---|
| REGULATING AND SUPPORTING SERVICES | Flood attenuation | 1.0 | Rehabilitation activities will help to increase residence times of floodwaters. |
| | Stream flow regulation | 0.0 | The impact on streamflow regulation is uncertain. On the one hand, rehabilitation will result in increased recharge of previously drained areas, providing greater storage. On the other hand, diffuse flows will encourage greater evaporative and transpirational losses that may negatively affect water availability. |
| | Sediment trapping | 1.0 | Rehabilitation activities will increase diffuse flows and encourage plant growth which will improve the effectiveness of the wetland at trapping sediments. |
| | Phosphate trapping | 0.0 | There is little demand for this service. Thus, although the potential of the wetland to provide this service will be improved, this is likely to have no material effect on the importance of this service. |
| | Nitrate removal | 0.0 | As above |
| | Toxicant removal | 1.0 | Wetland rehabilitation activities are being designed to improve the water purification functions of the wetland. |
| | Erosion control | 0.0 | While rehabilitation activities will address a head-cut, the risk of erosion in this system is limited. As such, rehabilitation is likely to have little effect on this service. |
| | Carbon storage | 1.0 | Rehabilitation will encourage greater plant growth and organic matter accumulation which will improve climate regulation and carbon storage functions. |
| | Biodiversity maintenance | 1.0 | Rehabilitation of degraded areas will improve vegetation characteristics and should provide improved habitat for wetland-dependant species. |
| PROVISIONING SERVICES | Water supply | 0.0 | A slight reduction in water supply can be anticipated. This is however likely to have little consequence for downstream users. |
| | Harvestable natural resources | 0.0 | Rehabilitation will increase the availability of harvestable natural resources. There is however no real demand for this service. |
| | Food for livestock | -1.0 | Rehabilitation will result in more frequent inundation of wetland areas and result in the rehabilitation of areas currently dominated by palatable terrestrial species. As such, rehabilitation is likely to have a minor negative impact on grazing availability. |
| | Cultivated foods | 0.0 | Rehabilitation will have no impact on current cultivation activities. |
| CULTURAL SERVICES | Cultural significance | 0.0 | No impact anticipated. |
| | Tourism & recreation | 0.0 | No impact anticipated. |
| | Education and research | 2.0 | The research undertaken by Coaltech will add to societies understanding of the role of wetlands in |

| Ecosystem Service | | Change Score | Comments |
|---|---|---|---|
| | | | water quality enhancement. This is likely to promote further research activities on the wetland in future. |

**Table 18.** Description of change scores used to rate the potential impact of rehabilitation on ecosystem service delivery.

| Change Score | Description of effect of rehabilitation on ecosystem service delivery |
|---|---|
| -2 | Substantial loss anticipated |
| -1 | Slight loss anticipated |
| 0 | No significant effect anticipated |
| 1 | Slight improvement anticipated |
| 2 | Substantial improvement anticipated |

## 7.3. Cost-effectiveness of proposed interventions

The cost-effectiveness of planned rehabilitation has been estimated and is summarized in Table 19, below. This suggests that rehabilitation proposed will be costly in relation to the gains in wetland condition anticipated. Gains in ecosystem goods and services and in particular anticipated improvements in water purification functions discussed above do however lend further support to undertaking rehabilitation of this wetland.

**Table 19.** Evaluation of expected cost-effectiveness of implementing the proposed rehabilitation strategy

| | |
|---|---|
| **Estimated Cost of planned interventions** | R 1 726 610 |
| **Hectare/Functional Equivalents of Wetland Habitat** | |
| Present Ecological State | 95.8 |
| Future scenario without rehabilitation | 94.9 |
| Future scenario with rehabilitation | 99.1 |
| **Hectare/Functional Equivalents Gained or Secured** | 4.2 |
| **Cost per Hectare/Functional Equivalent** | R 414 873 |
| **Cost-effectiveness** | **Low** |
| **Anticipated Maintenance Requirements** | **Low** |

Note: Figures presented above are indicative based on the wetlander's interpretation of available data .

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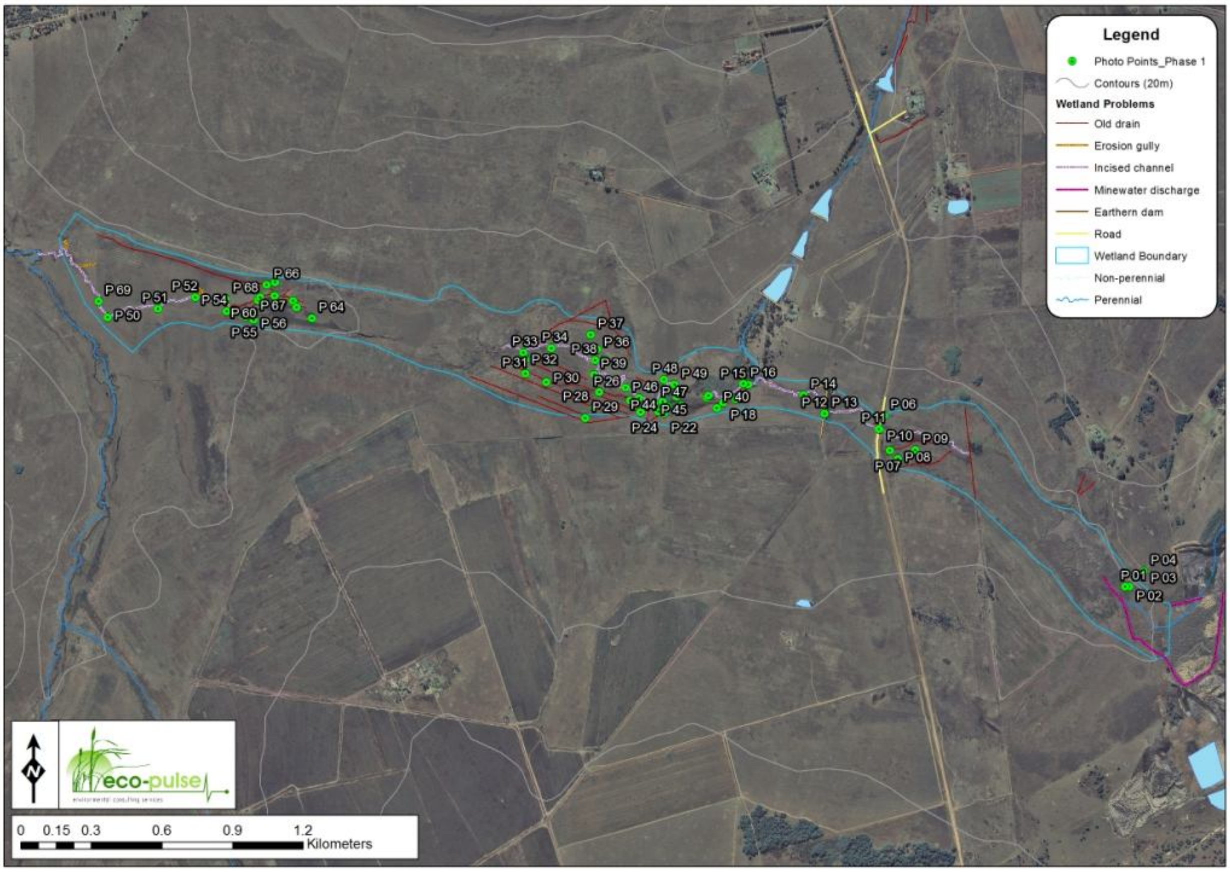
# 9. ANNEXURES

## 9.1. Annexure 1. Photographic record of the wetland prior to rehabilitation.




Map indicating the location of Photo points taken as part of preliminary wetland investigations.

| | | | |
|---|---|---|---|
|  | | No image available | |
| P 01 | View over permanant Typha and Phragmites reedbed | P 02 | View SE along edge of wetland. |

P 03 View towards upper reaches of wetland where active mining is underway.

P 04 View SW over the upper reaches of the wetland

P 05 View SSE over main wetland body showing typical Phragmites marsh.

P 06 View E along the edge of the wetland. Note divers vegetation community in seasonal and temporary wetland areas.

P 07 View over shallow vegetated drain.

P 08 Further evidence of shallow drains in this area.

P 09 View E along the edge of the wetland. This area appears to be largely undisturbed.

P 10 View E above road showing area dominated by Typha and Phragmites.

P 11 View W over drained wetland area below the district road.

P 12 View E showing disturbed area above small dam.

P 13 View W below dam. Area is dominated by ruderal and terrestrial species.

P 14 Incised channel below earthern dam.

P 15 View over area dominated by Poplar trees.

P 16 Minor drain joins the main channel at this point.

P 17 View W over moist grassland area.

P 18 View W towards largely intact wetland area.

P 19 View SW over "floodout" resulting from heavy Typha growth in the main channel.

P 20 View E above floodout. Recovery is limited in this area with the area dominated by grasses and rude species.

| | | | |
|---|---|---|---|
|  | |  | |
| P 21 | View over inundated marsh - dominated by sedges and rushes. | P 22 | View SW along drain |
|  | |  | |
| P 23 | View W over "island" dominated by terrestrial ghrass species. | P 24 | View W over area impacted by ridge and furrows. |
|  | |  | |
| P 25 | View along the remnants of an old drain. | P 26 | View E up main channel. An elevated lip on the northern bank suggests that this was artificially created. |

P 27 View E up area carrying limited flow. Potential site for earthern berm.

P 28 Another view E along areas impacted by historic ridge and furrow cultivation.

P 29 Area dominated by terrestrial grass species.

P 30 Remnants of a large drain running through the wetland.

P 31 View over moister area with a range of charachteristic wetland species present.

P 32 Vegetation typical of seasonal wetland areas.

P 33 View E showing reeds established along the lower reaches of an old drain.

P 34 View E up drain. Rehabilitation of this area is likely t be easier than the upper reaches.

P 35 View N showing an area dominated by a mix of ruderal and charachteristic weetland species.

P 36 Area charachterised by wetland grasses, sedges et (charachteristic of seasonal areas).

P 37 View W along old berm - this is having no significant impact on water movement.

P 38 View W along elevated berm aonlg main drain - thi zone is dominated by terrestrial species.

P 39 Area dominated by terrestrial grasses and ruderal weeds.

P 40 View W along approximate wetland boundary.

P 41 View S along channel that has been largely deactivated.

P 42 View of vegetation cover within area dominated by Poplars.

P 43 View SW along drain.

P 44 Point at which channels converge. Area upstream has not been thoroughly investigated.

P 45 View towards head-cut (located approximately 10m E of this point).

P 46 Useful point for an intervention on the main channe

P 47 View W along shallow drain.

P 48 View E over intact Typha and Phragmites reed beds

P 49 Shallow drain / channel (<1m deep) runs between the poplars and intact marsh area.

P 50 View along stable incised channel.

| | | | |
|---|---|---|---|
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| P 51 | View E along channel. Vegetation on either side of the cvhannel is dominated by terrestrial grass species. | P 52 | Crossing point utilised by cattle. |
|  | |  | |
| P 53 | View N over well vegetated and stable erosion feature. | P 54 | View E over large drain (c.a. 3m wide). |
|  | |  | |
| P 55 | View E over seasonal wet meadow. | P 56 | View E over intact permanent wetland area. |

P 57 Typha and Cyperus dominated zone along the lower reaches of the permanantly inundated zone.

P 58 View over intact area dominated by Bulboschoenu Choenoplectus species.

P 59 Lateral drain enters large drain at this point.

P 60 View up main drain (c.a. 2m wide).

P 61 Secondary lateral drain enters main drain at this point.

P 62 Channel incised to approximately 1.5m at this point

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| P 63 | View E up old drain (c.a 4m wide & 0.5 m deep). | P 64 | Intact Typha / Phragmites marsh - permanant inundation expected. |
|  | |  | |
| P 65 | View E over wet meadow. | P 66 | View along narrow lateral drain - now largely blocke with vegetation. |
|  | |  | |
| P 67 | Vegetation composition shifts towards terrestrial grass species SW of this point. | P 68 | Stable erosion gully. |

| | | |
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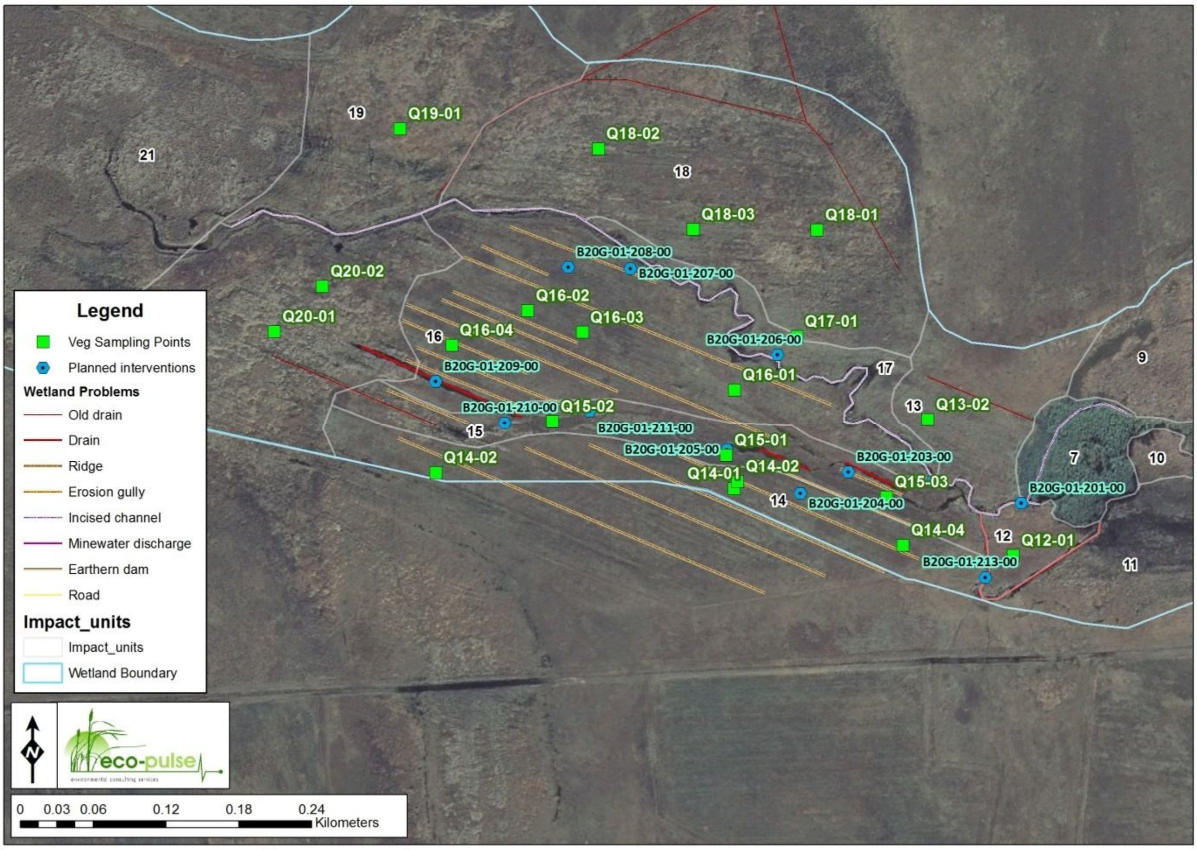
| P 69 | Evidence of a berm on the eastern section of the main channel. | |

## 9.2. Annexure 2A. Map indicating the location of vegetation plots




## 9.3. Annexure 2B. Photos of vegetation sample plots

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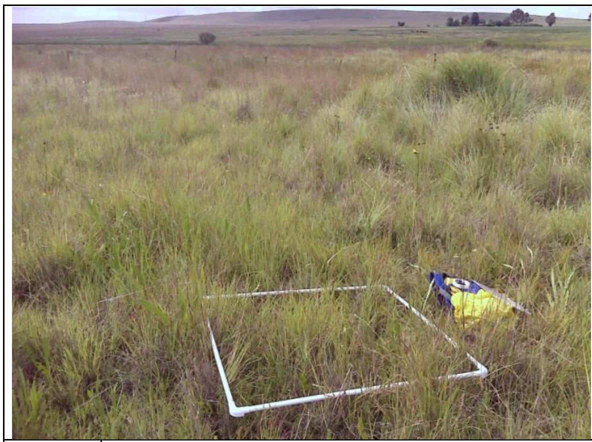
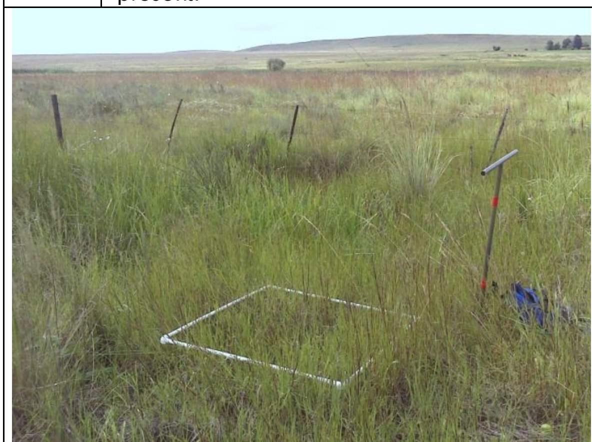
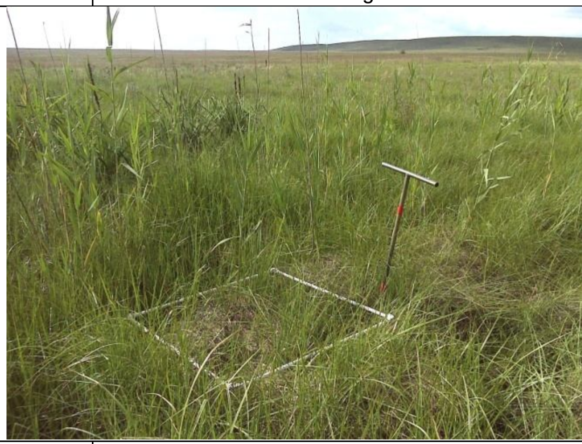
|---|---|---|---|
|  | |  | |
| Q12-01 | Grassland dominated area with species such as *T.triandra*, *A.appendiculartus* and *Eragrostis spp.* Being most dominant. Terrestrial forbs also common. | Q13-01 | Area dominated by terrestrial grasses such as *T. Triandra*, *E.chloromelus*, *E.curvula*, *H.turgidulum*, and *Setaria spp.*. *E.complanata* also common. |

| | | | |
|---|---|---|---|
|  | |  | |
| Q14-01 | Grass dominated area between old ridges. Soils appear temporarily wet at this point. | Q14-02 | Grass dominated ridge. |
|  | |  | |
| Q14-03 | Edge of ridge and furrow area close to inflow point of secondary seepage wetland. Dominated by grass species, principally *Eragrostis spp.* With some forbs and *T.triandra* present. | Q14-04 | Located between 2 berms downstream of Iplanned intervention. Area charachterised by a mix of grasses, forbs and species such as *F.complanata*. |
|  | |  | |
| Q15-01 | Grass dominated zone with Cyperus and other obligate wetland species in the nearby channel. Quad located just south of low point. | Q15-02 | Shallow drain dominated by wild rice grass (*Leersia hexandra*) but with occasional patches of *E. Curvula* and occasional *Kniphoffia* plants. |

<table>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Q15-03</td><td>Located within side channel of low lying area. Very diverse range of species including range of grasses and obligate wetland species.</td><td>Q16-01</td><td>Clearly disturbed area dominated by ruderal weeds with patches dominated by grass species such as T.triandra, A.lacnantha and Eragrostis spp.</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Q16-02</td><td>Area affected by historic ridge and furrow cultivation. Dominated by terrestrial grass species such as T. Triandra, Eragrostis spp. and terrestrial forbs.</td><td>Q16-03</td><td>Ridge and furrow area. Area dominated by Eragrostis spp. And forbs with some T. Triandra present.</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Q16-04</td><td>Area affected by ridge and furrow cultivation. Dominated by grass species including I.cylindrica, H.turgidulum and a range of forb species.</td><td>Q17-01</td><td>Clearly disturbed zone north of main channel. Dominated primarily by grasses and a range of terrestrial forb species.</td></tr>
</table>

| | | | |
|---|---|---|---|
|  | |  | |
| Q18-01 | Largely intact and diverse wetland community of obligate and facultative wetland species. | Q18-02 | Saturated area dominated by wild rice grass (*Leersia hexandra*). Remnants of old drain visible with some standing water. |
|  | |  | |
| Q18-03 | Recovering area north of main channel. Locally dominated by ruderal species and *Leersia hexandra* though quite variable in character in the surrounding area. | Q19-01 | Permanantly wet area dominated by obligate wetland species with some *Phragmites* present (though still limited at this point). |
|  | |  | |
| Q20-01 | Floodout area below drain in area unaffected by historic cultivation. *Leersia hexandra* dominates with some ruderal weeds and grass species present. | Q20-02 | Seasonally inundated area in line with large willow in maindrain. Area dominated by *L.hexandra*, with *H.turgidulum* and *Eliocharis spp.* Also common. |

## 9.4. Annexure 2C. Results of baseline vegetation monitoring in selected disturbance units.

Species were identified as far as possible[6] and classified into (i) alien vs. indigenous and (ii) functional groups (Table 1) as a basis for reporting changes over time.

**Table 1.** Criteria used to inform the delineation of wetland habitat based on wetland vegetation (adapted from Macfarlane et al., 2007 and DWAF, 2005).

| SYMBOL | HYDRIC STATUS | DESCRIPTION/OCCURRENCE |
|---|---|---|
| **ow** | Obligate wetland species | Almost always grow in wetlands (>99% occurrence) |
| **fw** | Facultative wetland species | Usually grow in wetlands (67-99% occurrence) but occasionally found in non-wetland areas |
| **f** | Facultative species | Equally likely to grow in wetlands (34-66% occurrence) and non-wetland areas |
| **fd** | Facultative dry-land species | Usually grow in non-wetland areas but sometimes grow in wetlands (1-34% occurrence) |
| **d** | Dryland species | Almost always grow in drylands |

A summary of the species composition of each disturbance unit is presented here. Figure 1 provides an indication of the hydric status od species encountered in each disturbance unit while Figure 2 provides an indication of the relative occurrence of alien and indigenous species. Detailed plot species data is available from SANBI on request.

[6] Note: Field guides for wetland plants are still under development in South Africa. The following guides were used in identifying wetland plants in the wetland assessed:

- Van Ginkel, C.E., Glen, R.P., Gordon-Gray, K.D., Cilliers, C.J., Muasya, M and van Deventer, P.P. 2011. Easy identification of some South African Wetland Plants (Grasses, Restios, Sedges, Rushes, Bulrushes, Eriocaulons and Yellow-eyed grasses). WRC Report No TT 479/10.
- Van Oudshoorn, F. 1992. Guide to grasses of South Africa. Briza Publikasies Cc, Arcadia.

In some cases, it was not possible to conclusively identify plants to species level.

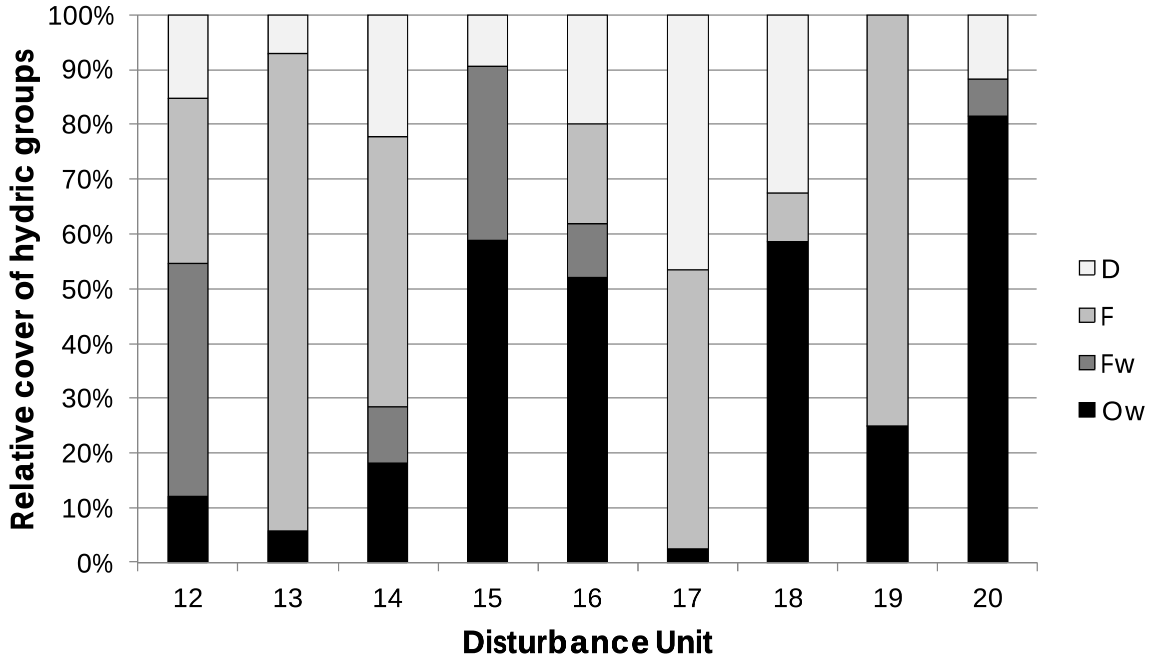



**Figure 1.** Relative cover of species belonging to different hydric groups in each disturbance unit assessed.

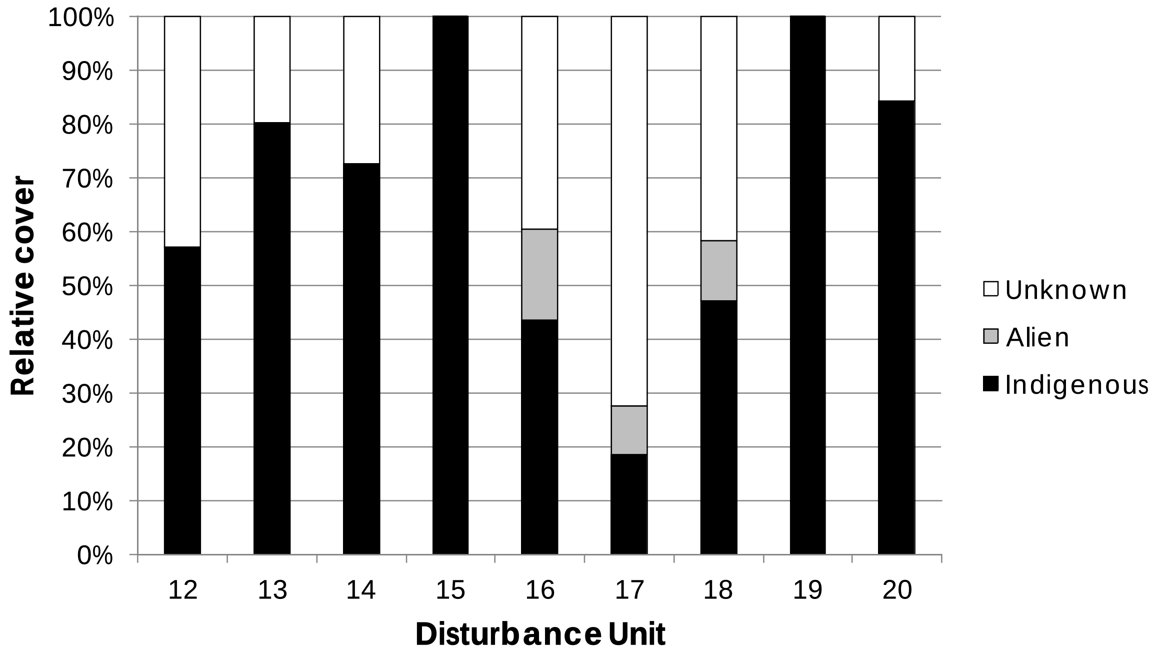
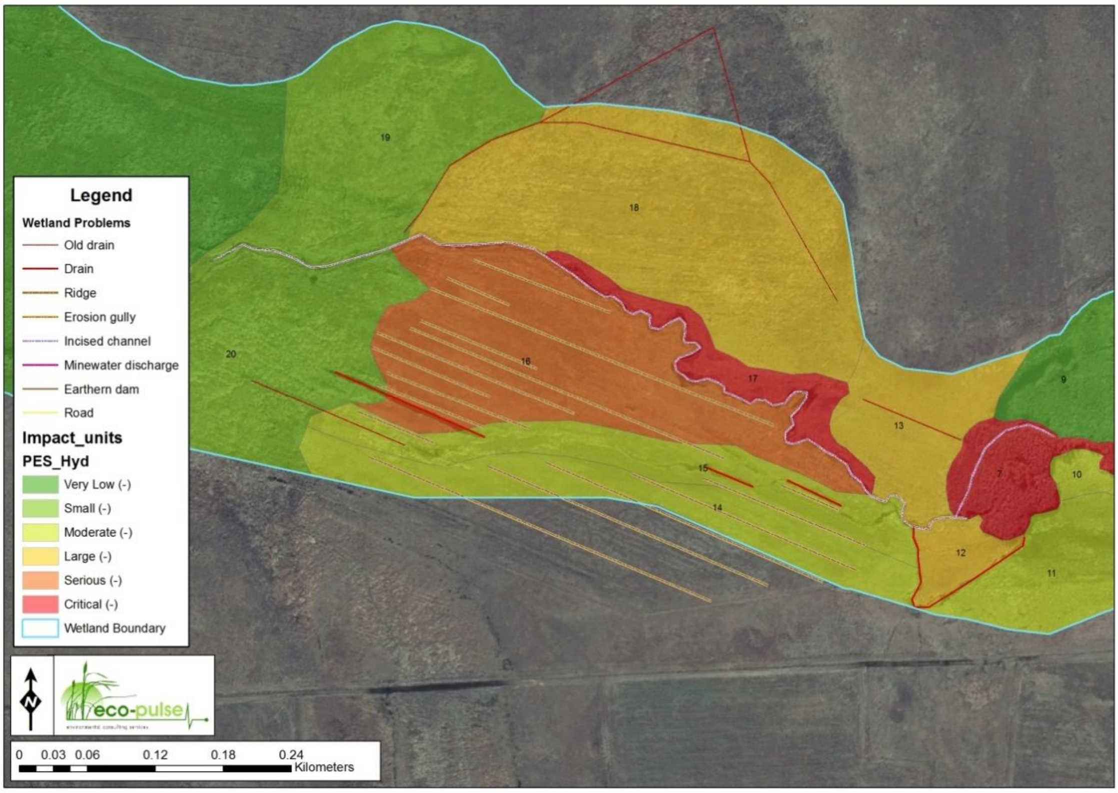



**Figure 2.** Relative cover of alien and indigenous species.[7]

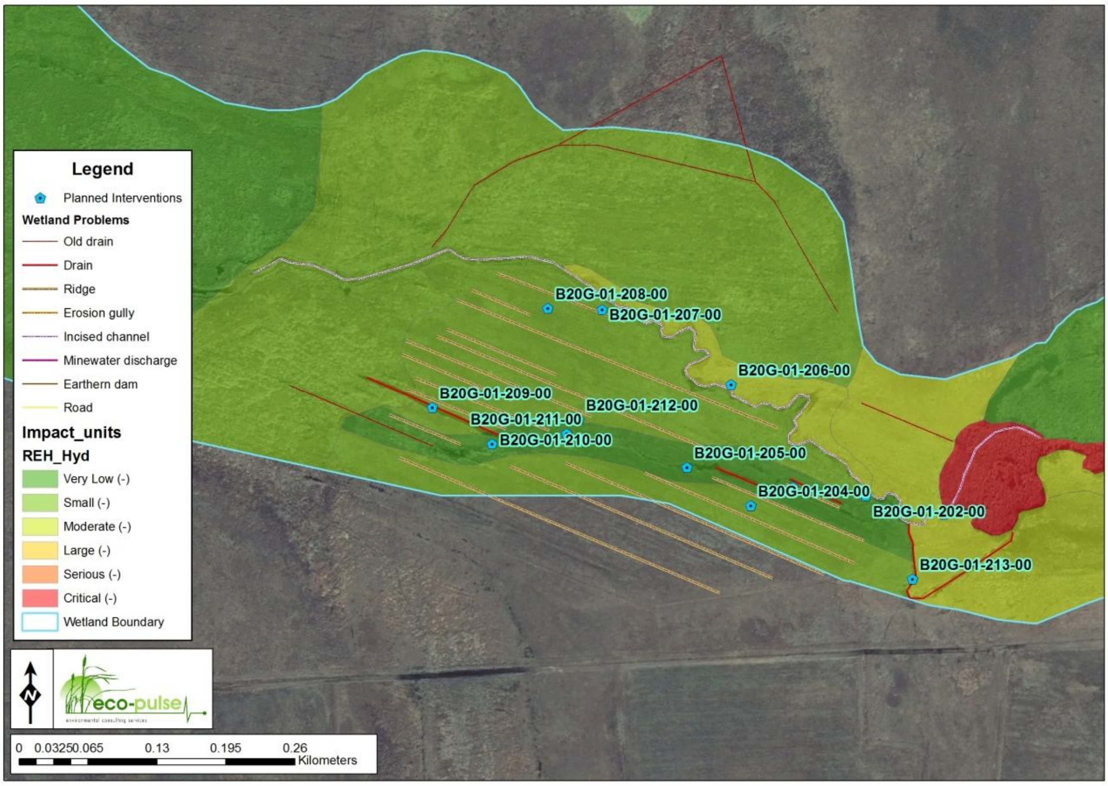
[7] Note: Unknown species refer to a range of forbs which were not identified to a species level.

## 9.5. Annexure 3A. Maps showing predicted impacts on water distribution and retention patterns with and without rehabilitation.

Without Rehabilitation

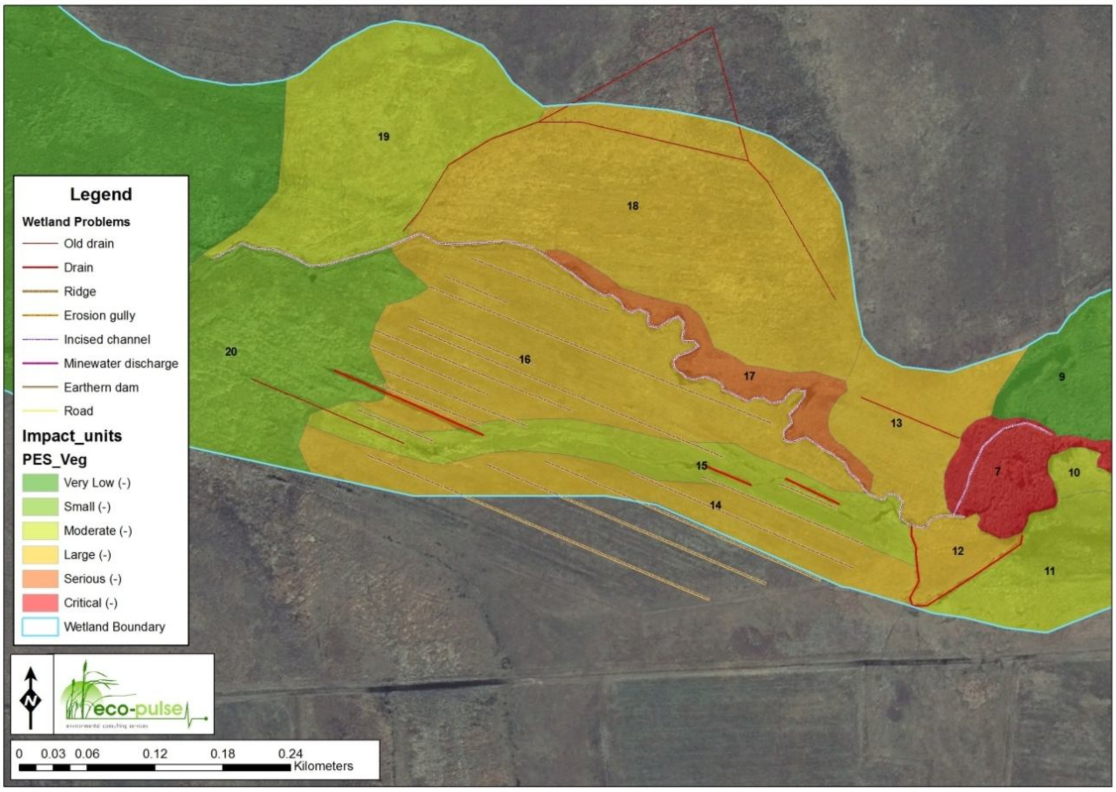



With Rehabilitation



## 9.6. Annexure 3B. Map showing predicted impacts to wetland vegetation integrity with and without rehabilitation.

Without Rehabilitation




With Rehabilitation