A STRATEGIC FRAMEWORK FOR IMPROVED WETLAND MANAGEMENT IN ETHEKWINI'S NORTHERN SPATIAL DEVELOPMENT PLAN AREA

Version 0.3

Date: December 2015

Report No: EP 181-01

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Suggested report citation:

Macfarlane, D.M., 2015. A strategic framework for improved wetland management in eThekwini's Northern Spatial Development Plan Area. Unpublished report prepared by Eco-Pulse Environmental Consulting Services. Version 0.3. December 2015.

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LIST OF ACRONYMS

BMZ	Biodiversity Management Zone
DMOSS	Durban Metropolitan Open Space System
NSDP	Northern Spatial Development Plan Area
DTPC	Dube TradePort Corporation
EPCPD	Environmental Planning and Climate Protection Department
EMA	eThekwini Municipal Area
FMZ	Functional Management Zone
NUDC	Northern Urban Development Corridor
NMT	Non-motorised Transport
SDF	Spatial Development Framework
SDS	Special Development Sites
SES	Sensitive Ecological Sites
SuDS	Sustainable Urban Drainage Systems
THD	Tongaat Hulett Developments

1. INTRODUCTION

1.1. *Overview of the project area*

The study area is located in the most northern extent of the eThekwini Municipal Area (EMA), contained within the Northern Urban Development Corridor (Figure 1). The area is designated as part of long term planning strategy as an important future urban node, incorporating industrial and commercial areas and a key transportation hub centred around the King Shaka International Airport located in the centre of the development area. Dube TradePort Corporation (DTPC) and Tongaat Hulett Developments (THD) are key landowners in this area and as such, have a central role to play in the future development of this node.

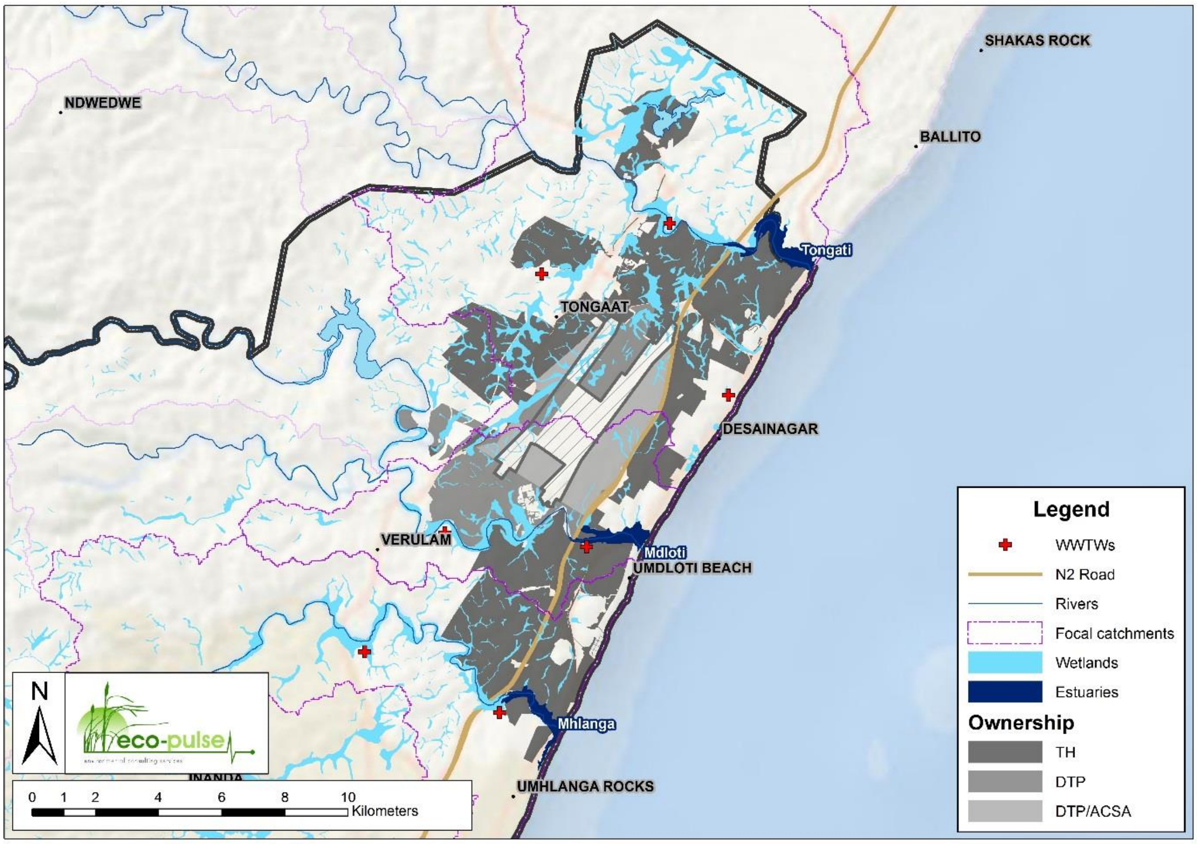


Figure 1 The eThekwini Northern Spatial Development Plan Area, showing in grey the initial focus areas for this project[1].

Economic growth and development has resulted in widespread exploitation of natural resources and a general erosion of natural capital across much of the eThekwini Municipality. This has been clearly demonstrated in the project area where historical agricultural practices have resulted in almost total destruction of natural habitats. This has been exacerbated through the establishment and expansion of human settlements and infrastructure

[1] At this stage, these guidelines have been specifically developed for land under DTPC and THD ownership. The applicability of these guidelines should ideally be extended beyond the footprints of these two developers to areas with similar sustainable development challenges in the Municipality.

which have altered hydrological regimes, increased pollution levels and created an increasingly hostile environment for natural biota to persist.

1.2. *A partnership for sustainable development*

The importance of sustainable development is enshrined in our constitution (Section 24) which obliges stakeholders - in civil society and government - to "secure ecologically sustainable development". The need to integrate social, economic and environmental factors into planning, implementation and decision-making are recognised as key to sustainable development. This cannot be achieved simply by environmental lobbies or government. It is therefore critical that partnerships be formed to translate the rhetoric of sustainable development into a workable practice.

TH, DTPC and eThekwini Municipality's Environmental Planning and Climate Protection Department, as key local role-players have therefore committed themselves to interact constructively in order to ensure that development of the region takes place in a manner that provides a model for government-private sector partnership that can deliver sustainable development. This is reflected through the meaningful collaboration achieved to date and common agreement to implement policies and practices that are underpinned by a new vision for the project area. The vision and objectives encapsulated by the following aspirational statements:

Overarching Vision:

- Cities should be designed as net producers of ecosystem services, by nurturing, restoring and mimicking nature.

Overarching Objectives:

- Create a new paradigm where urban development and ecological infrastructure nurture and support one another, to create flourishing cities that foster ecological and human well-being in an integrated manner.
- Develop a strategic framework and associated guidelines that demonstrates how to turn ecological constraints into development opportunities.
- Redefine the 'green line' (or the 'urban edge') from a conceptual tool that separates humans from nature, to becoming a tool that integrates humans and nature for the well-being of the whole.
- Create regenerative, resilient developments that function like a mature ecosystem to ensure that the relationship between ecology and urban development is one of cooperation, mutual support (symbiosis as in nature) rather than conflict.
- Identify current negative externalities associated with urban development, and redesign these to be positive externalities based on nature's models.
- Create a framework that embeds into planning processes the understanding that humans are part of nature, and not separate from nature.

Part of this vision, includes a commitment to develop a framework for wetland management in the study area that is compatible with this vision and recognises the critical role that these ecosystems play in securing a more resilient future.

1.3. *Purpose of this document*

Wetlands have been at the centre of debates around future development of in eThekwini's Northern Spatial Development Plan Area. Whilst the importance of these ecosystems is acknowledged by all parties, there is a need to formalise this understanding in a manner that provides a clear framework for improved wetland management and decision making in the study area. This document has therefore been compiled in order to clearly articulate the initial proposed policy objectives and implementation framework for wetland management in the study area. This framework should not be viewed as complete in its current form however, and has not been developed in order to address every potential challenge. Instead it has been compiled in order to initiate the development of a "living" framework that is inspirational, something that we can aspire towards in order to achieve a more sustainable future.

This framework, together with supporting documentation therefore effectively sets the scene for a series of collaborative working sessions with the clients, consultants and officials currently working to address these challenges, in order to strengthen the framework and ensure a robust outcome. Through subsequent engagement, it is hoped that the framework will be co-developed through learning cycles which are aimed at accommodating a broad variety of perspectives and knowledge types. This process of co-development will create ownership of the framework by those people that will be called to implement it, making it seamless to integrate into the processes of design and evaluation.

2. THEORETICAL BASIS FOR IMPROVED WETLAND MANAGEMENT

Meeting aspirations for a more sustainable future requires a shift in the way development is undertaken.
In the context of wetland management, this means that development needs to be underpinned by an understanding of ecological limits and that if development proceeds unchecked, it will have negative impacts both on human society and the natural environment. This section of the document provides a theoretical basis for local wetland policy interventions which responds to the local context of the project area.

2.1. *Ecosystem protection & biodiversity maintenance*

Setting ecological limits is commonplace in conservation practice and levels of transformation are typically used to define conservation targets for different ecosystems. In the case of wetlands, a national conservation target of 20% (of total area) per wetland vegetation group has been set (Nel *et.al.* 2011[2]). One is therefore able to report on the success of conservation actions from an ecosystem protection perspective by assessing the threat status of different wetland ecosystems.

The link between transformation and threat status is illustrated graphically in Figure 2, below. This shows two hypothetical scenarios depicting different rates of transformation and associated habitat loss. Under Scenario

[2] Technical Report: National Freshwater Ecosystem Priority Area (NFEPA)

1, transformation is relatively slow, but if unchecked, results in critical levels of biodiversity loss in the long term. Scenario 2 illustrates a process of more rapid decline. As loss continues, the importance of implementing policies and practices to safeguard remaining wetland habitat increases. If steps are not taken to counter ongoing impacts, sustainability thresholds for biodiversity are exceeded as reflected by a critically endangered (CR) threat status. Under such a scenario, rehabilitation is required in order to meet sustainability aspirations.

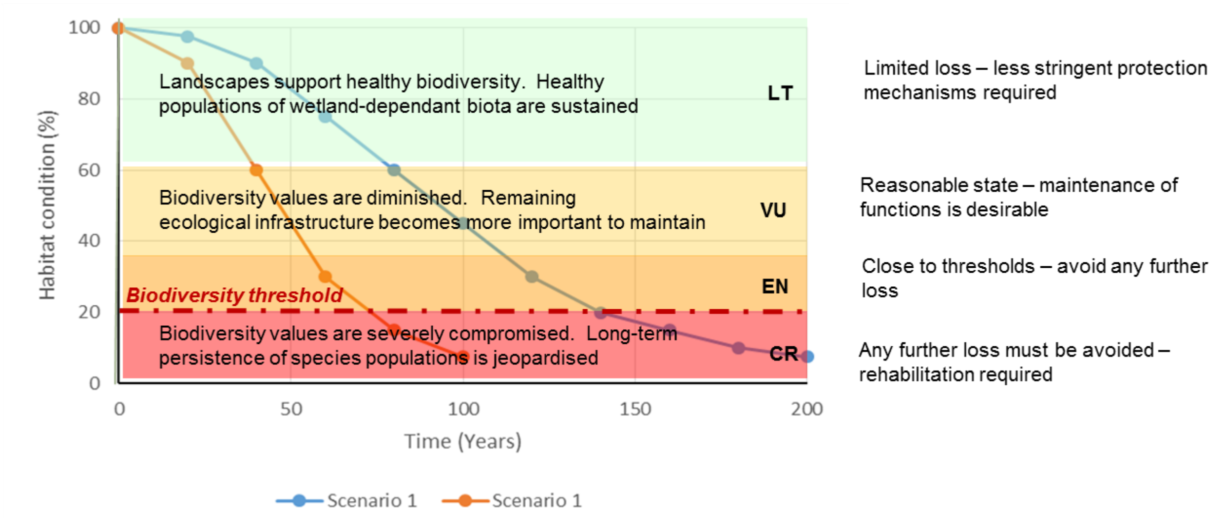


Figure 2 Ecosystem thresholds in relation to wetland habitat loss.

Widespread transformation and degradation of wetland ecosystems has been experienced across the country. These impacts are reflected in the National Biodiversity Assessment (Nel *et al.*, 2011) which showed that of South Africa's 791 wetland ecosystem types, 48% are critically endangered, 12% are endangered, and 5% are vulnerable with only 35% being classified as least threatened. Wetland loss has also been extensive within eThekwini Municipality, with wetlands in the study area falling within a critically endangered wetland vegetation group (Figure 3). Biodiversity thresholds for ecosystem protection have therefore been largely exceeded in the municipality.

The implication is that most wetlands in the study area have been significantly modified from their natural state. They have therefore lost much of their natural structure and functioning, and species associated with the ecosystem may have been lost. We are therefore in danger of losing the last remaining natural examples of these ecosystem types. National guidelines advocate that any further loss of natural habitat or deterioration in condition of the remaining healthy examples of these ecosystem types must be avoided, and the remaining healthy examples should be the focus of urgent conservation action (Nel *et al.*, 2011). This emphasises the importance of implementing policies that secure wetlands of high biodiversity value and ideally aim to reinstate biodiversity values where feasible. This is particularly important where wetlands contain species of conservation concerns such as the critically endangered Pickersgill reed frog (*Hyperolius pickersgilli*) which occurs in the study area.

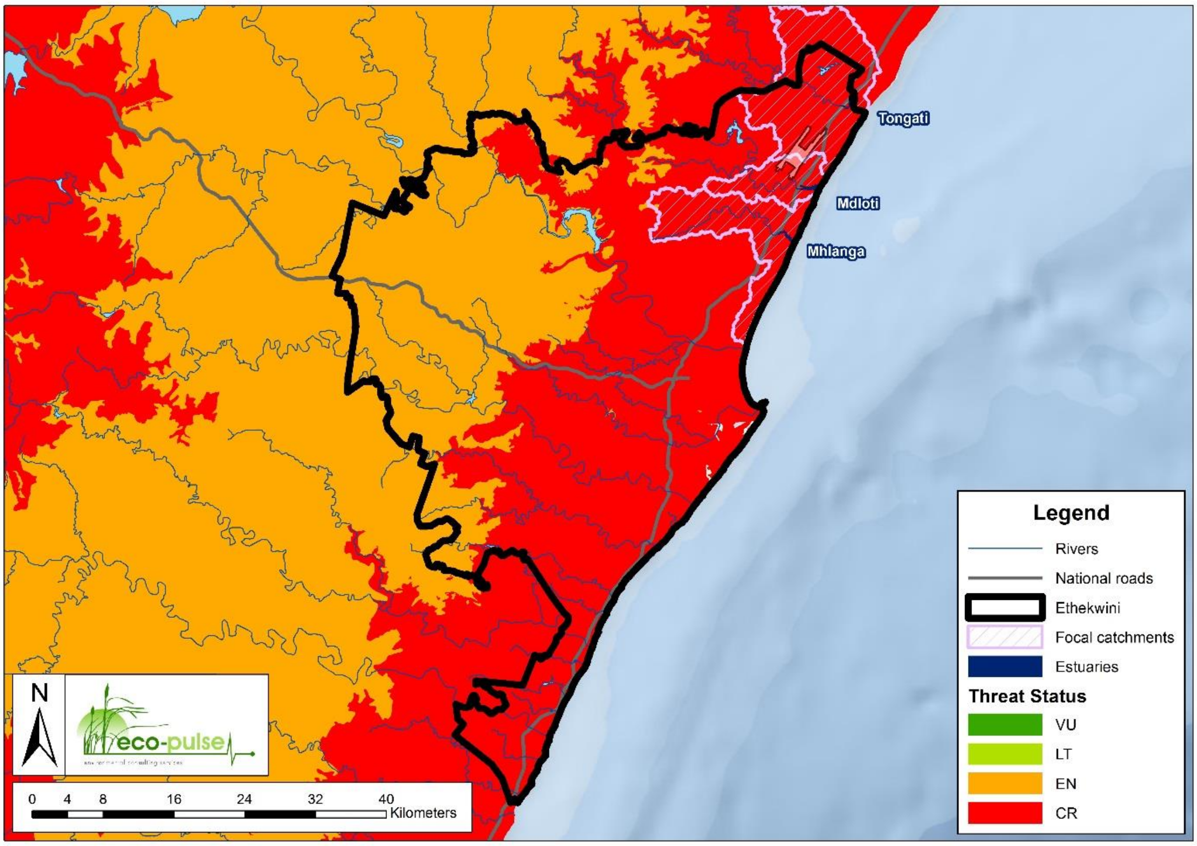


Figure 3 Threat status of wetland vegetation groups in the eThekwini Municipality.

Box 1: Policy implications: Wetland biodiversity

Transformation and loss of wetland habitat has reached a critical level, with wetland vegetation types in the study area recognized as being Critically Endangered. This has also impacted negatively on wetland biota with a number of wetland-dependent species recognized as being highly threatened. Management interventions within this planning domain should therefore seek to:

- Ensure formal protection and improved management of priority wetlands such as Lake Victoria and Froggy Pond;
- Enhance to viability of these areas by creating corridors and rehabilitating connected habitats in order to increase the extent of wetland habitat under formal protection;
- Implement management measures to ensure that development impacts to priority wetlands are minimized.

2.2. *Securing key functional values*

Wetlands are not only important from a biodiversity perspective but are widely recognised for the range of ecosystem goods and services they provide. Key regulating and supporting services include water quality enhancement and sediment trapping which helps to buffer downstream water resources (including rivers and estuaries) from upstream impacts. These services are also important to society in that functioning wetlands help to improve the suitability of water for domestic consumption and recreational use whilst flood attenuation functions helps to reduce risks to human health and built infrastructure.

As with biodiversity, a reduction in functional values provided by wetlands typically accompanies development as illustrated in the two development scenarios depicted in Figure 4. As long as wetlands continue to deliver functions in line with societies demands and ecological limits, some loss if wetland functions may be acceptable (above the sustainability threshold). Where wetlands can no longer deliver these functions, the sustainability threshold has been exceeded and further degradation will result in unacceptable impacts to water resources and downstream users.

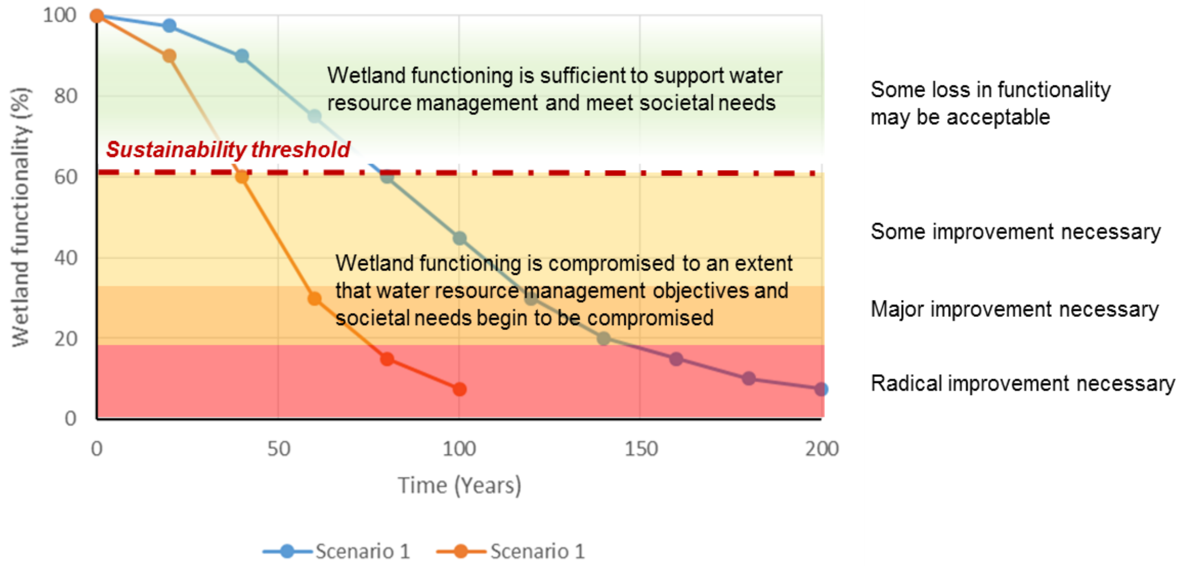


Figure 4 Sustainability thresholds for maintaining functional values provided by wetlands.

In the above example, the sustainability threshold for wetland functioning is set at 60%. This threshold is likely to be highly context-specific however and is responsive to the demand for the functions provided by wetlands in the landscape. This is demonstrated in Figure 5 which shows how the sustainability threshold (indicated by way of dashed line) could vary under different scenarios.

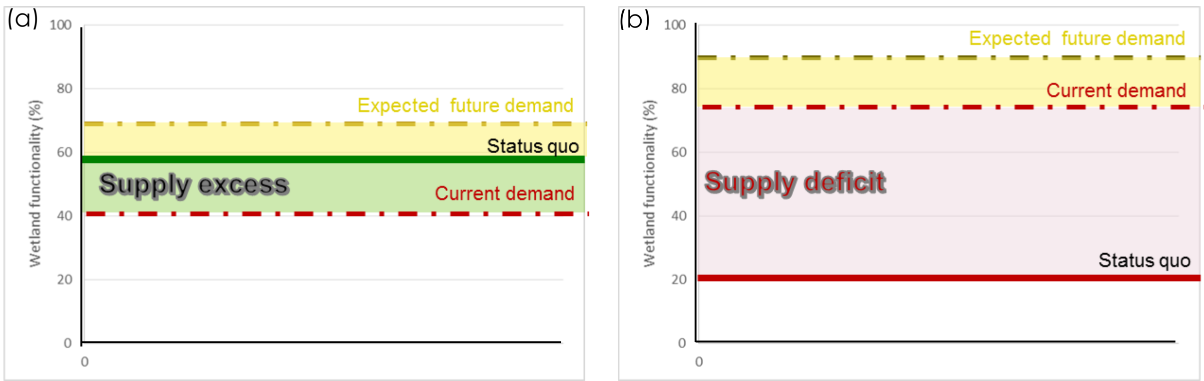


Figure 5 Supply and demand for wetland functions in (a) a typical rural agricultural landscape and (b) in a rapidly developing urban landscape.

In Figure 5 (a), the landscape is characterised by moderate levels of transformation; low pollution loads; low flood risk; and limited erosion. Despite some wetland loss, the demand for wetland functions may therefore be low such that the supply of benefits such as sediment trapping and water quality enhancement may exceed demand. Depending on expected future demand, there may not be an urgent need to improve wetland management in order to meet sustainable development aspirations.

In Figure 5(b) however, the demand for wetland functions is high and is linked to high pollution loads; increasing flood risk and widespread erosion and sediment loss that affects downstream users. Unfortunately wetlands have been highly degraded and are unable to meet current demands. Under such a scenario, there is a clear supply deficit which may worsen in response to future development plans. Under such a scenario, there is a clear need to rehabilitate wetlands in order to improve their functioning and to implement additional interventions to address anthropogenic impacts. For development to be sustainable, it is therefore important that the context of the development project be taken into account.

Within the study area, it is clear that water resource quality is deteriorating in response to growing human pressures and that there is a high demand for regulating and supporting services provided by wetlands. This is evident through the state of the downstream oHlanga, Mdloti and Tongaat estuaries as reported through recent studies (e.g. Demetriades *et al.,* 2007; *Forbes and Demetriades, 2010 and* DWA, 2013). Impacts to these estuaries includes very poor water quality conditions with serious implications for estuarine biota and recreational use activities. Whilst a range of scenarios are being investigated to address waste water impacts, further urbanization of the catchment is likely to place further pressure on these ecosystems. The demand for wetland functions in this landscape are therefore likely to remain high and possibly increase further over time.

Whilst the demand for these services is high, most wetlands have been heavily degraded (Figure 6), with wetland functioning estimated currently sitting at <40% in the Mdloti & oHlanga catchments and <20% in the Tongaat catchment. This results in a clear mismatch between supply and demand. It is therefore clear that sustainability thresholds for wetland functioning have been exceeded in the project area and that drastic action is required to ensure that the existing “supply deficits” are addressed. The implication is that a “no-net-loss” approach to managing wetland impacts is not sufficient and that a more aggressive policy approach is required to wetland management in the study area.

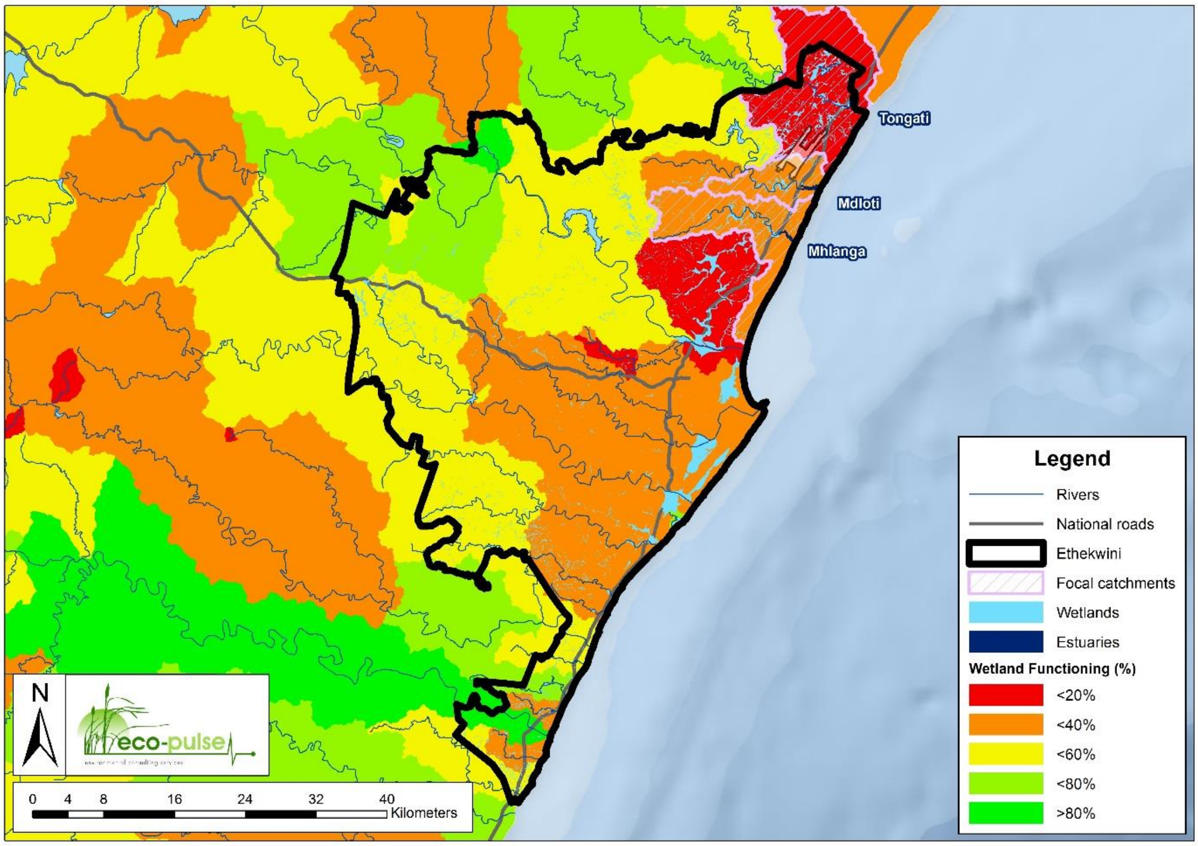


Figure 6 An overview of wetland functioning based on the NFEPA wetland dataset.

The typical response to development applications under a "no-net-loss" approach is illustrated graphically in Figure 7, below. In this instance, on-site wetland rehabilitation is only implemented under medium to high-impact scenario. Rehabilitation measures are also designed so as to compensate for residual impacts such that the functions provided by wetlands in a post-development scenario are no worse off than they would have been in the absence of development. Offsets are only required when impacts cannot be adequately mitigated on-site and aim to ensure no net loss of key ecosystem services at the broader landscape scale.

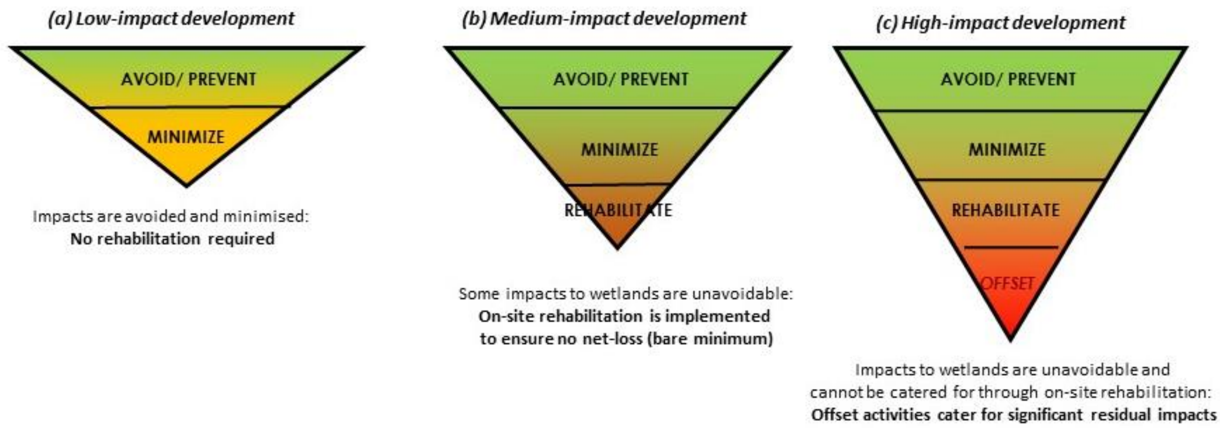


Figure 7 Typical approach to decision making under a "no-net-loss" approach.

The above approach is entirely valid in a situation where sustainability thresholds have not been exceeded as this will help to ensure that wetlands continue to deliver a sustainable supply of services in the landscape (Figure 8a). In situations where wetland functioning has been seriously compromised as is the case in the study area, application of a "no-net-loss" approach would not be appropriate. A more aggressive policy approach is required in order to ensure a "net-gain" in the functional values provided by wetlands (Figure 8b).

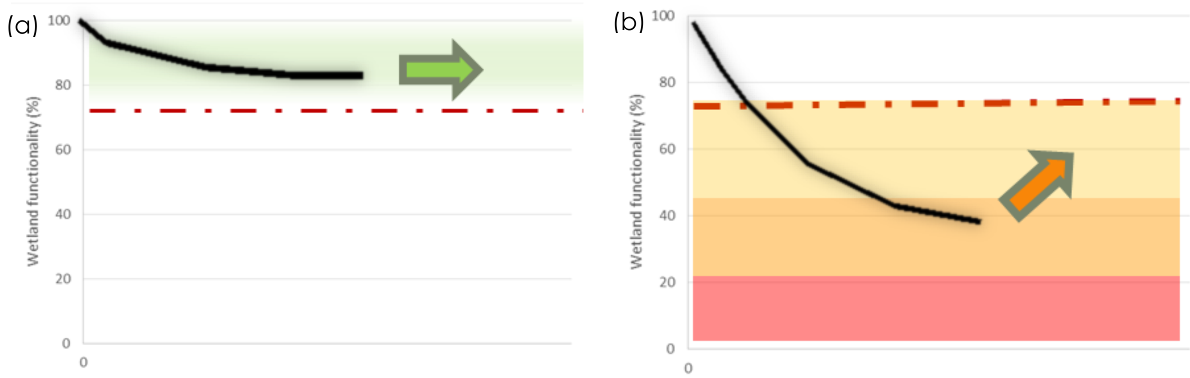


Figure 8 The implications of offset policies under (a) a "no-net-loss" and (b) "net-gain" approach.

The implications of a net gain approach is a more pro-active approach to wetland management and higher offset obligations for any negative impacts to wetland ecosystems. One option would be to apply considerably higher offset ratios to any developments that have a significant negative impact on wetland ecosystems (as per current ecosystem protection requirements). Whilst such an approach would have a net-positive benefit, an improvement in wetland management would only be triggered under a moderate-high impact development scenario. Following discussions with stakeholders, an alternative approach was adopted that recognises the importance of rehabilitating all remaining wetland habitat in order to have the best chance at meeting or getting close to sustainability thresholds (Figure 9). Put another way, it is assumed that in such a context the situation is so critical that all remaining wetlands needs to be rehabilitated to meet some semblance of sustainability i.e. only if the rehabilitation potential is fully realised can sustainability thresholds possibly be met. Thus, any wetland loss compromises the inherent potential of remaining wetlands in the landscape to meet such thresholds. As a result such loss needs to be offset in such a way as to reinstate the 'inherent rehabilitation potential / opportunity' that existed before such loss occurred. This is in line with the existing policy stance adopted by Ezemvelo KZN Wildlife who advocate wetland rehabilitation as a standard requirement for development applications in this landscape. Under this new approach, any wetland loss would need to be offset by not only compensating for the current functional values provided by wetlands but would also need to account for the potential losses associated with not rehabilitating targeted wetland ecosystems. This approach will ensure that the rehabilitation potential of wetlands is realised in the broader landscape if it cannot be fully achieved at a development site.

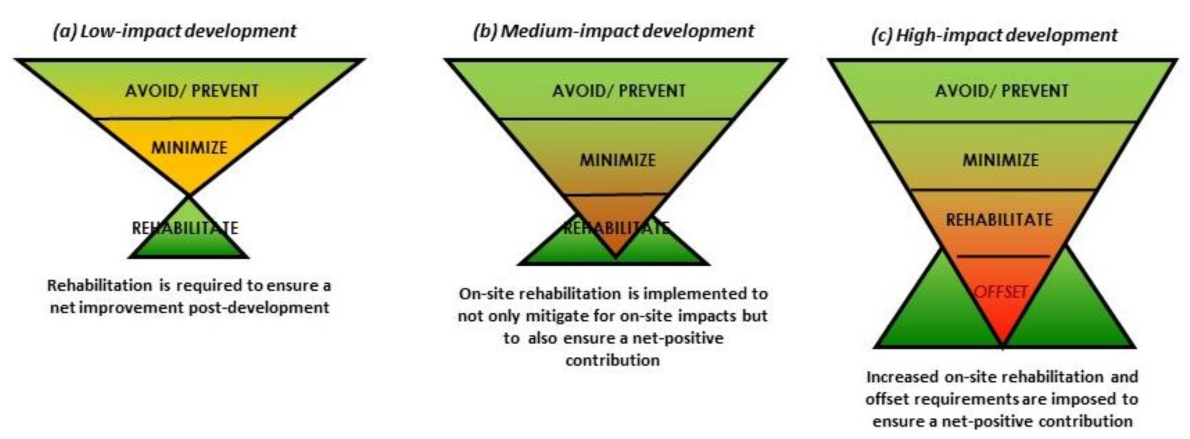


Figure 9 Proposed approach to decision making under a "net-gain" approach.

The cultural, educational and recreational values of wetlands and water resources must also be considered. At present, use is largely restricted to the estuaries and the Mt Moreland wetlands which provide important tourism and recreational opportunities. As development unfolds, an opportunity exists to enhance the aesthetic and social benefits provided by wetlands and to integrate these areas as part of an accessible public open space network.

Box 2: Policy implications: Wetland functioning

Human activities in the study area and upstream catchment have increased pollution loads, elevated flood risks and exacerbated erosion. This has negatively impacted water resources to the extent that biodiversity values, recreational use opportunities and regulating and supporting services provided by water resources including downstream estuaries have been severely compromised and can no longer meet ecological requirements and user expectations.

Wetlands are recognizing as key ecological assets in the study area. If correctly managed, they can provide valuable ecosystem services necessary to improve the state of water resources whilst also providing recreational and other use opportunities that can enhance human wellbeing. Interventions within this planning should therefore be designed to ensure that the potential key functions (water quality enhancement, sediment trapping and stormwater attenuation) of wetlands are realized in the landscape through appropriate on-site rehabilitation and associated compensation activities. Opportunities to improve the aesthetics and recreational use values provided by wetlands and to integrate these areas as part of an accessible public open space network should also be pursued.

3. VISION AND POLICY OBJECTIVES

A vision and associated policy objectives for wetland management in the study area have been developed in order to direct future decision making in the study area are presented below:

Vision:

To enhance and secure the biodiversity and functional values that wetlands provide as an integral part of an open space network that also delivers tangible societal benefits.

Policy Objectives:

- To manage priority wetlands so as to secure and enhance existing biodiversity and functional values.
- To ensure that impacts to wetlands are avoided as far as practicable through appropriate implementation of the mitigation hierarchy.
- To ensure that wetland functions are improved by integrating wetland rehabilitation as part of standard development practice.
- To promote innovative rehabilitation measures that enhance wetland functions where this is desirable and achievable.
- To ensure that offset activities adequately cater for reasonable functional and habitat enhancement opportunities lost as a result of development impacts.
- For developments to compensate for the loss of wetland habitat by making a meaningful and net positive contribution to wetland habitat restoration, protection and management through appropriate offset activities.
- To ensure that the viability of species of conservation concern is enhanced through wetland management activities.
- To specifically accommodate recreational use and enhance social values provided by wetlands as part of a functional open space network.

4. FRAMEWORK FOR IMPLEMENTATION

The vision for wetland management will only be realised if it is translated into a series of practical approaches and activities designed to give effect to the policy objectives outlined above. An implementation framework has therefore been developed in order to guide wetland management in the study area and includes:

- A wetland offset framework;
- Identification of strategic wetland offset receiving areas;
- A spatial hierarchy for wetland management; and
- Development planning guidelines.

An overview of these aspects is provided here, and is supported by a range of supplementary reports. The importance of applying an adaptive management approach and adjusting activities as required is also emphasised.

4.1. *Wetland offset framework*

The study area is located within the Northern Urban Development Corridor and will undergo substantial changes in landuse as development proceeds. Whilst application of the mitigation hierarchy must be adhered to as far as possible, impacts to wetland ecosystems are inevitable, particularly in areas earmarked for strategic developments. A standardised approach to wetland offsets is therefore required to bring consistency to the manner in which wetland offset requirements are assessed and to ensure that offset activities contribute meaningfully to the vision that has been articulated for the project area.

The national guidelines for wetland offsets[3] (SANBI & DWS, 2014) represent current best-practice in wetland offset design and are recognised as a useful starting point to inform offset planning in the study area. A number of substantial adjustments have however been made in order to accommodate the notion of "sustainability thresholds" and the need to implement policies and practices that result in a "net-gain" in wetland functions and habitat values. A strategic offset plan is also being developed in order to maximise potential gains that offset activities deliver in the landscape (See Section 4.2). A broad overview of the specific goals for wetland offsets in the study area, together with a description of changes that have been made to the national offset calculations is presented here.

4.1.1 Goals for wetland offsets

Establishing clear policy goals for wetland offsets is critical in order to inform wetland offset planning and implementation. **Goals for wetland offsets** have been based on the national guidelines but refined for the project area as outlined in Figure 10, below.

[3] Wetland offsets are defined here as enduring measurable conservation outcomes resulting from actions designed to compensate for residual adverse impacts on wetlands.

Water Resources and Ecosystem Services

To impliment a "net-gain" policy for offset activities that results in meaningful improvements in the ability of wetlands to supply key ecosystem goods and services in the landscape.

Ecosystem Conservation

To rehabilitate and formally protect a network of priority wetlands, riparian corridors and estuaries so as to make a positive contribution to meeting conservation targets for aquatic ecosystems.

Species of Conservation Concern

To specifically compensate for residual impacts on threatened or otherwise important (e.g. wetland-dependent) species through appropriate offset activities that seek to secure core habitats and improve the viability of species populations.

Figure 10 Goals for wetland offsets in the study area.

4.1.2 Assessing impacts and calculating wetland offset requirements

As outlined in the wetland offset guideline, there are three components that need to be specifically assessed when evaluating offset requirement: Water Resources and Ecosystem Services, Ecosystem Conservation, and Species of Conservation Concern (Figure 10). In each case, the significance of potential impacts needs to be assessed as part of the environmental authorization process, and offset requirements need to be calculated for any significant impacts on wetland ecosystems.

Water Resources and Ecosystem Services

Defining offset requirements for Water Resources and Ecosystem Services is based initially on an assessment of residual impacts which includes the extent of wetland impacted and the functional value of the affected wetlands. Given the local policy objective to specifically accommodate "opportunity loss", functional value is assessed based on the reasonable potential for wetlands to provide services rather than the functional values delivered by wetlands in their current state[4]. As such, offset requirements are not down-weighted for wetlands that are in a poor state but are based on a realistic rehabilitation state. The resultant value is then modified by a functional ratio to generate a final functional offset target, reported in terms of functional hectare equivalents (Figure 11).

[4] This approach differs from the National Wetland Offset Guidelines where functional value is assessed based on the present ecological state (PES) of the wetland prior to development.

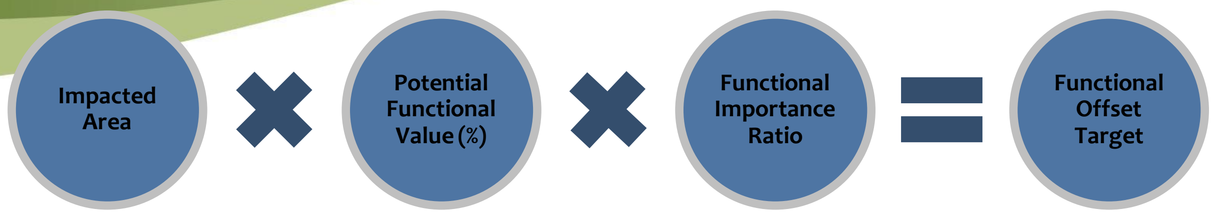


Figure 11 Offset calculation for determining offset requirements for water resources and ecosystem services.

The assessment of functional value is based on the new functional assessment methodology (Macfarlane and Edwards, 2015) and specifically integrates the importance of ecosystem services in the study area as part of the offset currency. To do so, the relative importance of different service groups provided by wetlands in the landscape needs to be evaluated. An overview of the weightings applied in the study area, together with a brief rationale is provided in Table 1, below.

Table 1. Rationale for weightings applied to service groups provided by wetlands in the study area.

Service Groups	Weighting %	Rationale for weightings applied
Flood Attenuation	10	Although little information is available on changes in flooding regimes, existing studies suggest that there has been a moderate increase in mean annual runoff (MAR) from the oHlanga catchment (+67.5%) whilst little change has been reported for either the uMdloti (-16.2%) or Tongaat (+0.6%) estuaries (DWA, 2013). The project area is located just inland from the coastline, with little downstream infrastructure or communities within flood lines that could be negatively impacted by flood events. Given the minor risks associated with flooding in the study area, flood attenuation services provided by wetlands in the landscape are not regarded as particularly important. With plans to limit development around wetlands and main river systems, future flooding risk is likely to remain low.
Streamflow Regulation	10	Stream flow regulation refers to the contribution that wetlands make towards sustaining stream flows during dry periods. This has implications for downstream water resources and downstream users, particularly if low flows have already been significantly impacted by catchment activities. Within the study area, existing studies suggest that base flows entering the oHlanga estuary have doubled while there has been a slight reduction of base flows reaching the Mdloti estuary and no noticeable change to flows reaching the Tongaat estuary (DWS, 2013). This suggests that base flows have not been impacted to a critical degree, as is the case with water quality, for example. Downstream users are also limited, with no direct abstraction for agricultural or domestic use. It is also important to note that wetlands are conduits of water in the landscape, and that most wetlands in the landscape are unlikely to be particularly well suited to providing this function (they do not frost back during the winter months, are generally not characterized by peat accumulation and are not located on underlying geologies with strong surface-groundwater linkages).
Sediment Trapping & Erosion Control	20	Whilst little information is available on sedimentation of estuaries and downstream water resources, development and agricultural activities in the catchment are likely to have significantly increased soil loss from the catchment. Whilst such sediment would accumulate in estuaries, breaching during high flows is likely to flush out excess sediments, thus limiting the potential long-term impacts of increased sediment inputs. Sedimentation can increase turbidity, smother natural habitat and alter the profile of wetland areas however and as such, sediment trapping and erosion control functions of wetlands are still regarded as being relevant in the study area.
Water Quality Enhancement	60	Increased nutrient inputs from wastewater treatment have caused eutrophication across all the estuaries in the study area. Emergent species thrive under these conditions and invasive aquatic macrophytes such as water hyacinth (*Eicchornia crassipes*) and water cabbage (*Pistia stratiotes*) outcompete indigenous plants

Service Groups	Weighting %	Rationale for weightings applied
		(DWS, 2013). Research suggests that these nutrient inputs have had far reaching impacts on other estuarine biota such as fish, with fish kills having reported in recent years in both the Mdloti and oHlanga estuaries (Bundy *et al.*, 2010). The small size of these estuaries also make them sensitive to water quality impacts as pollutants accumulate during periods of mouth closure. Managing water quality impacts which includes improving the functioning of wetlands in the landscape is therefore regarded as critical to efforts to improve the condition of water resources in the study area.

The demand for key regulating and supporting services is also used as a basis for defining the functional importance ratio of the affected wetland (Table 2). By following this approach, loss of wetlands located in critical catchment contexts (high local demand scores) are therefore regarded as more significant (with higher offset requirements) than those located in contexts with low local demand. Loss of wetlands located in critical catchment contexts (high local demand scores) are therefore regarded as more significant (with higher offset requirements) than those located in contexts with low local demand.

Table 2. Overview of functional importance ratios used to in offset calculations (Macfarlane and Edwards, 2015).

Ratio	Rationale
0.75	Wetlands located within a context where they provide very limited benefits to society
1	Wetlands quite poorly placed to address key water-resource challenges
1.25	Wetlands are well positioned to address key water-resource challenges
1.5	Wetlands located in critical areas, where wetland functions are particularly important

In summary then, offset requirements for wetland functioning are calculated as follows:

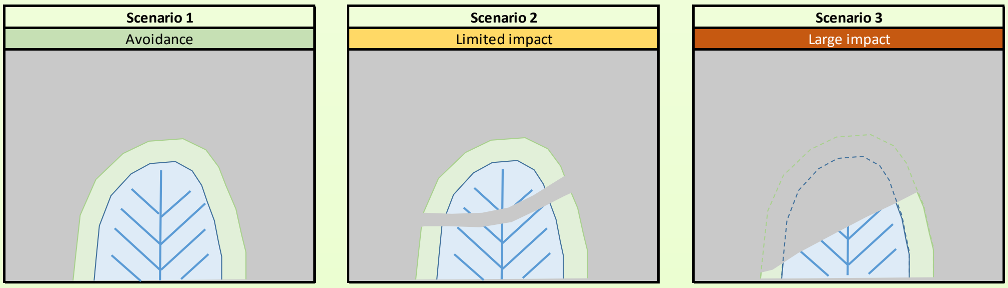
1. Delineating the wetland that will be impacted by the proposed development.
2. Calculating the predicted wetland functionality (as a percent) based on a realistic rehabilitation state and the area of wetland over which this impact will apply.
3. Calculating the functional importance ratio based on the landscape context and local demand.
4. Multiplying the area of wetland, functionality (%) and functional importance ratio to calculate the number of functional hectare equivalents that will be required.

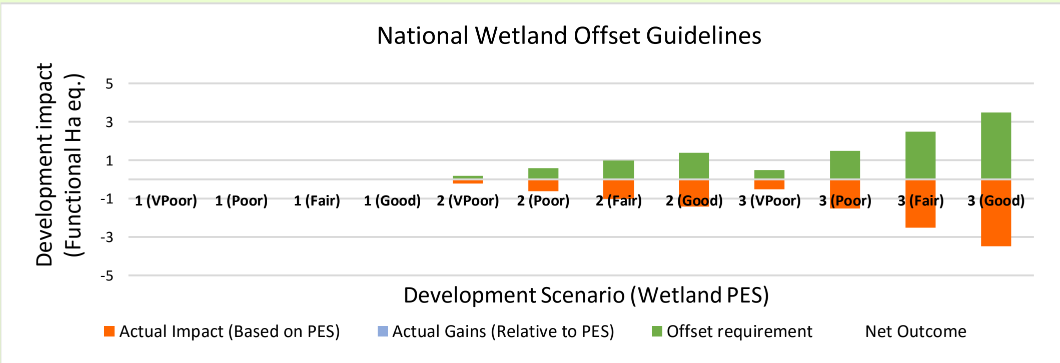
In order to demonstrate "proof of concept", the outcomes of applying this approach were contrasted to the typical "no-net-loss" approach by comparing outcomes based on a number of hypothetical development scenarios (Box 3). This included complete avoidance of wetlands through careful planning (Scenario 1) through to developments with significant direct impacts (Scenario 3). In each case, wetland area was taken as 10ha with the extent of direct impacts under each scenario ranging from 0 to 5ha. These scenarios were further refined by considering wetlands ranging from "Very Poor" functionality (10%) through to wetlands with "Good" functionality (70%) prior to development. It was further assumed that an attainable state of 60% across all wetlands could be achieved through reasonable rehabilitation efforts apart from those with "Good" functioning which were assumed to not require any active rehabilitation

Box 3: Contrasting expected functional outcomes under the proposed “No opportunity loss” approach relative to a typical “No-Net-Loss” approach

Application of a “no-net-loss” approach

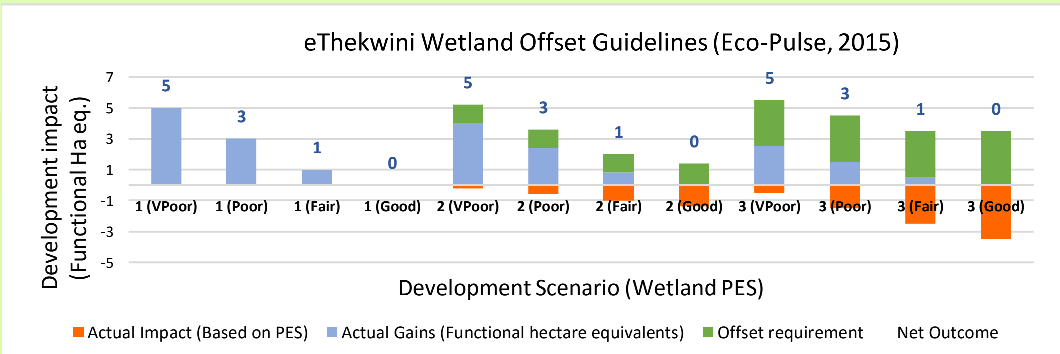
The expected outcomes associated with applying the national wetland offset guidelines (SANBI & DWS, 2014), are presented below. This shows that when applying a "No-net-loss" approach, gains are directly commensurate for losses, with no net improvement in functional value at the landscape scale. It is also worth noting that offset requirements could be avoided if on-site rehabilitation activities could be undertaken to address residual impacts.





Application of a proposed “No opportunity loss” approach

The outcomes of applying this revised approach are strikingly different. Where development impacts are avoided, functional gains are achieved through the implementation of reasonable rehabilitation measures. This essentially reflects the realistic “opportunity” for functional enhancement under a new landuse scenario and therefore reflects the desirable “Net Outcome” for each development scenario (4 blue bars on left of graph). Where direct impacts occur, the opportunity for on-site rehabilitation is foregone, giving rise to additional offset liabilities which are commensurate to the lost opportunities (rather than the actual impact). On-site rehabilitation is also implemented to ensure that realistic on-site gains can be achieved as far as possible.



Ecosystem Conservation

Whilst guidelines for biodiversity offsets are still under development, the primary purpose of a biodiversity offsets as reflected in emerging national policy is to contribute to the conservation estate, in accordance with the National Protected Areas Expansion Strategy (e.g. DEA, 2015). Under this "Managed draw-down" approach, habitat loss is essentially traded for improved habitat protection rather than incentivising the rehabilitation of degraded habitats. This approach to habitat loss is also reflected in the National Wetland Offset Guidelines, where ecosystem protection targets are based on (i) the area of wetland impacted, (ii) change in habitat condition and (iii) an ecosystem conservation ratio (SANBI & DWS, 2014).

Given the critically endangered status of wetlands in the project area, it is clear that rehabilitation is required in addition to protection to ensure a net gain in wetland habitat suitable for wetland-dependent biota. For this reason, the approach taken to assess offset requirements is aimed at ensuring a no-net-loss of rehabilitation potential. Offset requirements are therefore calculated on the same basis as functional targets (Figure 12).

Figure 12 Offset calculation for determining offset requirements for ecosystem conservation.

The potential habitat value is typically assessed using the vegetation module of WET-Health (Macfarlane *et.al.* 2008). This value (expressed as a %) is then multiplied by the area of wetland affected (in hectares) to give a basic indication of the offset required for Ecosystem Conservation in habitat hectare equivalents.

Species of Conservation Concern

Offset requirements for species of conservation concern may also be triggered in situations where development will have a significant negative impact on important wetland-dependent biota. Determining appropriate offset targets needs to be undertaken by an appropriate specialist with reference to the guidance provided in the national wetland offset guidelines (SANBI & DWS, 2014).

Figure 13 Offset calculation for determining offset requirements for species of conservation concern.

4.1.3 Assessing gains from proposed offset activities

The assessment of gains from proposed offset activities also reflects the shift in thinking with a focus on ensuring that opportunities for improving the functional and habitat value of wetlands is realised. A brief overview of the assessment framework is provided here, with reference to the National Wetland Offset Guidelines as appropriate.

Water Resources and Ecosystem Services

The assessment of functional gains for offset receiving areas follows the same approach applied to impacted sites with gains in functional value being calculated based on the expected improvement in ecosystem functioning relative to baseline conditions (Figure 14)[5]. The improvement in functioning is then simply calculated by subtracting the current functional value score from that expected following successful rehabilitation.

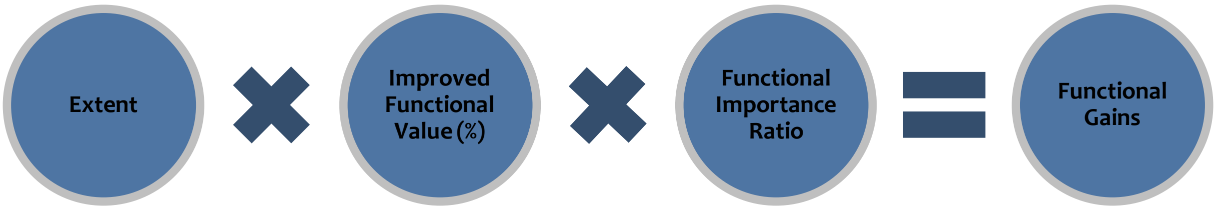


Figure 14 Outline of the approach used to assess functional gains from planned offset activities.

The preliminary offset gains are then adjusted based on the functional importance ratio of the targeted wetland (See Table 2). By following this approach, preference is given to wetlands located within scenarios with high demand for regulating and supporting services[6].

In summary then, the anticipated contributions to meeting functional targets are calculated by:

1. Delineating wetlands within the offset site.
2. Calculating the predicted change in wetland functionality (in percent) as a result of proposed offset activities and the area of wetland over which this change will apply.
3. Calculating the functional importance ratio based on the landscape context and local demand.
4. Multiplying the area of wetland, functionality change (%) and functional importance ratio together to calculate the number of functional hectare equivalents that will be gained.

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[5] It is important to note that the no adjustment has been made to functional gains to account for risks associated with offset implementation. The rationale for this is that (i) a similar risk is typically associated with on-site rehabilitation and was not used as a basis for down-weighting residual impacts; (ii) offset targets are already onerous and application of an additional adjustment factor would be unfair to the developer and (iii) by implementing a composite offset and by applying strict monitoring and management measures, the risk of rehabilitation failure is likely to be low.

[6] This approach is in line with the national wetland offset guidelines which have specifically highlighted the importance of selecting offset sites that are well placed to improve key ecosystem services.

Ecosystem Conservation

When accounting for offset contributions, ecosystem conservation gains are based largely on contributions made to enhance wetland habitat. Simply fencing off and managing an intact wetland therefore contributes little towards ecosystem protection targets under this approach whereas rehabilitation of highly degraded habitats provides the most substantial gains[7]. It is also important to note that actions to enhance and protect wetland and buffer zone habitat may contribute towards ecosystem conservation targets[8].

An overview of the approach used to assess offset contributions is outlined in Figure 15, below. Wetland contributions are essentially assessed based on the extent of wetlands targeted and the change (improvement) in habitat value brought about through rehabilitation and management measures. As with impacted sites, this assessment is undertaken using the vegetation module of WET-Health (Macfarlane *et.al.*, 2008). This should ideally be supplemented with a floristic survey to record baseline conditions and track recovery of wetland vegetation in clearly delineated disturbance units. The wetland contribution may then be adjusted to cater for the level of security and length of formal protection that is being applied to the site[9].

Buffer contributions are then based on the extent of buffer zones secured and the compatibility of these areas as a support zone for biodiversity. These contributions may again be adjusted to account for the levels of protection provided[14].

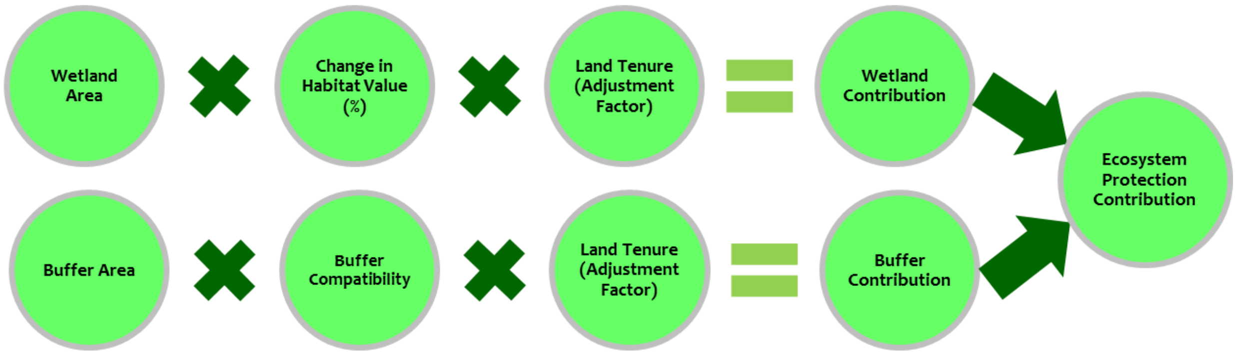

Figure 15 Outline of the approach used to assess ecosystem conservation gains from planned offset activities.

In summary then, the anticipated contributions to meeting ecosystem protection targets are calculated by:

1. Delineating wetlands within the offset site.

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[7] Note: There is a concern here that there is little incentive to protect and manage remaining examples of intact habitat under this approach. ***This issue will need to be discussed with Ezemvelo KZN Wildlife to ensure that the offset framework stimulates the most appropriate offset activities in this context.***

[8] Buffer zone contributions are capped to 1/3 of offset contributions for any wetland to ensure that offset activities are primarily directed towards enhancing wetland habitat.

[9] The need to introduce an adjustment factor in this context is questionable and will need to be ***discussed further with Ezemvelo KZN Wildlife.***

2. Calculating the predicted change in habitat value (in percent) as a result of proposed offset activities and the area of wetland over which this change will apply.
3. Deciding on any adjustment factors to account for security of tenure.
4. Multiplying the area of wetland, change in habitat value (%) and any agreed adjustment factors together to calculate the wetland habitat contribution in habitat hectare equivalents.
5. Delineating an agreed buffer zone around targeted wetlands (up to a maximum of 500m from the wetland boundary).
6. Assessing buffer compatibility that can be realistically achieved through rehabilitation and management activities.
7. Multiplying the buffer area, buffer compatibility score and any agreed adjustment factors together to calculate buffer contributions in habitat hectare equivalents.
8. Calculating final offset contributions by summing wetland and buffer contributions[13].

Species of Conservation Concern

As per the national guidelines for wetland offsets (SANBI & DWS, 2014).

4.2. *Identification of strategic wetland offset receiving areas*

Based on initial engagements with project partners, it is likely that large wetland offsets will be required in order to compensate for anticipated development impacts in the study area. Implementation of this wetland offset framework will therefore stimulate the rehabilitation, management and protection of wetlands in the project area. An opportunity therefore exists to take a landscape view and to direct offset activities towards strategically placed wetland offset receiving areas which are established to meet any offset obligations generated through development applications in the study area.

4.2.1 Benefits of consolidated offset sites

The benefits of pooling resources in order to maximise conservation outcomes are logical and have been discussed in some detail in a recent report on conservation banking[10] by Von Hase (2013). Some of the key ecological benefits that have been highlighted include:

[10] Conservation banking is a mechanism used to deliver conservation outcomes through activities that protect, restore and/or enhance biodiversity, and specifically where these outcomes are required to compensate for or offset residual impacts by development projects on biodiversity / natural resources. The concept of conservation banking is therefore closely linked to compensation and offsetting. However, conservation banking is just one way of providing compensation or offset outcomes. One of the things that sets conservation banking apart from other delivery mechanisms is that conservation measures and outcomes are translated into 'biodiversity credits', according to a set of clear rules. These rules include a pre-determined, specific metric / currency for credits and debits, definition of a geographic area in which trades (i.e. credit-debit exchanges) are allowed to occur as well as the specifics regarding the timeframe, etc.

- The conservation of larger consolidated areas, thereby limiting piece-meal approaches with small sites spread throughout the landscape that may fail to consider strategic biodiversity conservation considerations (clustering outcomes spatially);
- The ability to specifically target and improve connectivity and so improve the viability of habitat for species of conservation concern.

While the ecological benefits make a strong case for consolidated offset sites, there are also a range of practical and economic benefits that should also be considered:

- The delivery of efficient, faster and effective offset / compensation requirements which means there is no or less of a delay in the provision of offsets relative to the impacts, and development processes can be streamlined because credits are readily available when needed;
- The potential for more efficient, streamlined and strategic land use planning and decision-making processes; and
- The ability to take advantage of economies of scale which leads to significant cost savings which can benefit various actors. Thus:
  - for applicants (and potential service providers) economies of scale arise when establishing and running the bank / offset sites, in terms of securing the land, investing in assessments and drawing up management plans, putting in place financing arrangements, and in undertaking conservation activities and other operational activities;
  - for the institutions/ regulators involved in terms of administering and overseeing offset projects (M&E of sites and actors).

4.2.2 Criteria used in prioritising potential offset receiving areas

Whilst the establishment of composite offset sites has a range of potential benefits, it is important that site selection is carefully undertaken to ensure that ecological benefits are realised and that the anticipated outcomes address a specific set of predicted impacts. An analysis of wetland priorities was undertaken in June 2015[11] (Biomimicry SA, 2015). Key ecological criteria that emerged from this analysis included:

- Safeguarding key wetland priority areas;
- Enhancing connectivity in order to improve resilience;
- Supporting enhanced estuarine functioning; and
- Targeting key functional features in the landscape.

Another key aspect that needed to be considered, was the cost and practicality of securing these areas. Land ownership was therefore a key consideration in the site selection process. Fortunately, a range of spatial information was available for the study area which was used to help identify priority areas for offset implementation.

[11] Participants included Doug Macfarlane (Eco-Pulse), Craig Cowden (Ground-Truth), Warren Botes (eThekwini), Shannon Royden-Turner (In/formal South) and Claire Janisch (Biomimicry SA)

Safeguarding key biodiversity areas

A range of information sources was used to guide the identification of key biodiversity areas in the study area. This included information on wetland condition and priorities, existing conservation initiatives and areas of importance for terrestrial conservation. These information sources are presented in a series of figures and are supported by a brief explanation of the data in relation to the relevance to the site selection process. The first figure illustrates the condition of wetlands, and shows the location of key water resources in the study area.

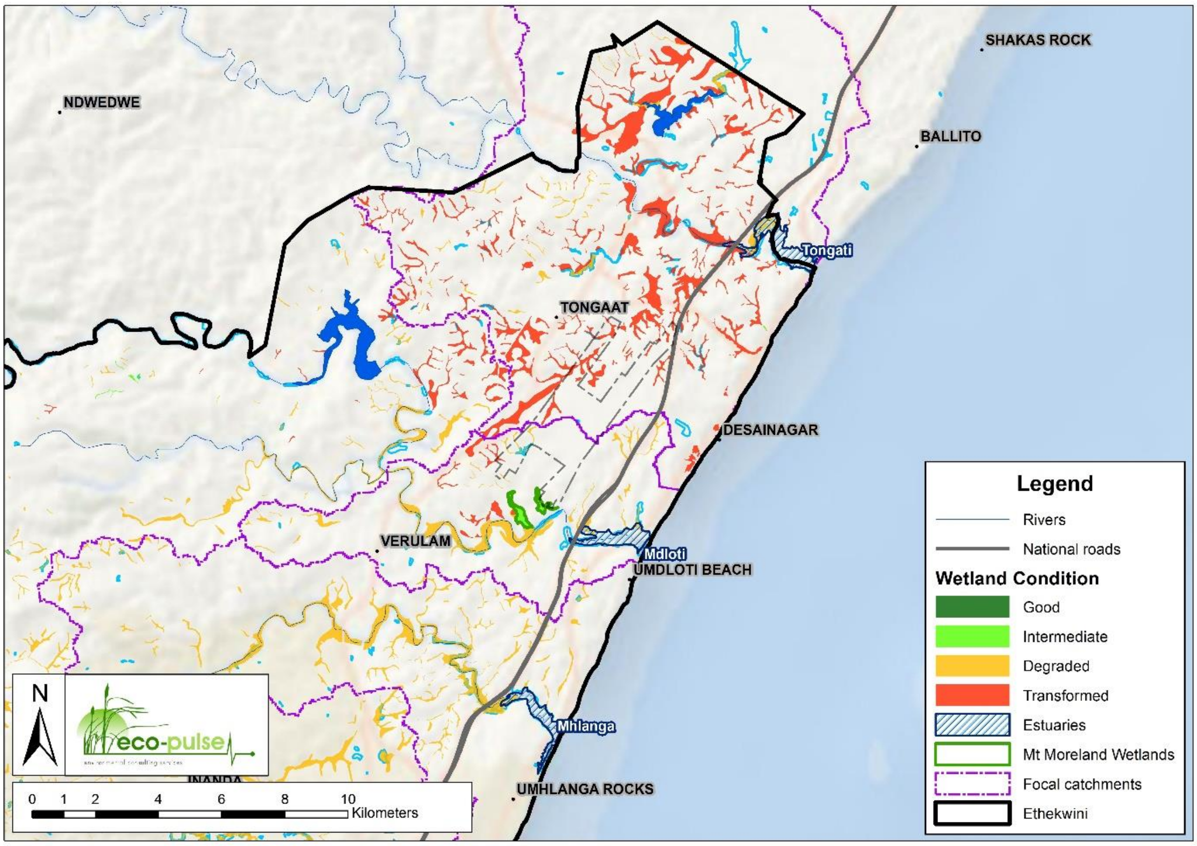


Figure 16 Key aquatic conservation priorities in the study area.

NFEPA Wetlands: Priority wetland and aquatic systems were identified through the National Freshwater Ecosystem Priority Areas (NFEPA) project (CSIR, 2010). This assessment highlighted the section of the Mdloti River upstream of the target catchment as a priority for river conservation and identified a number of wetland priorities in the study area. Whilst the concept of identifying priority areas to meet aquatic conservation targets is well understood and is generally supported, this information correlates poorly with more detailed assessments however and was therefore not considered further as part of the site selection process.

Wetland Condition: The information on wetland condition was obtained from eThekwini Municipality and is based on desktop mapping and interpretation. This clearly shows that most wetlands in the study area are in a transformed or degraded state, with no wetlands classified as being in good condition in the study area. The only two wetlands in intermediate condition are the two Mt Moreland wetland systems which are recognised as priority wetlands in the eThekwini Municipality (See below). It is worth noting however that large areas of wetland habitat has been identified along the main Mdloti and oHlanga rivers which are in a degraded, rather than transformed state.

Mt Moreland Wetlands: These wetlands are amongst the most important (priority) wetland systems in eThekwini Municipality and the only priority wetlands recorded by eThekwini in the target catchments[12] (Warren Botes, 2015, *pers. comm*.). Amongst others, the principle reasons for their high importance value is related to the presence of a large population of migrant European Barn Swallows and the diversity of frog species, including the presence of endangered frog species. According to Harvey (2007), on a local scale, given the large-scale loss and degradation of natural habitats along the KwaZulu-Natal coast, it is likely that the area holds significant populations of many species that are rare elsewhere within the greater Durban region. However, the site is more significant on a national scale because of the presence of several threatened species, including *Hyperolius pickersgilli* (Critically Endangered), together with a large population of *Afrixalus spinifrons* (Near Threatened), *Hemisus guttatus* (Vulnerable) and large numbers of *Leptopelis natalensis* (KZN endemic). Given the significance of these wetlands, it is logical for efforts to focus on improving the condition of wetlands in close proximity to these ecosystems in order to increase connectivity and the area of habitat available for threatened species already known to utilise these wetlands.

Enhancing connectivity in order to improve resilience

Given that wetland offset activities provide an opportunity to enhance biodiversity values, it is important to consider opportunities to build on existing conservation efforts and terrestrial conservation priorities (i.e. provide outcomes that are over and above already anticipated or realised conservation outcomes from these activities such as linking existing reserves in the landscape). Figure 16 shows that the KSIA Conservation Zone that is currently being established is by far the most prominent conservation initiative in the area. The extent of this area has recently been refined to include the Mt Moreland wetlands which will help to secure these critically important wetlands. A number of reserves have also been established around the oHlanga Estuary and includes the oHlanga Lagoon Reserve, Hawaan Forest along the southern banks and the Mhlanga Forest just north of the estuary. Other formal reserves include Trenance Park and Hazelmere Dam which are located some distance inland. A portion of the Mdloti estuary was also purchased by the Municipality whilst a few small conservation servitudes occur in the study area.

Broader conservation priorities are included in the Durban Metropolitan Open Space System (DMOSS) and in the landscape corridors identified by Ezemvelo KZN Wildlife[13]. This map clearly highlights opportunities to build

[12] Whilst a number of FEPA wetlands occur in catchments U20M, U30B & U30D, their importance has not been verified and is largely based on desktop information. As such, the significance of these features is regarded as questionable at this point.

[13] These altitudinal and bio-geographic corridors were created in KZN to facilitate evolutionary, ecological and climate change processes to create a linked landscape for the conservation of species in a fragmented landscape.

on the existing protected area network. Logical priorities here, include expanding the KSIA east to link with the Mdloti estuary and expanding the extent of conservation zones around the oHlanga estuary (Figure 17).

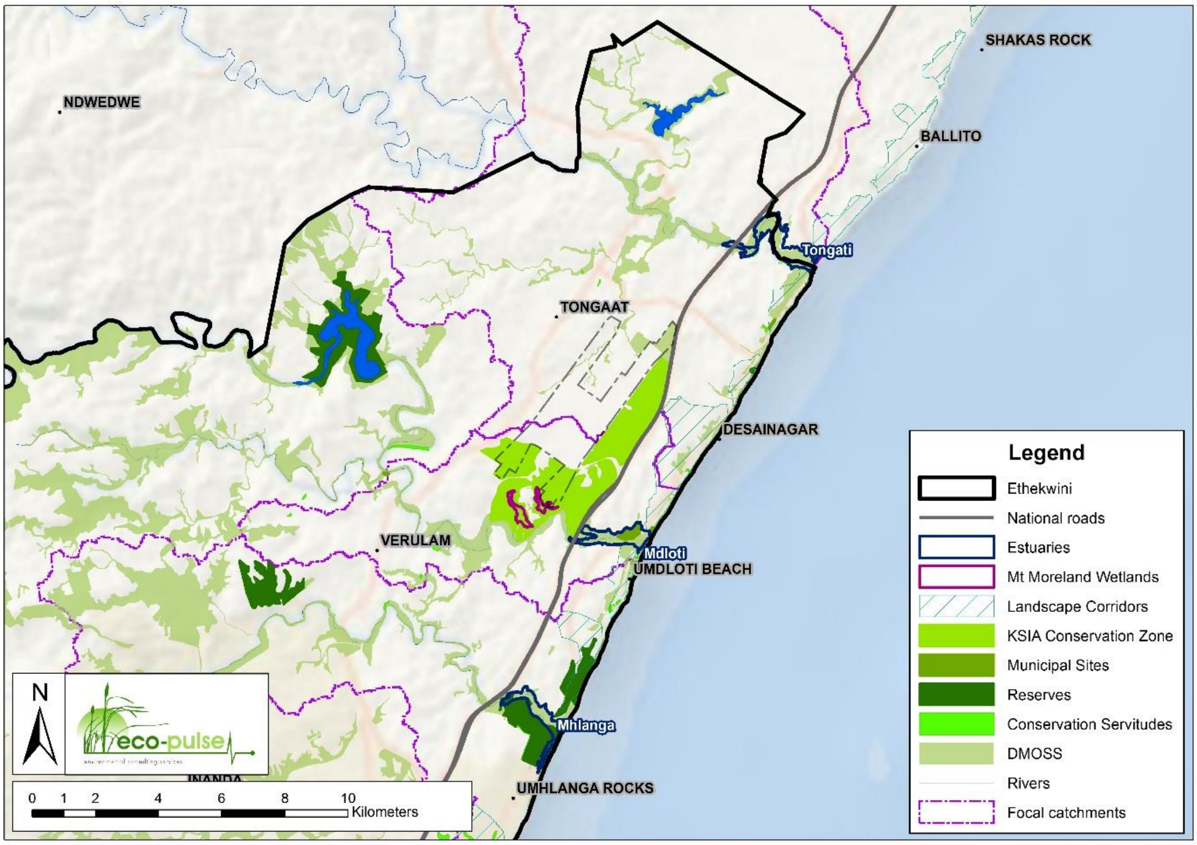


Figure 17 Overview of existing conservation initiatives and conservation priorities in the study area.

Supporting enhanced estuarine functioning

Estuaries are a particularly important water resources, acting as an important interface between the freshwater and marine environments. They provide critical nursery functions for fish, prawns and crab species and rich food sources for fish, birds and mammals. Estuaries also provide a range of social values linked to aesthetics, cultural and recreational uses. As such, maintaining and where possible improving the condition and functioning of estuaries in the study area is a logical priority.

Three estuaries occur in the study area and include the Tongaat, Mdloti and oHlanga estuaries (Figure 17). Despite the importance of these ecosystems, they have all been largely modified (D class) by anthropogenic activities (DWS, 2013). According to recent studies, the biodiversity importance of all three estuaries is still regarded as high (DWS, 2013). The oHlanga system has been highlighted as particularly important however and has been identified as a national priority for full protection. This emphasises the importance of expanding conservation efforts around this estuary.

A comparison of Present Ecological State (PES) with the recommended ecological categories (REC) for these systems highlights the need for management and rehabilitation activities to improve management of these systems. In the case of the oHlanga, the REC is a B class, suggesting that major intervention is required in order to improve the status quo. The REC for the Mdloti and Tongaat are a C & D class respectively suggesting that rehabilitation requirements may be less critical. It is worth noting however that each of these estuaries was identified in the list of hotspots[14] for management intervention in a recent study (DWS, 2013). Thus, whilst, the Mdloti and Tongaat estuaries rank lower in terms of their importance for conservation, they nevertheless represent priority areas for rehabilitation and management.

Targeting key functional features in the landscape

As previously indicated, water quality enhancement is regarded as the most important regulating and supporting service provided by wetlands in this landscape (Table 1). Wetlands that are particularly well suited to provide this service should therefore be targeted for rehabilitation and management. Whilst a wetlands ability to assimilate pollutants is determined by a range of site-attributes, wetland type provides a useful surrogate. Unchannelled valley bottoms are particularly important in providing this service whilst channelled systems such as channelled valley bottoms, riparian zones and floodplains are typically less well suited to provide this service. The distribution of different wetland types in the study area, shaded broadly according to their potential to improve water quality is indicated in Figure 18, below. The demand for water quality enhancement functions is another critical aspect that needs to be considered. Whilst sources of pollutants vary, the most significant impacts are likely to be linked with waste water treatment works and the settlements on Tongaat and Verulum. Wetlands located between these pollutant sources and key conservation priorities are therefore most well placed to assimilate pollutants and so protect downstream water resources. From this perspective, key priority areas would include wetlands linked with the main Tongaat, Mdloti and oHlanga rivers and downstream of these impact sources.

[14] These hotspots represent estuaries with a high Integrated Environmental Importance which could be under threat due to its importance for water resource use.

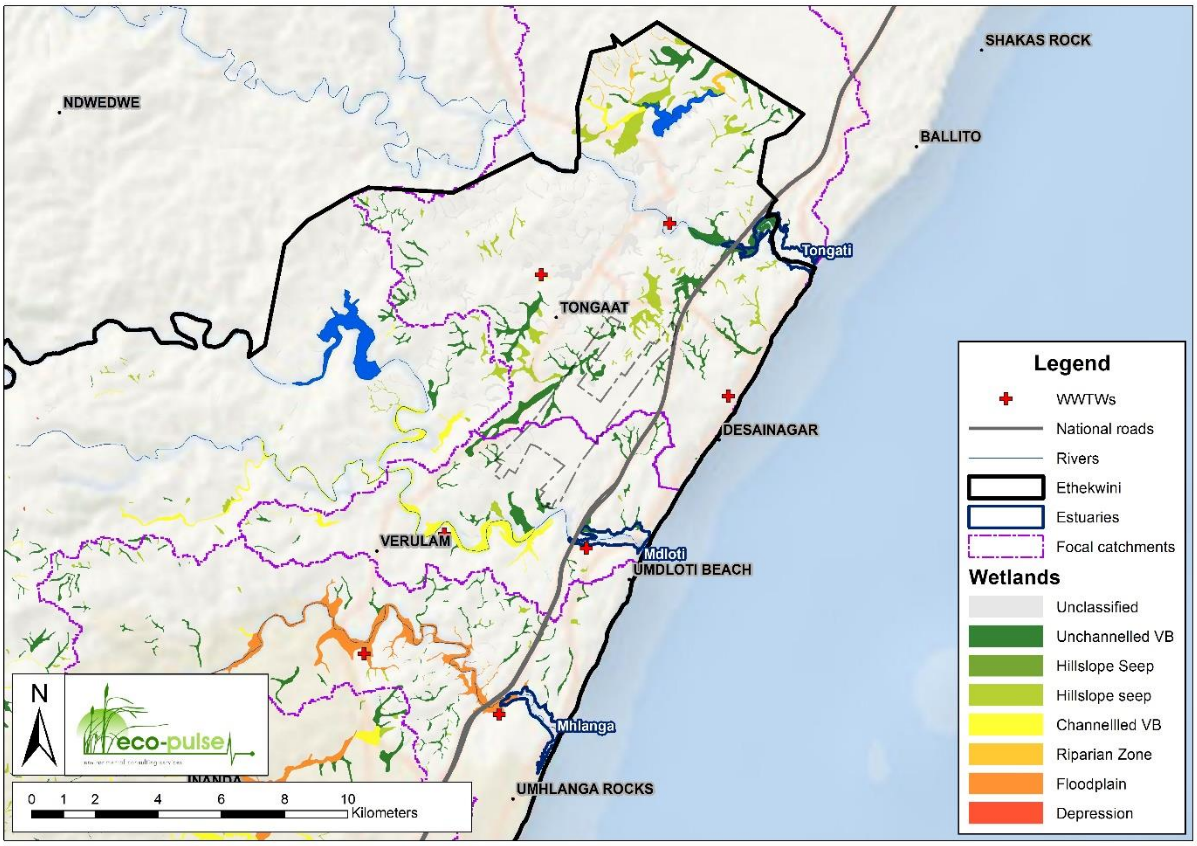


Figure 18 Location and extent of different wetland types in the study area in relation to waste water treatment works.

Land ownership

Land ownership is another key consideration as this affects the costs of establishing offset receiving areas and has implications for long-term management and legal arrangements. As such, it is clearly preferable to identify offset receiving areas located on land already owned by either TH or DTPC. Fortunately these organization both own large tracts of land in the study area, thus providing a wide range of options for site selection (Figure 19).

4.2.3 Identification of focal areas for further investigation

Based on the site selection criteria identified, three focal areas for offset activities were identified for further consideration[15]. A broad indication of the extent of these areas is indicated in Figure 19 whilst a brief rationale for the selection of each of these sites is documented in Table 3, below.

Table 3. Rationale for the selection of focal areas for further offset investigation.

Focal Area	Justification
Tongaat	The Tongaat estuary is currently heavily degraded, largely in response to very poor water quality and severe habitat destruction. An opportunity exists to rehabilitate wetland systems linked to the estuary and main stem river in order to help address water quality impacts and to improve the habitat and aesthetic value of this area.
Mdloti	The Mdloti estuary has been highlighted as an important estuary, but is affected by flow modification, poor water quality and habitat destruction. An opportunity exists to rehabilitate the estuary and associated wetland habitat and to link this with existing protected areas. This would enhance both the functional and biodiversity values of this area whilst enhancing aesthetics and creating an important recreational space for the broader community.
oHlanga	The oHlanga is recognised as a priority estuary for conservation action with a number of protected areas already established around this estuary. The estuary is however heavily impacted by flow modification, poor water quality and habitat destruction. Rehabilitation of the estuary and upstream wetland areas would serve to enhance existing biodiversity values whilst also addressing pollution risks. Such rehabilitation could also have positive social spin-offs which would benefit the broader community.

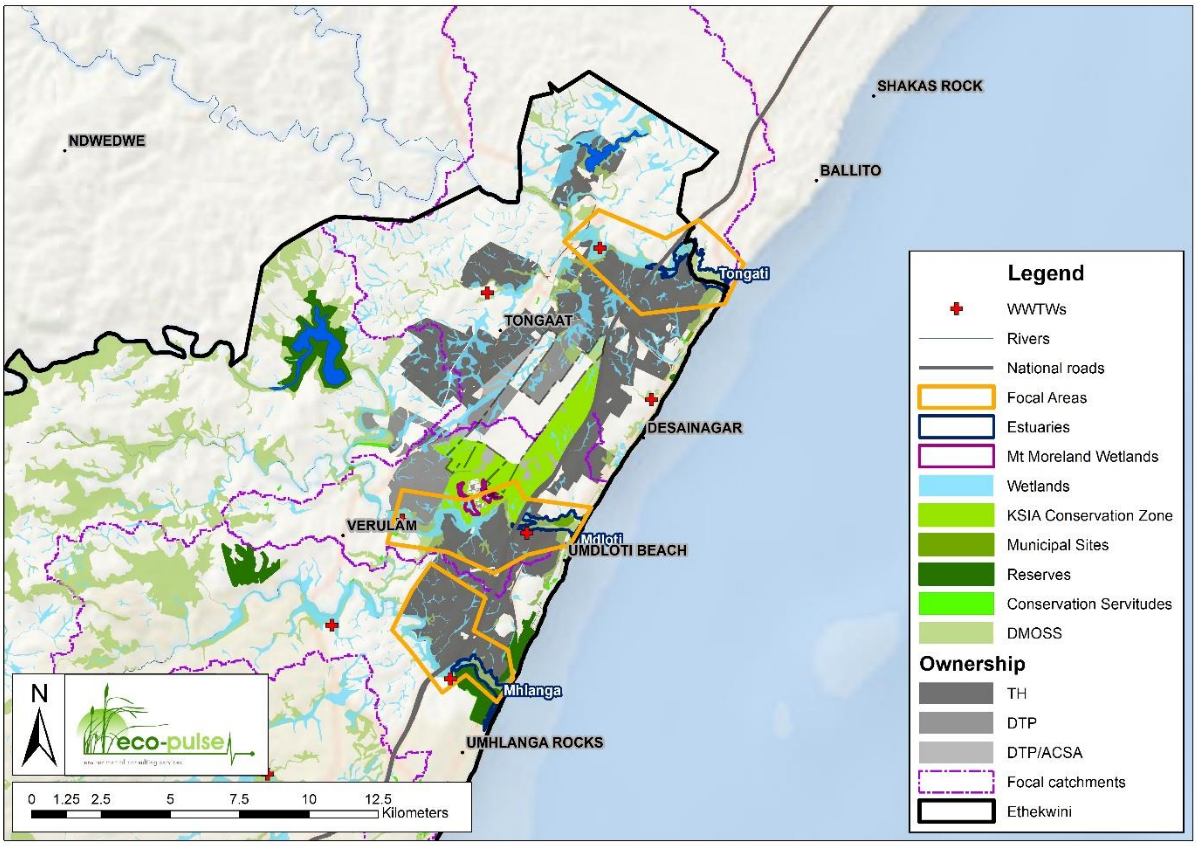


Figure 19 Preliminary focal areas identified to meet wetland offset requirements.

[15] Additional priority areas considered included wetlands around Dudley Pringle Dam and wetlands in catchments leading into Hazelmere dam. These were regarded as being of a lower priority than the other sites however and were located some distance from where most impacts to wetlands are expected.

4.2.4 Selection of priority offset receiving areas

Once focal areas had been agreed to by eThekwini Municipality, THD and DTPC, further planning was commissioned to assess the feasibility of these sites in meeting offset obligations which are likely to arise in response to proposed developments in the study area. This assessment was undertaken by Eco-Pulse Consulting and Ground-Truth and focussed initially on specifically calculating offset obligations using the revised offset methodology. Refined mapping and assessment of focal areas was then undertaken in order to prioritise areas for inclusion in offset receiving areas. The outcomes of this process are documented in a supporting report entitled "A Strategic Wetland Offset Assessment for Dube TradePort Corporation and Tongaat Hulett Developments in the eThekwini North Region, KwaZulu-Natal" (Edwards, *et.al*. 2015). This document forms the basis for discussions with regulating authorities during which offset requirements and associated offset sites will need to be formalised.

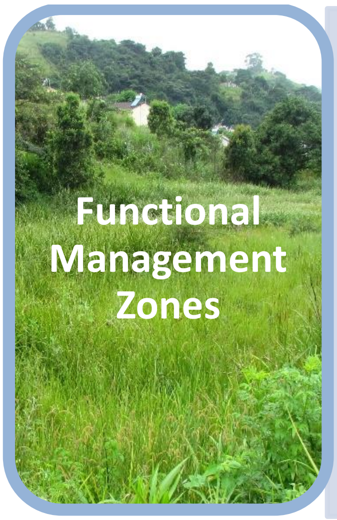
4.3. *A spatial hierarchy for wetland management*

4.3.1 Biodiversity and Functional Management Zones

Offset receiving areas effectively represent priority zones for wetland management, and particularly for enhancing and securing key biodiversity values. The importance of rehabilitating and managing wetlands outside of these priority areas is also acknowledged however. For this reason, wetlands have been separated into two typologies in the study area: "biodiversity" wetlands and "functional" wetlands. Biodiversity wetlands are those included within offset receiving areas and for which stringent rehabilitation and management measures will need to be implemented to reach desired outcomes. Functional wetlands on the other hand, encompass all other wetlands in the landscape that fall outside of earmarked offset receiving areas.

It is important to recognise however that wetlands are part of a broader and connected aquatic environment than needs to be managed in an integrated manner. For this reason, Management Zones have been defined that specifically include river networks and associated estuaries. Where biodiversity is a key focus, as in the case of offset receiving areas, these zones are defined as ***Biodiversity Management Zones*** (BMZs) whilst remaining areas are classified as ***Functional Management Zones*** (FMZs). While both types of management zones are designed to secure wetland values, these areas may differ widely in character and management objectives as outlined below:

- These zones include wetlands, rivers and estuiaries located within earmarked offset receiving areas.
  - The primary management objective in these areas is to **secure and enhance biodiversity values** so as to make a meaningful contribution to the conservation of wetland habitat and species of conservation concern. The importance of these areas in providing a broader suite of ecosystem services is also recognised including opportunities to enhance key functional values such as water quality and erosion control.
  - These zones also provide ideal opportunities for enhancing the wellbeing of local communities. Here, a key emphasis will be on creating opportunities for learning, promoting recreational use and adding value to developments by enhancing aesthetics and creating opportunities for society to interact with nature. As such, human use will be specifically accommodated through appropriate zonation and access without compromising the ecological character of these areas.



- These zones include all other wetlands and rivers located outside of offset receiving areas and typically falling within a development site.
  - The primary management objective in these areas is to **improve key wetland functions** (water quality enhancement, sediment trapping and stormwater attenuation) so as to ensure that development contributes towards improving water resource quality. Whilst the importance of on-site mitigation must still be upheld, these areas may also be enhanced and managed so as to help address broader water quality and flood attenuation risks.
  - As with biodiversity zones, opportunities to enhance human well-being will be accommodated. This may include more intensive manipulation of wetland systems so as to improve the aesthetic and recreational use values of these areas. Such use must however be balanced with the need for improving key wetland functions and must not compromise objectives of downstream biodiversity zones.

It is important to emphasise that this classification system is designed as a course-level filter to inform wetland management. The develop of fine-scale zoning schemes in which specific activities are controlled and managed would serve to further refine management and use and should ideally be developed as an integral part of the management plans for BMZs.

4.3.2 Buffer Zones

The establishment of buffer zones around water resources is a common approach used to protect water resources from the effects of adjacent developments. Their establishment and management also provides an important interface between natural ecosystems and developed areas which can provide important habitat for biota whilst also providing amenity values to society. Whilst the extent and specific rehabilitation requirements for buffer zones should be finalised at a site level, generic guidelines for buffer zone establishment are outlined in Table 4, below.

Table 4. Generic guidelines for buffer zone establishment.

Generic requirements	1. Site-based buffer requirements must be established with input from relevant specialists and using approved best-practice guidelines[16]. 2. Complimentary site-based mitigation measures should be implemented on development sites in order to reduce the risks posed by the development on the receiving water resources.
BMZs	3. A minimum ecological buffer of 50m should be established from the edge of the wetland or active channel and maintained so as to reduce risks from pollutants in diffuse surface runoff and to cater for species movement. 4. In the case of estuaries, no development should be permitted within the estuarine boundary unless specifically accommodated through zonation as part of an estuarine management plan. 5. Broader buffers should be established where necessary in order to maintain or improve connectivity so as to promote species movement. 6. Where species of conservation concern are expected to occur, specialist input must be sought to define core area requirements and any additional requirements to protect core areas from outside disturbance. 7. Buffer zones must be designed to cater for practical management requirements including implementation of appropriate fire regimes (e.g. need for fire breaks).
FMZs	8. A minimum aquatic impact buffer of 15m must be established to reduce risks from pollution in diffuse surface runoff during storm events. 9. Riparian zones must be protected and rehabilitated where possible in order to improve a range of key functions provided by these areas.

4.3.3 Expectations for management and rehabilitation

Once the location and spatial extent of BMZs and FMZs has been established, the rehabilitation and management of these areas needs to be formalised to ensure that they function in line with expectations. This needs to be informed through appropriate specialist input and should comply with the requirements outlined in Table 5, below.

Table 5. General management planning and rehabilitation requirements.

Management Planning	
BMZs	1. Management plans must be developed in consultation with stakeholders. Where estuaries are included within offset sites, these plans must be aligned with the "Guidelines for the Development and Implementation of Estuary Management Plans" and include: a. A situational assessment which clearly documents baseline conditions and the current status of management; b. A vision and objectives for site management; c. Spatial zonation of activities; d. Management objectives and activities; e. An integrated monitoring plan (including performance indicators); f. Institutional capacity and arrangements. 2. Management must be integrated with broader landuse planning to ensure that opportunities for social benefits (e.g., NMT Routes) can be maximized without undermining the ecological character of the site. 3. Adequate costing of rehabilitation and management must be undertaken and an appropriate funding mechanism (e.g. trust fund) established to secure long-term management.
FMZs	4. Management plans will need to be developed on a site-by-site basis linked to development applications. 5. These would typically form part of the Environmental Management Programme for the development.

[16] Application of the Preliminary guideline for the determination of buffer zones for rivers, wetlands and estuaries (Macfarlane et. al., 2014) as refined is recommended.

Rehabilitation guidelines	
Wetlands, rivers and estuaries	
Generic requirements	6. Desired outcomes, including clear, measurable targets and objectives, must be clearly documented; 7. Wetland rehabilitation must be undertaken with due regard for legal requirements; 8. Rehabilitation planning must be undertaken by suitably qualified specialists with sound rehabilitation planning experience; 9. Interventions must be designed with due regard for landscape risks and catchment-related impacts.
BMZs	10. Planning must be informed by a sound baseline assessment; 11. Interventions should be designed to enhance key biodiversity values including habitat available for species of conservation concern; 12. In the case of wetlands, expected outcomes must be documented using the same currency used to define offset requirements.
FMZs	13. Rehabilitation should be designed to enhance the key functional values provided by wetlands; 14. Options to integrate stormwater management or improve social use values should be specifically integrated into the rehabilitation planning process.
Buffer Zones	
Generic requirements	15. Buffer zones should be established with naturally occurring species adapted to local site conditions. 16. Application of fertilizers in the buffer should be avoided where possible to reduce risk of pollutants being washed into watercourses.
BMZs	17. Adding forbs (non-woody plants other than grass, i.e. wildflowers and legumes) should be introduced where possible to provide a source of food and structure that attracts insects and to enhance general biodiversity values. 18. Shrubs and trees should be introduced to add structural diversity, provide escape cover and valuable nesting habitat for bird species. 19. Selection of tree species that provide food and/or cover for wildlife should be encouraged. 20. Where buffers are established specifically to cater for species of conservation concern, selection of plant species should be tailored to meet basic habitat requirements for target species.
FMZs	21. Landscaping of buffer zones is encouraged to enhance aesthetic and amenity values as long as soil disturbance is limited and good vegetation cover is maintained.
Securing long-term management	
BMZs	22. Formal protection of the site must be secured through an appropriate legal mechanism. 23. Clear rules and governance structures are essential. The roles and responsibilities of different parties for long-term management and oversight must therefore be formalized through an appropriate agreement between parties. 24. Monitoring and evaluation procedures and responsibilities must be clearly defined. This should include monitoring of structural integrity and ecological outcomes.
FMZs	25. Management of these zones will need to be clarified and formalized between parties as a condition of authorization. This must include details of responsibilities and the funding mechanism to be used to ensure effective management. 26. Monitoring and reporting requirements must also be clarified to enable management effectiveness to be reviewed on a regular basis. 27. A conservation servitude / similar mechanism must be registered for functional zones with restrictions on future use.

4.3.4 Provision for infrastructure including future road requirements

Whilst the focus of management of wetland zones is on the maintenance and enhancement of key functional and biodiversity values, it is recognised that some infrastructure development may be required in these areas. This has already been catered for to some extent in BMZs by accounting for key planned road infrastructure that will traverse these areas[17]. Given the need for supporting service infrastructure, further impacts can be

[17] For the purposes of this assessment, a 20m zone was specifically excluded from BMZs to account for potential wetland impacts in these areas. Construction of these facilities will however need to be undertaken in a sensitive manner to ensure that direct impacts are minimised and that appropriate passage infrastructure for NMT users and wildlife is provided for.

expected. It is however important that infrastructure development (including roads and service infrastructure) minimises impacts to wetland management zones and seeks to avoid disruption of natural corridors as far as practicable. Environmental impact assessments will therefore still be required for these developments which will include appropriate assessment and mitigation of environmental impacts. Where impacts cannot be effectively managed, this may trigger the need for additional offset activities[18]. A suite of design principles and associated guidance has therefore been provided below to inform infrastructure design in the project area.

Infrastructure guidelines	
Road Crossings	
Generic requirements	1. Crossings should be aligned perpendicular to flow (not near-parallel), located in areas of least sensitivity (along existing corridors of disturbance), placed at a narrow section of the wetland / riverine system and designed in a manner that causes least disturbance to natural habitat through the incorporation and implementation of the following objectives and best practice design measures: a. *Avoid and/or minimize the constriction of riverine and/or wetland flows*. This should be achieved through the establishment of an adequate number and adequately sized culverts across the riverine and wetland systems, taking into account the full extent / width of these systems. b. *Avoid and/or minimize the deactivation of valley bottom and floodplain areas*. This should be achieved through ensuring impedance of flow and sediment distribution is limited through appropriate bridge design and by minimizing encroachment of road fill embankments. In this regard, bridges should be widened and/or culverts should be installed within fill embankments to maintain the natural distribution of flows and sediment across the relevant fluvial surfaces. c. *Maintenance and/or establishment of faunal movement and habitat connectivity*. Wetland, aquatic and terrestrial faunal movement and habitat connectivity must be maintained (or improved) as far as practicable through the establishment of adequately sized culverts and bridges. d. *Reduce visual impact*. Infrastructure features should be designed to be aesthetically pleasing and not detract from the open space.
BMZs	2. Only strategic road crossings will be permitted, as aligned with the strategic planning framework for the area. Construction of secondary roads through these areas must be limited as far as possible.
FMZs	3. Design should ideally be integrated into wetland rehabilitation planning and stormwater design to ensure that road alignment and design does not undermine rehabilitation objectives.
Water and sewer pipe crossings	
Generic requirements	4. Crossings should be aligned perpendicular to flow (not near-parallel), located in areas of least sensitivity (along existing corridors of disturbance), placed at a narrow section of the wetland / riverine system and designed in a manner that causes least disturbance to natural habitat through the incorporation and implementation of the following objectives and best practice design measures: a. *Avoid and/or minimize the extent of direct physical disturbance*. Pipe bridges are preferred over underground trenched crossings. In this regard, the number of piers/plinths established within the riverine / wetland habitat must be minimized and where possible the riverine / wetland habitat must be spanned. Where possible, such infrastructure should be accommodated alongside existing road networks. b. *Minimize indirect erosion, sedimentation and pollution / water quality impacts*. i. Sewer pipelines should not be located within 30m of the riverine and wetland systems and where crossings are unavoidable, pipelines must cut across the watercourses at as close to perpendicular to flow as possible.

[18] It is important to note that BMZs have been specifically delineated to compensate for negative residual impacts associated with planned developments. Any impacts to these areas will reduce the benefits realized from these areas. As such, the impact from any developments within BMZs will need to be assessed. If these are significant, additional offsets may be required to address negative impacts. In the case of FMZs, infrastructure development should be assessed as per any other development activities. Impacts to wetlands should be accounted for in initial offset planning. If this has not been done, the need for additional compensatory actions will need to be investigated.

Infrastructure guidelines	
	ii. Sewer manholes should not be located within 30m of the riverine and wetland systems except at unavoidable crossings. In this regard, no manholes should be located within 15m of the riverine and wetland habitat. iii. No sewer pump stations must be located within 15m of the riverine and wetland systems and the pump stations must have emergency generators and at least 24hrs freeboard. c. *Reduce visual impact.* Infrastructure features should be designed to be aesthetically pleasing and not detract from the open space.
BMZs	5. Only strategic water and sewer pipe crossings will be permitted, as aligned with the strategic planning framework for the area. 6. Design criteria to minimize impacts to BMZs must be integrated into project design.
FMZs	No further requirements
NMT access	
Generic requirements	7. Integrate functional zones with ecological corridors, NMT corridors and other open spaces to maximise amenity and environmental benefits. Ensure a multi-functional attractive space, functioning as a "working" space and as a recreational and aesthetic amenity.
BMZs	8. Under special circumstances, the NMT route may meander within BMZs but should not undermine key ecological functions and values. The design of the NMT route must therefore be undertaken with due regard for the sensitivities of the receiving environment. Construction design and activities must also be done sensitively with minimal disturbance.
FMZs	No further requirements
Low impact access trails	
Generic requirements	9. **NMT access**. Ensure that NMT infrastructure brings visitors to Special Development Sites within BMZs and FMZs while avoiding Ecologically Sensitive Areas. Visitors should be routed to rivers and wetlands to provide a nature experience whenever possible, as allowed by the ecological context. The design of NMT routes should be designed so as to mimic natural vegetated buffer attributes. Where this is not achievable, a larger buffer zone will need to be established to cater for a loss of buffer functions. 10. **Low impact access trails**. Hiking pathways and boardwalks should provide opportunities for visitors to access, enjoy and engage with the natural features (e.g. bird hides, fishing spots) within BMZs and FMZs.
BMZs	11. Location of trails must be undertaken with due regard for the sensitivities of the receiving environment.
FMZs	No further requirements

4.4. *Development planning guidelines*

The vision and policy objectives for wetland management in the study area have implications beyond wetland rehabilitation and management. Whilst it is assumed that best-practice urban and environmental planning will be implemented in the study area, further guidance is required to ensure that development in the area does not undermine the biodiversity and functional values of wetlands in the landscape. A supplementary preliminary guideline for the land-use planning and stormwater management in the study area has therefore also been prepared to support effective wetland management (Royden-Turner *et al.,* 2015). The main focus of the guideline is to ensure that:

- Land-uses abutting all wetlands, adjacent structures and related landscapes are in harmony with the vision and objectives of the eThekwini Municipality's NSDP; and are to the benefit of the environment and investment value of eThekwini North as a whole.
- Stormwater management design limits risks of flooding, pollution, erosion and other detrimental effects on wetlands within eThekwini.
- Wetland management objectives of wetland protection and rehabilitation that produce a biodiversity net-gain and incorporate best-practice treatments of urban wetlands are supported.

- Developers are incentivised to design appropriately, and regulators are given the appropriate set of management tools to guide sensitive and sustainable development, and that development approval processes are streamlined.

Whilst further refinements to these guidelines will be required, they begin to flesh out the broader response required to ensure that urban landscapes begin to mimic nature and so contribute towards a more sustainable future.

5. CONCLUSION AND WAY FORWARD

This document sets out a new direction for wetland management in the study area. It represents a bold move forward to ensuring that the value of wetlands as critical ecological infrastructure are recognised and upheld as development proceeds in the study area. The approach is not simply protectionist however and aims to strike a balance between protection and use such that society reaps the benefits.

Whilst this framework represents an important step towards realising the vison for improved wetland management, a learning-by-doing approach is recognised as critical amongst stakeholders in order to achieve real and lasting outcomes (Figure 20). This framework has therefore been developed in order to set in place a process of learning and feedback loops that strengthens the wetland management framework as it matures.

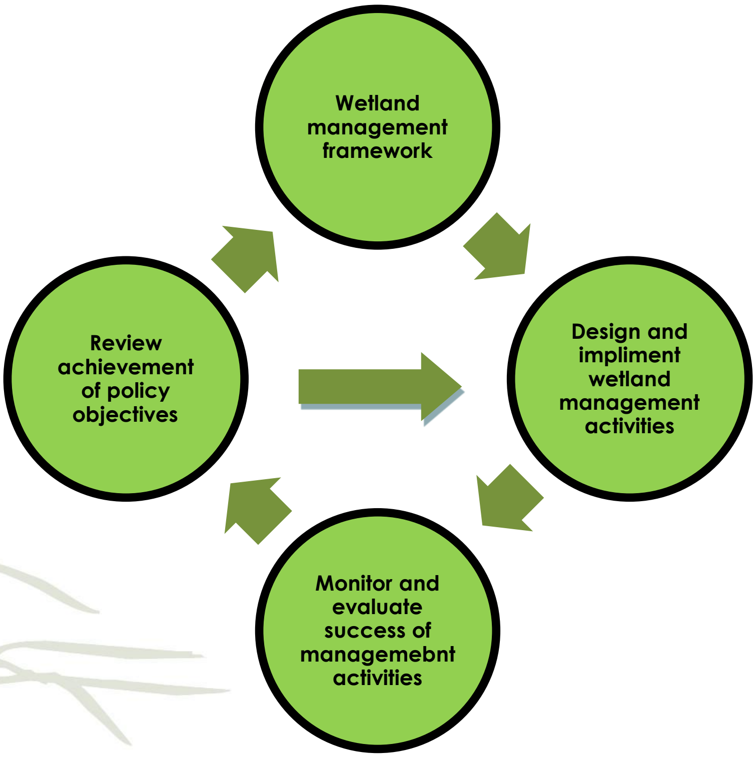


Figure 20 Learning by doing - the adaptive management cycle.

In moving forward, a series of collaborative working sessions with the clients, consultants and officials currently working to address these challenges, are required in order to strengthen the framework and ensure a robust outcome. Through subsequent engagement, it is hoped that the framework will be co-developed through learning cycles which are aimed at accommodating a broad variety of perspectives and knowledge types. This process of co-development will create ownership of the framework by those people that will be called to implement it, making it seamless to integrate into the processes of design and evaluation. Much additional work is also required to formalise agreements and to develop supporting implementation plans to ensure that the vision articulated in this document is realised. These will be developed and formalised as implementation and refinement of this framework proceeds.

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A REVISED FUNCTIONAL ASSESSMENT METHODOLOGY FOR WETLAND OFFSETS IN ETHEKWINI MUNICIPALITY'S NORTHERN SPATIAL DEVELOPMENT PLAN AREA

Version 0.2

Date: December 2015

Report No: EP 181-02

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Suggested report citation:

Macfarlane, D.M., & Edwards, R., 2015. A revised functional assessment methodology for wetlands in eThekwini Municipality's Northern Spatial Development Plan Area. Unpublished report prepared by Eco-Pulse Environmental Consulting Services. Version 0.2. December 2015.

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1. INTRODUCTION

The eThekwini Municipality's Northern Spatial Development Plan Area is characterised by wetlands that have been heavily impacted by sugarcane farming and other anthropogenic activities. This has significantly undermined the ability of wetlands to provide key regulating and supporting services that are necessary to ameliorate risks and address existing water resource challenges. Given the extent of wetland loss, a local policy decision has been taken to improve the functions and values provided by wetlands in this landscape. This includes a revised approach to wetland offset calculations which aims to account for both current and future opportunity loss from future developments and to incentivise the protection, rehabilitation and management of highly functional wetland areas (Macfarlane, 2015).

Whilst the importance of wetlands has been recognised, the reality is that not all wetlands perform all services equally well. It is therefore important to be able to differentiate between those wetlands of high value and those of lower importance and to ensure that local policies provide appropriate incentives to encourage the avoidance and protection of critical ecosystems. Wet-Ecoservices (Kotze *et al.*, 2008) was the first tool developed in South Africa to help users understand the importance of ecosystem services provided by wetland ecosystems. The development of this tool was a huge step forward for wetland science in the country and the authors are acknowledged for this pioneering work which has helped to raise the awareness of the importance of a wide range of benefits that wetlands provide. Government has taken the importance of ecosystem goods and services to heart, with the specific integration of functional values in the national guidelines for wetland offsets that have recently been developed (SANBI & DWS, 2014). The guidelines specifically require an assessment of impacts to water resources and ecosystem services to be undertaken as part of the impact assessment process and provides guidance on how to assess and quantify the anticipated residual impacts on water resources and ecosystem services.

In the absence of more suitable tools, wetland area and condition have been proposed as a surrogate measure for the indirect (regulating and supporting) services that are critical for water resources. The reality however is that wetland condition provides a very poor surrogate for ecosystem services provided by wetlands and a more direct tool is therefore required to more accurately quantify gains and losses. Whilst Wet-Ecoservices provides a sound basis for highlighting important services provided by wetlands, it was not designed to specifically quantify the benefits supplied by a wetland. ***A decision was therefore taken to update and refine the Wet-Ecoservices tool and to use this as the basis for assessing gains and losses with respect to regulating and supporting services provided by wetlands in the study area***.

Details of this revised functional assessment methodology, together with how the results have been specifically integrated into preliminary offset calculations in eThekwini's Northern Spatial Development Plan Area are outlined in this document. Whilst this revised method represents a significant step forward in developing an offset currency for goods and services provided by wetlands, this tool should ideally be refined and tested further to improve the credibility of the approach.

2. APPROACH USED TO UPDATE THE METHODOLOGY

The authors had been working on refinements to the Wet-Ecoservices approach for some time. This was initiated in 2009 when Doug Macfarlane was working on a project aimed at quantifying the benefits provided by wetlands in the upper Orange/ Senqu basin (Sullivan *et al.,* 2008). During this project, a concern with this approach not adequately differentiating between user requirements (demand) and benefit availability (supply) was highlighted. Concerns with the tool generating average scores for wetlands with high benefit availability and low user requirements and vice versa was also highlighted. The Wet-Ecoservices datasheet was therefore modified to separately account for benefit availability and user requirements (Macfarlane & Texeira-Leite, 2009).

A number of additional changes have been slowly integrated into the tool in response to learnings gained from applying the tool across a wide range of projects and contexts. It was however only following the development of wetland offset guidelines (SANBI & DWS, 2014), where the importance of developing an improved functional assessment tool was highlighted, that further work on this tool commenced in earnest. The key emphasis was on ensuring that the results could be integrated into a currency for wetland offset calculations. This was initially applied on a test-case basis to a number of wetland projects in the eThekwini Municipality. Following agreement on the need for a more formalised approach, Eco-Pulse Environmental Consulting Services were then formally contracted by Tongaat Hulett Developments and Dube TradePort Company to develop a refined methodology for application in eThekwini Municipality's Northern Spatial Development Plan Area.

During this process, each of the criteria for assessing demand and supply across the full suite of ecosystem services were re-evaluated. Where necessary, new criteria were added and others were removed to align with the revised approach. The rationale for any changes were then documented, including any changes to the way that final scores were calculated. A draft tool was then applied by Eco-Pulse Consulting and Ground-Truth to a sub-set of wetlands in the project area. Learnings from this initial testing were then integrated into the revision of the tool and the user interface and reporting aspects of the tool were enhanced. Following further internal testing, the tool was then applied to more than 100 hydrogeomorphic units in the study area. Whilst the results are seen as a big improvement to the condition-based assessment, the authors acknowledge that further refinement and testing of the approach is ideally required. The authors also wish to thank Donovan Kotze, Craig Cowden and Scott Haworth for their contributions.

Note: Whilst not required for offset calculations, a decision was made to also update the Wet-Ecoservices tool to better account for the full suite of ecosystem goods and services provided by wetlands. This entailed relatively minor changes to the approach used for scoring biodiversity maintenance, provisioning and cultural services. These changes largely reflect an attempt to integrate new spatial planning information and to add or refine selected criteria where necessary. The datasheet has also been structured in such a manner that information requirements for assessing the various service groups is clearly indicated. As such, users have the option of completing the full assessment or specifically focussing on those aspects that are required for offset calculations.

3. OVERVIEW OF THE REVISED METHODOLOGY

The value of regulating and supporting services provided by wetlands depends on their (i) hydrogeomorphic position in the landscape; (ii) inherent wetland attributes, (iii) importance of downstream ecosystems and (iv) the position of human settlements, near and far, who find value in these ecosystems. The first two attributes affect the **supply** of benefits provided by wetlands whilst the last two aspects affect the **demand** for these services. The importance of these four aspects were specifically considered when developing a refined methodology to assess gains and losses in functional values within the project area and so differentiate between high and low value wetland ecosystems. This document provides a brief overview of changes made to the Wet-Ecoservices framework which have been integrated into a new functional assessment tool (Eco-Pulse Consulting, 2015). Detailed commentary on specific changes made in relation to the original Wet-Ecoservices assessment tool are included in Annexure 1 of this document.

3.1. Evaluating supply of ecosystem services

A key change that has been made to the assessment, is the way in which supply of ecosystem services is calculated. In the updated tool, supply of regulating and supporting services is calculated by integrating the concepts of "potential" and ability or "effectiveness". ***Potential*** represents the opportunity for the wetland to provide the service in relation to other wetlands in the catchment. This is based on the hydrogeomorphic position of the wetland in the landscape. According to Mitch and Gosselink (2000), hydrogeomorphic position means the degree to which a wetland is open to hydrologic and biological fluxes with other systems, including urban and agricultural landscapes. Wetlands such as floodplains with large catchments are well placed to intercept flows and pollutants from a broad landscape whereas wetlands with small contributing catchment such as seeps are less able to perform regionally important functions. This principle is illustrated by Crumpton *et. al.* (1993) who showed that upstream wetlands trap few nutrients, while downstream wetlands in key watershed positions can remove up to 80% of inflowing nitrates (Cited in Zelder, 2003). The size of a wetlands catchment has therefore been specifically integrated into the assessment as the primary indicator for potential.

The concept of assimilative capacity is widely understood in ecological circles and typically refers to the ability to take up nutrients and other pollutants. This capacity is constrained by a range of factors which may compromise the ability of a wetland to realise its potential. Arguably the most important factor here is the size of the wetland relative to the catchment. Researches such as Carleton *et. al.* (2001) have shown that this is a key factor in determining residence time and the capacity of a wetland to perform a range of ecosystem services. The findings of this research has therefore been integrated into the model by adjusting the potential score based on an understanding of the importance of the size of the wetland relative to the catchment in influencing the supply of different ecosystem services.

The ***effectiveness*** of a wetland in delivering a service is then assessed based on an understanding of the importance of different wetland attributes in providing the relevant service. Given that this assessment aims to differentiate between wetlands on a hectare-for-hectare basis, the ability or effectiveness of a wetland to provide a particular service is assessed relative to an ideal or "reference" wetland. Here, a 'reference' wetland is defined as one which has morphological and structural attributes that makes it optimally suited to provide the service in question and would receive an effectiveness score = 4 in the assessment. The effectiveness of a wetland being assessed is therefore scored in relation to what are regarded as optimal wetland attributes for providing each service.

The ability of a wetland to supply a particular service is essentially constrained initially by the 'potential' to provide the service which is based on the hydrogeomorphic position in which the wetland is found, assessed in terms of catchment size and the size of the wetland relative to the catchment. The degree to which this potential can be realised is then determined by wetland attributes that affect the effectiveness in providing this service. As such, the ***supply score*** calculated in the tool is based initially on the potential score and then adjusted down based on the effectiveness score. This differs considerably to the initial Wet-EcoServices approach where an effectiveness score was typically generated independent of the hydrogeomorphic context.

3.2. Assessing the demand for ecosystem services

The value of wetlands also depends on the demand placed on these services by society. This is affected by factors such as the level of pollution received and increases in flood peaks experienced by the wetlands and the positions of important downstream ecosystems and human settlements, near and far, who find value in these ecosystems. The availability of alternative infrastructure, both hard (e.g. dams) and soft (e.g. intact wetlands and riparian areas) may also reduce the demand for services by reducing impacts prior to them reaching the wetland. A range of criteria have therefore been identified to help evaluate demand for different ecosystem services in the landscape. Whilst still based largely on the Wet-Ecoservices approach, additional criteria have been added to the tool and calculations have been refined in order to provide what is believed to be a more robust indication of the local demand for ecosystem services.

3.3. Integrating demand and supply to provide an overall indication of importance

Understanding the importance of a wetland in providing ecosystem goods and services is central to decision making. Where wetland importance is low, some level of impact may be acceptable whereas a much more conservative approach is required for wetlands that have high value to society. The tool has therefore also been updated to provide an integrated measure of importance based on the supply and demand of services provided by wetland ecosystems. Whilst further testing is needed to define how best to integrate these elements, a combined importance score is calculated at this stage using the following formula:

Wetland importance (/ha) = (Supply score x 2 + Demand score)/3

This approach places the primary emphasis on the ability of a wetland to supply ecosystem services. This is done in order to avoid strongly discounting wetlands that are well placed to provide a service but are currently located in a setting with low demand. This is an important consideration as demand is likely to increase as development pressures rise over time. The calculation is still useful however in emphasising the importance of wetlands in settings where current demands for wetland functions are high. Combined scores are then used to categorise wetlands according to an importance category for reporting purposes. This is based on simple scoring classes as outlined in Table 1, below.

Table 1. Importance categories for reporting on the ecosystem goods and services provided by wetlands.

Importance category	Combined score
Very Low	0-0.5
Low	0.6-1.0
Moderately-low	1.1-1.5
Moderate	1.6-2.0
Moderately-high	2.1-2.5
High	2.6-3.0
Very high	>3.0

4. PRESENTATION OF RESULTS

The functional assessment tool (Eco-Pulse Consulting, 2015) has been developed to enable users to rapidly run through an assessment and to then present outcomes in two different formats which may be useful for reporting in different contexts. These include a condensed summary sheet and graphic illustrations, both of which may be generated for a present state and potential future rehabilitation state scenario.

4.1. Condensed Summary Sheet

This sheet summarises the outcomes of the assessment by providing scores for supply and demand together with the overall importance score and associated importance categories. Results are then colour-coded to emphasise the relative importance of different services (Figure 1).

		Benefit Summary - Present State				Benefit Summary - Rehab State			
	ECOSYSTEM SERVICE	Supply	Demand	Importance Score	Importance	Supply	Demand	Importance Score	Importance
REGULATING AND SUPPORTING SERVICES	Flood attenuation	0.3	0.7	0.4	Very Low	1.2	0.7	1.0	Moderately Low
	Stream flow regulation	1.0	2.0	1.3	Moderately Low	1.3	2.0	1.5	Moderate
	Sediment trapping	1.4	3.0	1.9	Moderate	2.1	3.0	2.4	Moderately High
	Erosion control	0.8	3.0	1.5	Moderate	1.4	3.0	1.9	Moderate
	Phosphate removal	1.1	2.5	1.6	Moderate	1.8	2.5	2.0	Moderately High
	Nitrate removal	1.1	2.0	1.4	Moderately Low	2.1	2.0	2.1	Moderately High
	Toxicant removal	1.2	2.5	1.6	Moderate	2.1	2.5	2.2	Moderately High
	Carbon storage	1.3	3.0	1.9	Moderate	1.7	3.0	2.1	Moderately High
	Biodiversity maintenance	1.8	2.0	1.9	Moderate	2.3	3.0	2.5	High
PROVISIONING SERVICES	Water supply	2.0	0.0	1.3	Moderately Low	2.6	0.0	1.7	Moderate
	Harvestable natural resources	0.7	0.6	0.7	Low	1.3	0.6	1.1	Moderately Low
	Food for livestock	0.3	0.0	0.2	Very Low	0.7	0.0	0.5	Very Low
	Cultivated foods	0.7	1.3	0.9	Low	0.0	0.2	0.1	Very Low
CULTURAL SERVICES	Cultural significance	0.0	0.0	0.0	Very Low	0.0	0.0	0.0	Very Low
	Tourism & recreation	1.7	2.0	1.8	Moderate	2.0	3.0	2.3	Moderately High
	Education and research	1.5	0.0	1.0	Low	2.0	0.0	1.3	Moderately Low

Figure 1. Condensed summary sheet produced as an output to the model.

4.2. Graphic illustration

Whilst the summary table provides information necessary for reporting purposes, the level of detail makes it difficult to quickly identify key services or to identify changes in functions in response to rehabilitation activities. The spider diagrams presented in Figure 2, below make the outcomes of the assessment more accessible to non-technical readers. In the example included below, the change in the importance of ecosystem services to rehabilitation is clearly indicated by way of the expanded black lines. The backgrounds of the graphics have also been colour coded to help differentiate between the different ecosystem service groupings.

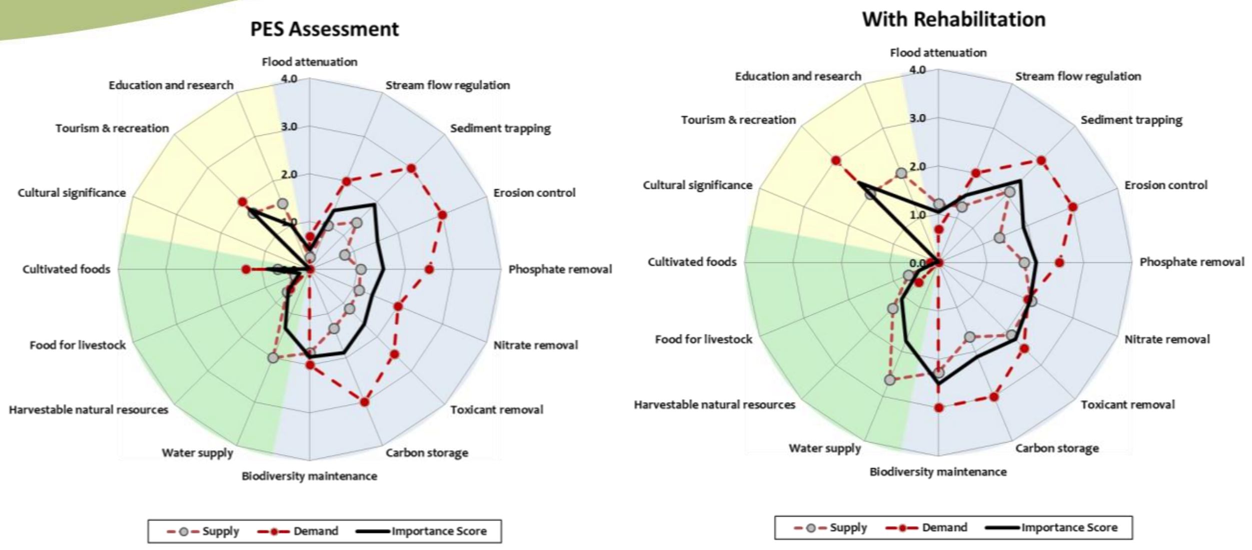

Figure 2. Spider diagram showing the results of a hypothetical assessment.

5. TRANSLATING THE RESULTS INTO AN OFFSET CURRENCY

5.1. Assessing functional offset requirements

Whilst scores representing the relative importance of different wetlands in providing ecosystem goods and services is useful, this needs to be translated into an offset currency for application in the study area. The assessment of offset requirements is based initially on the extent of wetland impacted and the potential functional value of the affected wetland. The resultant value is then modified by a functional ratio to generate a final functional offset target, reported in terms of functional hectare equivalents (Figure 3).

Figure 3. Outline of the approach used to identify the required wetland offset for regulating and supporting services.

Given the existing local policy that recognises the need to improve wetland functioning, the residual impact is based not on the present functioning of impacted wetlands but on a realistic rehabilitated state. In the case of functional wetlands, this assumes that reasonable efforts would have been made to improve the functional values provided by the wetland without significant investments being made to specifically enhance biodiversity values. An assessment of wetland functioning both in the current state and under a realistic rehabilitation case is therefore required.

Recognition has also been given to the need to specifically account for differences in the importance of regulating and supporting services provided by wetlands in the study area. This is accounted for in the offset calculations by specifically weighting wetland Function / Service groups based on the catchment context. In this particular example, water quality impacts are regarded as particularly problematic due to a range of existing anthropogenic impacts and the sensitivity of downstream water resources (most notably estuaries) to pollution

(Table 3). The importance of each Function / Service group must therefore be evaluated by assigning a weighting (%) relative to other groups and providing a supporting justification. These weightings are then used to calculate a functional value score under both a present state and future rehabilitation scenario (Table 2). It is important to note here, that the final weighted score is divided by 3 (realistic best-case[1]) rather than 4 (theoretical best-case). An ideal or "reference" wetland is therefore described as one which is well suited to provide a high level of services relevant to local communities.

Table 2. Calculating functional hectare equivalents using the revised functional tool.

Effectiveness is supplying regulating and supporting services			
Function / Service Groups	**Weighting (%)**	**PES Score**	**Rehab Score**
Flood Attenuation	10%	0.3	1.2
Streamflow Regulation	0%	1.0	1.3
Sediment Trapping & Erosion Control	20%	1.1	1.7
Water Quality Enhancement	70%	1.1	2.0
Functional Value (%)		34.2%	61.9%
Wetland Area (Ha)		10.0	10.0
Functional Hectare Equivalents		**3.42**	**6.19**

In the example above, the development impact is therefore calculated by multiplying the functional value (%) with the wetland area. Taking the rehabilitation score, the destruction of a potentially moderately well-functioning wetland (61.9%) of 10 hectares would translate to a functional offset target of 6.19 functional hectare equivalents.

Wetlands in some areas may be playing more valuable roles than those in other areas. The loss of these wetlands may thus have a greater relative impact on Water Resources and Ecosystem Services, and would require an increased offset target to adequately compensate for the services to be lost. A functional offset ratio is therefore introduced in order to differentiate between systems based on local demand. Loss of wetlands located in critical catchment contexts (high local demand scores) are therefore regarded as more significant (with higher offset requirements) than those located in contexts with low local demand.

In the study area, the functional importance ratio is automatically calculated for each wetland based on the local demand scores and weightings applied to the different Function / Service groups (Table 3). As with supply scores, the functional offset modifier is allocated with reference to a realistic "high demand" scenario. A final ratio is then allocated automatically based on the local demand score (Table 4).

Table 3. Calculating the functional importance ratio based on the demand for key regulating and supporting services.

Local demand for regulating and supporting services		
Function / Service Groups	**Weighting%**	**Demand Score**
Flood Attenuation	10%	0.7
Streamflow Regulation	0%	2.0
Sediment Trapping & Erosion Control	20%	3.0
Water Quality Enhancement	70%	2.3
Weighted Demand Score		2.3
Functional Importance Ratio		**1.25**

[1] This change was made following testing in the study area which revealed that even the most functional wetlands tend to score well for some services and not for others.

Table 4. Allocation of a functional importance ratio based on local demand scores for key ecosystem services.

Demand score	Ratio	Rationale
0 – 1.0	***0.75***	Wetlands located within a context where they provide very limited benefits to society
1.1 – 2.0	***1***	Wetlands quite poorly placed to address key water-resource challenges
2.1 – 3.0	***1.25***	Wetlands are well positioned to address key water-resource challenges
>3.0	***1.5***	Wetlands located in critical areas, where wetland functions are particularly important

In summary then, offset requirements for wetland functioning are calculated as follows:

1. Delineating the wetland that will be impacted by the proposed development.
2. Calculating the predicted wetland functionality (as a percent) based on a realistic rehabilitation state and the area of wetland over this impact will apply.
3. Calculating the functional importance ratio based on the landscape context and local demand.
4. Multiplying the area of wetland, functionality (%) and functional importance ratio to calculate the number of functional hectare equivalents that will be required.

5.2. *Assessing functional gains from planned offset activities*

The assessment of functional gains for offset receiving areas follows the same approach applied to impacted sites with the exception that gains are based on the expected improvement in ecosystem functioning relative to baseline conditions and incorporates an additional adjustment factor (Figure 4)[2]. Where wetland offset activities are directed to "Biodiversity" wetlands, rehabilitation needs to be designed according to the guidelines for these areas which includes efforts to improve the biodiversity value of these wetland areas. The improvement in functioning is then simply calculated by subtracting the current functional value score from that expected following successful rehabilitation.

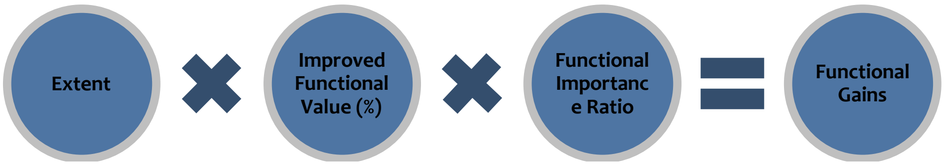

Figure 4. Outline of the approach used to assess functional gains from planned offset activities.

The preliminary offset gains are then adjusted based on the functional importance ratio of the targeted wetland. By following this approach, preference is given to wetlands located within scenarios with high demand for regulating and supporting services[3].

In summary then, the anticipated contributions to meeting functional targets are calculated by:

1. Delineating the wetland that will receive the offset.
2. Calculating the predicted change in wetland functionality (%) as a result of the offset implementation activities and the area of wetland over which this change will apply.

[2] It is important to note that the no adjustment has been made to functional gains to account for risks associated with offset implementation. The rationale for this is that (i) a similar risk is typically associated with on-site rehabilitation and was not used as a basis for down-weighting residual impacts; (ii) offset targets are already onerous and application of an additional adjustment factor would be unfair to the developer and (iii) by implementing a composite offset and by applying strict monitoring and management measures, the risk of rehabilitation failure is likely to be low.

[3] This approach is in line with the national wetland offset guidelines which have specifically highlighted the importance of selecting offset sites that are well placed to improve key ecosystem services.

3. Calculating the functional importance ratio based on the landscape context and local demand.
4. Multiplying the area of wetland, functionality change (%) and functional importance ratio together to calculate the number of functional hectare equivalents that will be gained.

6. RECOMMENDATIONS FOR FURTHER REFINEMENT

The revisions to the Wet-Ecoservices approach that have been integrated into this methodology represent an important step forward in terms of better quantifying gains and losses to ecosystem goods and services provided by wetland ecosystems. It is however important to recognise the complexity of the processes underpinning ecosystem services and the lack of data for many services. As such, there are inherent uncertainties with assessments of this nature (Schulp *et al*., 2014; Eigenbrod *et al*., 2010; Egoh *et al*., 2012; Jacobs *et al*., 2015 all cited in Science for Environment Policy, 2015)). Thus whilst this tool draws from best-available science to try and capture this complexity, we recognise that many assumptions are made in the tool, many of which are untested and are based on first-principles rather than being strongly supported by scientific research.

Jacobs *et al.* (2015) cited in Science for Environment Policy (2015) further recommend that ecosystem services assessments, especially those that incorporate expert judgment, should specifically include 'confidence reporting' based both on scientific evidence itself and degree of agreement between researchers. They further emphasise that models should be checked for reliability and validated using both primary data and expert opinion from different sources.

Thus whilst the methodology has been applied across a sub-set of wetlands in the project area, broader testing and discussion with other wetland ecologists should ideally be undertaken in order to improve the robustness of the tool. Key priorities for further testing and refinement include:

- Discussing and refining the conceptual workings of the model including the manner in which supply and demand are integrated into calculations;
- Evaluating preliminary outcomes across case study sites;
- Reviewing wetland characteristics and associated scoring classes;
- Evaluating and refining the sensitivity of the tool to input parameters;
- Specifically integrating riparian zones into the assessment;
- Testing the repeatability of the tool amongst users; and
- Testing and refining the tool for application at a National scale.

As an initial priority, the involvement of Dr Donovan Kotze is recommended in order to review and further customise the tool for local application. Thereafter, opportunities should be sought to refine the tool and associated guidance for broader national application.

Given the need for such refinement, calculations undertaken using this methodology should be viewed as preliminary and as providing an indication of the relative importance of wetlands in providing ecosystem goods and services. It is also important to note that the tool has not been tested for a broader target area. As such, the assumptions and generalizations included in the tool may not be equally relevant to other areas. Use of the tool beyond the study area must therefore be applied with this limitation in mind.

7. REFERENCES

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8. ANNEXURES

Annexure 1: Overview of changes made to the original Wet-Ecoservices framework.

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Flood attenuation			
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Opportunity to contribute to flood attenuation based on catchment size and landscape context	-	New criterion	This criterion was included in order to factor in the location of the wetland in terms of the quantity of water likely to pass through the system. Floodplains which generally have large contributing catchments are therefore scored highest compared with other wetland types which typically have smaller contributing catchments. Hillslope seeps and other headwater wetlands typically score low here, which is also consistent with international literature which suggests that there is inconclusive evidence of the benefits of these systems in attenuating flows (e.g. Bullock & Acreman, 2003).
Size of the wetland relative to the HGM units catchment (Box 4.1a)	Size of the wetland relative to the HGM Units catchment (Box 4.1a) - But included under "Effectiveness" calculation.	Retained criterion but moved to "Potential" calculation.	Assimilative capacity is an important consideration when assessing the potential for a wetland to provide flood attenuation functions. Where wetlands are very small in relation to their catchments, their capacity to assimilate floods is likely to be lower than for wetlands which are large in relation to their catchments.
Potential Score	**-**	**New formula**	When assessing potential, catchment size and landscape context is regarded as the primary consideration. This score is however adjusted by accounting for the second criterion. Note: The second criterion is regarded as less important and adjusts the initial score by 15% in accordance with findings from available research (Carleton *et al*, 2000).
What is the ability or effectiveness of the wetland (relative capacity on a hectare by hectare basis) to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			
Frequency with which storm flows spread across the wetland	Frequency with which storm flows spread across the wetland	Retained	Wetlands can only attenuate floods if floods spread out across the wetland and water is slowed down and retained in the wetland. If this does not occur (e.g. as is the case with floodplain systems that have become severely incised) they simply act as conduits for floodwaters. This is therefore regarded as the most important criterion when considering the ability of the wetland to attenuate floods.
Slope of wetland	Slope of wetland	Retained	If floodwaters over-top the channel banks and spread out across the wetland, these factors are key in determining the degree to which flows are likely to be slowed and water detained within the wetland.
Surface roughness of wetland	Surface roughness of wetland	Retained	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Depressions	Depressions	Retained	
Sinuosity of the stream channel	Sinuosity of the stream channel	Retained	
Representation of different hydrological zones	Representation of different hydrological zones	Retained	
Effectiveness score:	**Average of criteria**	**New formula**	The effectiveness score is initially set based on the first criterion which is critical to flood attenuation. This is then adjusted based on the average scores for the remaining criteria. In this way, a wetland which has all the correct attributes for flood detention but which is never activated by flooding scores very low. A wetland will also score poorly if it is regularly activated but on-site attributes make it poorly suited to attenuate flood waters.
Score for supply:	-	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (linked to setting and catchment characteristics). The degree to which this service is supplied is then based on wetland attributes that affect the effectiveness in providing this service. As such, the supply score is based initially on the opportunity score and then adjusted down (or maintained) based on the effectiveness score.
Runoff intensity from the wetland's catchment	Average slope of the wetland's catchment Inherent runoff potential of soils in catchment Contribution of catchment land-uses to changing runoff intensity from the natural condition Rainfall intensity	All criteria have been retained in the field sheet. A composite (average) score is calculated to reflect "Runoff intensity from the wetland's catchment".	The intensity of runoff affects flood magnitude and therefore the risk of flooding that could affect communities.
Degree to which upstream dams attenuate floods	-	New criterion	This criterion has been added to cater for situations where upstream dams attenuate floods and therefore reduce the demand for wetlands to provide this service.
Extent of floodable property downstream	Extent of floodable property downstream	Retained	These criteria provide an indication of the importance of this service for downstream users. The maximum value is used as risks associated with either property or human health are equally relevant.
Presence of communities downstream at risk of flooding events	-	New criterion	
Score for demand:	-	**New formula**	The demand for this service is based both on a coarse assessment of elevated flood risk (based on catchment attributes) and the demand for this service based on the susceptibility of infrastructure and communities downstream to flood damage / risks. Given that demand is essentially a reflection of user requirements, this was calculated by first assessing the maximum demand score for downstream users. This was then adjusted by accounting for catchment-related risk.

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Stream flow regulation			
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Link to the stream network	Link to stream network. But included under "Effectiveness" calculations	Retained criterion but moved to "Potential" calculation.	Unlike most other regulatory and supporting services, opportunity is not linked to the size of the catchment. The key issue here is whether or not the wetland is linked to the stream network. If it is, then it has the potential to contribute to flow regulation services.
Potential Score	-	**New formula**	Based on the score for 'Link to stream network'
What is the ability or effectiveness of the wetland (relative assimilative capacity on a hectare by hectare basis) to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			
Representation of different hydrological zones	Representation of different hydrological zones	Retained	These criteria are useful surrogates for assessing the degree to which the wetland is likely to be able to provide this service. There is currently insufficient information available to use as a basis for weighting the relative importance of these criteria. It is important to note that 'Link to stream network' and 'Presence of important wetlands or aquatic systems downstream' criteria have been removed from effectiveness calculation.
Presence of fibrous peat or unconsolidated sediments below floating marsh	Presence of fibrous peat or unconsolidated sediments below floating marsh	Retained	
Reduction in evapotranspiration through frosting back of the wetland vegetation	Reduction in evapotranspiration through frosting back of the wetland vegetation	Retained	
HGM unit occurs on underlying geology with strong surface-groundwater linkages	HGM unit occurs on underlying geology with strong surface-groundwater linkages	Retained	
Effectiveness score:	**Average of criteria**	**Average of criteria**	The effectiveness score is simply calculated as an average of the scores for each of the criteria assessed.
Score for supply:	-	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (dependant on linkage to stream network). The degree to which this service is supplied is then based on wetland attributes that affect the effectiveness in providing this service. As such, the supply score is based initially on the opportunity score and then adjusted down based on the effectiveness score.
Demand for benefits			
Reduction in low flows of downstream water resources as a result of catchment impacts or direct abstraction	-	New criterion	This criterion provides an indication of the degree to which anthropogenic impacts have reduced stream flows and thus the potential vulnerability of downstream users, particularly during dry periods.
Reliance of local communities and other downstream users on run-of-river abstraction	-	New criterion	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Presence & sensitivity of any important wetlands or aquatic systems downstream	Presence of any important wetlands or aquatic systems downstream	Retained, but 'sensitivity' included in the criterion description	These criteria provide an indication of the importance of this service for downstream users. The maximum value is used as risks associated with either property or human health are equally relevant.
Score for demand:	-	**New formula**	The demand for this service is based both on the level of stress (reduction in flows) and the demand for this service from either users or the environment. Given that demand is essentially a reflection of user requirements, this was calculated by first assessing the maximum demand score for downstream users. This was then adjusted by accounting for catchment-related impacts.
Sediment trapping			
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Opportunity to contribute to water quality enhancement functions based on catchment size and landscape context	-	New criterion	This criterion was included in order to factor in the location of the wetland in terms of the quantity of water (with associated pollutants) likely to pass through the system. Wetlands with large to very large catchments score highest for this criterion.
Size of the wetland relative to the HGM units catchment	-	New criterion	Assimilative capacity is an important consideration when assessing the potential for a wetland to provide sediment trapping functions. Where wetlands are very small in relation to their catchments, their capacity to trap sediment is likely to be lower than for wetlands which are large in relation to their catchments.
Potential Score	**-**	**New formula**	Where the wetland is not connected to the downstream network (Opportunity Score = 0), this is regarded as the over-riding factor, and a score of 0 is assigned. The second criterion is regarded as less important and adjusts the initial score by 15% in accordance with findings from available research (Carleton et al, 2001).
What is the ability or effectiveness of the wetland (relative assimilative capacity on a hectare by hectare basis) to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			
Effectiveness in attenuating floods	Effectiveness in attenuating floods	Retained	The criteria used to assess the effectiveness of flood attenuation are relevant here and provide an indirect measure of the ability of the wetland to trap sediments. The score for flood attenuation is therefore simply carried forward.
Direct evidence of sediment deposition	Direct evidence of sediment deposition	Retained	This criteria provides an opportunity to evaluate effectiveness based on a direct indicator of depositional features in the wetland.
Effectiveness score:	**Average of criteria**	**New formula**	Both direct and indirect indicators are useful criteria for assessing effectiveness of the wetland in trapping sediment. A final effectiveness score is calculated here by using the maximum score of the above two criteria.

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Score for supply:	-	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (linked to setting and catchment characteristics). The degree to which this service is supplied is then based on wetland attributes that affect the effectiveness in providing this service. As such, the supply score is based initially on the opportunity score and then adjusted down based on the effectiveness score.
Demand for benefits			
Extent of sediment sources within the HGM unit and associated catchment	Extent of sediment sources within the HGM unit and associated catchment	Retained	The extent of sediment sources in catchment and/or wetland is proxy for the catchment-scale sediment loss and sedimentation risks / threats to wetland and aquatic ecosystems as well as dams. The higher the risk, the higher the demand.
Extent to which dams are reducing the input of sediment	Extent to which dams are reducing the input of sediment	Retained	This criterion accounts for situations where upstream dams trap sediment and therefore reduce the opportunity for wetlands to provide this service.
Location and importance of dams relative to the wetland	-	New criterion	These criteria provide an indication of the importance of this service for downstream users. The maximum value is used as risks associated with either property or human health are equally relevant.
Presence & sensitivity of any important wetlands or aquatic systems downstream	Presence of any important wetlands or aquatic systems downstream	Retained, but 'sensitivity' included in the criterion description	
Score for demand:	-	**New formula**	The demand for this service is based both on the level of sedimentation risk and the demand for this service from either users or the environment. Given that demand is essentially a reflection of user requirements, this was calculated by first assessing the demand score for downstream users. This was then adjusted by accounting for catchment-related impacts.
Erosion control			
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Slope of wetland	Slope of wetland - But included under "Opportunity" calculation	Retained criterion but moved to "Potential" calculation.	These criteria are regarded as key inherent factors affecting erosion risk.
Erodibility of the soil in the wetland	Erodibility of the soil in the wetland - But included under "Opportunity" calculation	Retained criterion but moved to "Potential" calculation.	
Potential Score	-	**New formula**	The opportunity for wetlands to provide this service is based on the inherent erosion risk. Erosion risk is low in wetlands with stable soils and gentle slope whilst risk is far higher for steep wetland systems with erodible soils.
What is the ability or effectiveness of the wetland to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Direct evidence of erosion	Direct evidence of erosion	Retained	This provides a very direct measure of soil loss from the wetland which would suggest that the service is not being provided.
Current level of physical soil disturbance in wetland	Current level of physical soil disturbance in wetland	Retained	This criterion increases the risk of soil loss, particularly during high flows and can therefore increase the vulnerability of the wetland to erosion, and thus detract from the wetland's ability to control erosion.
Surface roughness	Surface roughness	Retained	These criteria provide an indication of the ability of the wetland to slow flows and bind soil, thereby reducing erosion risk.
Extent of vegetation cover	Extent of vegetation cover	Retained	
Effectiveness score:	**Average of criteria**	**New formula**	Both direct and indirect indicators are useful criteria for assessing effectiveness of the wetland in controlling erosion. A final effectiveness score is calculated here by using the minimum scores calculated based on (i) direct evidence of erosion and (ii) average of scores for the indirect indicators of erosion risk.
Score for supply:	-	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (linked to slope and erodibility of soils). The degree to which this service is supplied is then based on wetland attributes that affect the ability of the wetland to provide this service. As such, the supply score is based initially on the opportunity score and then adjusted down based on the effectiveness score.
Demand for benefits			
Contribution of catchment land-uses to changing runoff intensity	Contribution of catchment land-uses to changing runoff intensity - but included in "Opportunity" calculation	Retained but moved to "Demand" calculation	The risk of erosion is largely dependent on factors that have increased the intensity of storm flows from the catchment.
Degree to which upstream dams attenuate floods	-	New criterion	This criterion has been added here to cater for situations where upstream dams attenuate floods and therefore slow down high flows and thereby reduce erosion risk.
Importance of wetlands in providing direct benefits (food for livestock, harvestable natural resources and cultivated foods)	-	New criterion	Soils provide the foundation on which a range of direct uses from wetlands are realised. As such, the demand for any of these services should also be considered when evaluating the demand for erosion control services.
Importance for carbon storage	-	New criterion	Wetland soils retain carbon. As such, the demand for erosion control is higher for wetlands that are regarded as important in supplying this service.
Location and importance of dams relative to the wetland	-	New criterion	Dams are susceptible to sediment inputs. As such, the demand for erosion control services is regarded as important where wetlands are situated upstream of dams.
Presence & sensitivity of any important wetlands or aquatic systems downstream	-	New criterion	Same as sediment trapping

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Score for demand:	-	**New formula**	Given that demand is essentially a reflection of user requirements, this was calculated by first assessing the maximum demand score for the range of potential users identified. Wetlands have formed under specific sediment and hydrological regimes. As such, erosion is likely to materialise where catchment impacts have altered water inputs into the system. The final demand score was therefore adjusted to account for catchment-related risks.
Phosphate removal			
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Opportunity to contribute to water quality enhancement functions based on catchment size and landscape context	-	New criterion	This criterion was included in order to factor in the location of the wetland in terms of the quantity of water (with associated pollutants) likely to pass through the system. Wetlands with large to very large catchments score highest for this criterion.
Size of the wetland relative to the HGM units catchment (Box 4.1a)	-	New criterion	Assimilative capacity is an important consideration when assessing the potential for a wetland to provide water quality enhancement functions. Where wetlands are very small in relation to their catchments, their capacity to assimilate pollutants is likely to be lower than for wetlands which are large in relation to their catchments.
Potential Score	-	**New formula**	Where the wetland is not connected to the downstream network (Opportunity Score = 0), this is regarded as the over-riding factor, and a score of 0 is assigned. The second criterion is regarded as less important and adjusts the initial score by 30% in accordance with findings from available research (Carleton et al, 2001).
What is the ability or effectiveness of the wetland (relative assimilative capacity on a hectare by hectare basis) to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			
Effectiveness of trapping sediment	Effectiveness of trapping sediment	Retained	The primary mechanism of P removal from surface waters is via co-deposition with sediments (via adsorption / binding to Fe and Al in soils under aerobic conditions). Other removal mechanisms are bioaccumulation and sedimentation that is largely controlled by the residence time (largely controlled by slope and the density and robustness of vegetation (surface roughness) that are also encapsulated in this criterion.
Hydrological zonation	-	New criterion	In general, phosphate assimilation is most efficient under aerobic conditions whilst reducing / waterlogged conditions are known to release P into overlying surface waters (Fisher & Acreman, 2004). Literature suggests that the retention of soluble P is much less efficient than the retention of particulate P (Fisher & Acreman, 2004). This in contrast to nitrate removal, which is most efficient under anaerobic conditions via denitrification (Fisher & Acreman, 2004).
Pattern of low flows within the wetland	Pattern of low flows within the wetland	Retained	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Extent of vegetation cover	Extent of vegetation cover	Retained	
Effectiveness score:	**Average of criteria**	**New formula**	The primary mechanism of phosphorous removal is co-deposition with (adsorption to) sediments under aerobic conditions (as particulate P). As such, wetland attributes affecting P co-deposition are the same as those for sediment removal. These include characteristics contributing to slow, shallow uniform flow, gentle slope, increased surface roughness and high infiltration rates. In contrast, the removal of dissolved P in anaerobic conditions is relatively ineffective, although some dissolved P can be removed via plant uptake and chemical processes, if residence times are long. Therefore factors increasing the time spent by dissolved P in the wetland, will increase its removal. The pattern of low flows and extent of vegetation cover have therefore been included as additional factors. Given the above, the effectiveness score was calculated by weighting sediment trapping double that of the remaining factors. It is also important to note that the criterion "application of fertilizers and biocides within the wetland unit" has been excluded. This criterion was included by Kotze et al., (2007) to factor in the reduced assimilative capacity of wetlands that are directly burdened by nutrient pollution. However, this criterion was excluded because both onsite and catchment pollutants are considered catchment pollutant inputs included in the demand calculation.
Score for supply:	**-**	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (linked to wetland context). The degree to which this service is supplied is then based on wetland attributes that affect the ability of the wetland to provide this service. As such, the supply score is based initially on the opportunity score and then adjusted down based on the effectiveness score.
Demand for benefits			
Extent of phosphate sources in the HGM unit and associated catchment	Extent of phosphate sources in the HGM unit and associated catchment - but included in "Opportunity" calculation	Retained but moved to "Demand" calculation	This criterion is used to assess the levels of phosphate sources added directly to the HGM unit and that emanating from the upstream catchment (previously assessed under 2 separate criteria (Box 4.4d & f)
Degree to which upstream water quality impacts are likely to be assimilated by existing ecological infrastructure (e.g. wetlands, riparian zones and their buffers)	-	New criterion	This criterion has been added to account for situations where existing ecological infrastructure is already playing an important role in assimilating pollutants, therefore reducing the demand for this service.

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Extent to which dams are reducing the input of sediment	-	New criterion	This criterion accounts for situations where upstream dams trap sediment and associated phosphates and therefore reduce the opportunity for wetlands to provide this service.
Presence & sensitivity of any important wetlands or aquatic systems downstream	Presence of any important wetlands or aquatic systems downstream	Retained, but 'sensitivity' included in the criterion description	
Location and importance of dams relative to the wetland	-	New criterion	Phosphates pose a eutrophication risk that can affect the suitability of water for recreation and potable use.
Reliance of local communities and other downstream users on run-of-river abstraction	-	New criterion	Phosphates pose a eutrophication risk which can reduce the suitability of water supply for domestic water supply.
Score for demand:	**-**	**New formula**	The demand for this service is based both on the risk of phosphate contaminants and the demand for this service from either users or the environment. Given that demand is essentially a reflection of user requirements, this was calculated by first assessing the maximum demand score for downstream users. This was then adjusted by accounting for catchment-related impacts.
Nitrate removal			
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Opportunity to contribute to water quality enhancement functions based on catchment size and landscape context	-	New criterion	This criterion was included in order to factor in the location of the wetland in terms of the quantity of water (with associated pollutants) likely to pass through the system. Wetlands with large to very large catchments score highest for this criterion.
Size of the wetland relative to the HGM units catchment (Box 4.1a)	-	New criterion	Assimilative capacity is an important consideration when assessing the potential for a wetland to provide water quality enhancement functions. Where wetlands are very small in relation to their catchments, their capacity to assimilate pollutants is likely to be lower than for wetlands which are large in relation to their catchments.
Potential Score	**-**	**New formula**	Where the wetland is not connected to the downstream network (Opportunity Score = 0), this is regarded as the over-riding factor, and a score of 0 is assigned. The second criterion is regarded as less important and adjusts the initial score by 30% in accordance with findings from available research (Carleton et al, 2000).
What is the ability or effectiveness of the wetland (relative assimilative capacity on a hectare by hectare basis) to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			
Hydrological zonation	Hydrological zonation	Retained	
Pattern of low flows	Pattern of low flows	Retained	
Extent of vegetation cover	Extent of vegetation cover	Retained	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Contribution of sub-surface water inputs relative to surface water inputs	Contribution of sub-surface water inputs relative to surface water inputs	Retained	
Effectiveness score:	**Average of criteria**	**Same formula**	Based simply on averaging a range of factors known to promote nutrient retention. Insufficient information currently available to differentiate between the importance of different factors. However, the criterion "application of fertilizers and biocides within the wetland unit" has been excluded. This criterion was included by Kotze et al., (2007) to factor in the reduced assimilative capacity of wetlands that are directly burdened by nutrient pollution. However, this criterion was excluded because both onsite and catchment pollutants are considered catchment pollutant inputs included in the demand calculation.
Score for supply:	**-**	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (linked to wetland context). The degree to which this service is supplied is then based on wetland attributes that affect the ability of the wetland to provide this service. As such, the supply score is based initially on the opportunity score and then adjusted down based on the effectiveness score.
Demand for benefits			
Extent of nitrate sources in the HGM unit's catchment	Extent of nitrate sources in the HGM unit's catchment - but included in "Opportunity" calculation	Retained but moved to "Demand" calculation	This criterion is used to assess the levels of nitrate sources added directly to the HGM unit and that emanating from the upstream catchment (previously assessed under 2 separate criteria (Box 4.4d & 4.5d)
Degree to which upstream water quality impacts are likely to be assimilated by existing ecological infrastructure (e.g. wetlands, riparian zones and their buffers)	-	New criterion	This criterion has been added to account for situations where existing ecological infrastructure is already playing an important role in assimilating pollutants, therefore reducing the demand for this service.
Presence & sensitivity of any important wetlands or aquatic systems downstream	Presence of any important wetlands or aquatic systems downstream	Retained, but 'sensitivity' included in the criterion description	
Location and importance of dams relative to the wetland	-	New criterion	Nitrates pose a eutrophication risk that can affect the suitability of water for recreation and potable use.
Reliance of local communities and other downstream users on run-of-river abstraction	-	New criterion	Nitrates pose a eutrophication risk which can reduce the suitability of water supply for domestic water supply.
Score for demand:	**-**	**New formula**	The demand for this service is based both on the risk of nutrient inputs and the demand for this service from either users or the environment. Given that demand is essentially a reflection of user requirements, this was calculated by first assessing the maximum demand score for downstream users. This was then adjusted by accounting for catchment-related impacts.
Toxicant removal			

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Supply of benefits			
What potential does this wetland have in providing this service in relation to other wetlands in the catchment?			
Opportunity to contribute to water quality enhancement functions based on catchment size and landscape context	-	New criterion	This criterion was included in order to factor in the location of the wetland in terms of the quantity of water (with associated pollutants) likely to pass through the system. Wetlands with large to very large catchments score highest for this criterion.
Size of the wetland relative to the HGM units catchment (Box 4.1a)	-	New criterion	Assimilative capacity is an important consideration when assessing the potential for a wetland to provide water quality enhancement functions. Where wetlands are very small in relation to their catchments, their capacity to assimilate pollutants is likely to be lower than for wetlands which are large in relation to their catchments.
Potential Score	**-**	**New formula**	Where the wetland is not connected to the downstream network (Opportunity Score = 0), this is regarded as the over-riding factor, and a score of 0 is assigned. The size of the wetland relative to the catchment is regarded as secondary to the first criterion. With reference to existing studies, the second criterion adjusts the final score by 30%.
What is the ability or effectiveness of the wetland (relative assimilative capacity on a hectare by hectare basis) to provide this service relative to an ideal "reference" wetland based on morphological and structural attributes			
Effectiveness in trapping sediment	Effectiveness in trapping sediment	Retained	Many toxics are bound to sediment, and as such, the effectiveness of the wetland in trapping sediment is regarded as an important criterion.
Hydrological zonation	Hydrological zonation	Retained	Permanently wet, diffuse flow conditions and long residence times are also known to contribute to toxicant trapping and removal from surface waters and as such these criteria broadly encapsulate these conditions. However, it is important to note that anaerobic / permanently wet conditions are not always effective at removing some toxicants. Furthermore, it is also important to note that the criterion "application of fertilizers and biocides within the wetland unit" has been excluded. This criterion was excluded because both onsite and catchment pollutants are considered catchment pollutant inputs included in the demand calculation.
Pattern of low flows	Pattern of low flows	Retained	
Extent of vegetation cover	Extent of vegetation cover	Retained	
Effectiveness score:	**Average of criteria**	**New formula**	Effectiveness was assessed by averaging the score for (i) sediment trapping ability and (ii) effectiveness in assimilating toxics that are not sediment bound.
Score for supply:	**-**	**New formula**	The ability of a wetland to provide this service is essentially constrained initially by the opportunity to provide this service (linked to wetland context). The degree to which this service is supplied is then based on wetland attributes that affect the ability of the wetland to provide this service. As such, the supply score is based initially on the opportunity score and then adjusted down based on the effectiveness score.

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Demand for benefits			
Extent of toxicant sources in the HGM unit and associated catchment	Extent of toxicant sources in the HGM unit's catchment - but included in the "Opportunity" calculation	Retained but moved to "Demand" calculation	This criterion is used to assess the levels of toxicant sources added directly to the HGM unit and that emanating from the upstream catchment (previously assessed under 2 separate criteria (Box 4.4d & 4.6b)
Degree to which upstream water quality impacts are likely to be assimilated by existing ecological infrastructure (e.g. wetlands, riparian zones and their buffers)	-	New criterion	This criterion has been added to account for situations where existing ecological infrastructure is already playing an important role in assimilating pollutants, therefore reducing the demand for this service.
Presence & sensitivity of any important wetlands or aquatic systems downstream	Presence of any important wetlands or aquatic systems downstream	Retained, but 'sensitivity' included in the criterion description	These criteria provide an indication of the importance of this service for downstream users. The maximum value is used as all are potentially important users.
Location and importance of dams relative to the wetland	-	New criterion	
Reliance of local communities and other downstream users on run-of-river abstraction	-	New criterion	
Score for demand:			The demand for this service is based both on the risk of toxicant inputs and the demand for this service from either users or the environment. The potential demand score was therefore set based on user requirements but was then adjusted by accounting for the actual risk posed by toxics entering the wetland.

Carbon storage			
Supply of benefits			
Hydrological zones	Hydrological zones	Retained	
Abundance of peat	Abundance of peat	Retained	
Level of soil disturbance in wetland	Level of soil disturbance in wetland	Retained	
Score for supply:	**Average of criteria**	**Average of criteria**	No change in formula. The supply score is based simply on an average of these three criteria.
Demand for benefits			
Demand for carbon storage	-	New criterion	Some indication of the demand for carbon storage is required. Globally, it is generally high to very high do to global warming phenomenon.
Score for demand:	**-**	**New formula**	Simply equals the single criterion

Biodiversity maintenance

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Supply of benefits			
Biodiversity Noteworthiness/Attributes:	Biodiversity Noteworthiness/Attributes	Retained	
Represents a good and/or representative example of a threatened or rare ecosystem or vegetation type (at provincial and/or national scales)	HGM unit is of a rare type or is of a wetland type or vegetation type subjected to a high level of cumulative loss (Box 4.9a)	Retained	Focus is on identifying good examples / representations of threatened and/or rare ecosystems. Subtle change in description but essentially the same thing. However, the focus is on wetland ecosystem types only.
Provides habitat for threatened or rare/endemic species (at provincial and/or national scales)	Red Data species or suitable habitat for Red Data species (Box 4.9c)	Retained	Subtle change in description but essentially the same thing.
Unusual or unique species, populations or habitats (at provincial and/or national scales)	Level of significance of other special natural features (Box4.9d)	New criterion (more specific)	Additional guidance is provided to assist users in identifying other noteworthy biodiversity features.
Species and/or habitat diversity / richness		New criterion (more specific)	
Important ecological corridor or ecological linkage in landscape	-	New criterion	Included to factor in the value of ecosystems / habitats in terms of a biodiversity maintenance supporting role in the landscape as an ecological corridor, linkage or refuge rather than a direct role based on onsite noteworthy attributes.
Score for noteworthiness:	**Average of criteria**	**New formula**	The noteworthiness score is based on the maximum of the five attributes assessed. This therefore accounts for a broad range of biodiversity attributes that are important for wetland conservation. It is also important to note that the criterion "level of cumulative loss of wetlands in the catchment" that is present in the "Noteworthiness" calculation of Kotze et al 2008 has been removed because cumulative loss at a catchment scale is not considered a large enough scale to ascertain the rarity of a particular wetland type at provincial and national scales, which is the focus of this revised assessment.
Integrity (Modifying Factors):	Integrity	Retained	
Alteration of hydrological regime	Alteration of hydrological regime	Retained	
Complete removal of indigenous vegetation	Complete removal of indigenous vegetation	Retained	
Invasive and pioneers species encroachment	Invasive and pioneers species encroachment	Retained	
Presence of hazardous/restrictive barriers	Presence of hazardous/restrictive barriers	Retained	
Extent of buffer around wetland	Extent of buffer around wetland	Retained	
Connectivity of wetland in landscape	Connectivity of wetland in landscape	Retained	
Alteration of sediment regime	Alteration of sediment regime	Retained	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Alteration of nutrient/toxicant regime	Alteration of nutrient/toxicant regime	Retained	
Score for integrity:	**Average of criteria**	**Same formula**	An average score is used to calculate the degree to which the integrity of the wetland and other key factors likely to affect persistence of biodiversity have been undermined.
Score for supply:	**-**	**New formula**	The biodiversity value of the wetland is essentially defined primarily on the basis of noteworthiness and other special attributes. A range of other factors do affect the integrity of the system and associated ability of the wetland to provide long-term biodiversity benefits. As such, the supply score is based initially on the noteworthiness score and then adjusted down based on other modifying factors.
Demand for benefits			
HGM unit is a rare and/or threatened ecosystem or vegetation type at a national scale (National Ecosystem Conservation / Threat Status)	-	New criterion (borrowed from "Noteworthiness" in Kotze et al 2008)	Now linked with threat status of wetland ecosystems - either wetland vegetation group or ecosystem types defined in NFEPA.
Protection status of the wetland ecosystem and/or vegetation type at a national scale	-	New criterion	Accounts for the degree to which ecosystem targets have already been achieved.
Regional & national conservation planning Importance	-	New criterion	Accounts for the importance in terms of meeting national and regional conservation targets.
Importance for tourism & recreation	-	New criterion	Accounts for wetlands in which biodiversity supports tourism and recreational activities.
Importance for education & research	-	New criterion	Accounts for wetlands in which biodiversity supports education and research activities.
Score for demand:	**-**	**New formula**	The demand for biodiversity protection can link to a range of factors including (i) importance in terms of meeting ecosystem conservation targets and (ii) importance in terms of supporting cultural services. Demand here is calculated by assessing the demand for each of these aspects and then taking the maximum of these scores. Note: When assessing demand for biodiversity protection, the threat status score and protection levels provides an indirect measure of demand whilst classification of the site as an important area provides a direct measure. Given that there are pros and cons with each approach, an average score is calculated based on these two aspects.

Water supply for direct human use

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Supply of benefits			
Availability of springs / open water for abstraction	-	New criterion. Replaces the following indirect criteria from Kotze et al, 2008: (i) Hydrological wetness zones and (ii) Streamflow regulation.	Accounts for availability of suitable abstraction points associated with the wetland.
Periodicity of supply	-	New criterion	Accounts for the seasonality of supply. A wetland is less important in terms of water supply if such supply is only seasonal. Often, low flow / dry season supply is the most important for subsistence use.
Score for supply:	**Average of criteria (But a different set of criteria)**	**New formula**	The score for supply is based primarily on the availability of suitable points for domestic water supply. This score is then adjusted based on the periodicity of supply. It is also important to note that in Kotze et al, 2008 there was no differentiation in criteria in terms of effectiveness (supply) and opportunity (demand).
Demand for benefits			
Current use for agricultural or industrial purposes	Current use for agricultural or industrial purposes	Retained - but included in "Demand" calculation	
Current use for domestic purposes	Current use for domestic purposes	Retained - but included in "Demand" calculation	
Substitutability of wetland water source	Substitutability of wetland water source	Retained - but included in "Demand" calculation	
Score for demand:	**-**	**New formula**	The score for demand is based primarily on existing levels of use (max score of first two criteria). This score is however adjusted downwards for situations in which supply can easily be replaced by alternative sources. It is important to note that the criterion "Number of households dependant on water supply" has been excluded from the calculation. This is because water supply to any number of people is considered important and the determination of the number of dependant households is not practically possible in practice (i.e. in the typical execution of the tool).
Harvestable natural resources			
Supply of benefits			
Availability of sedges for craft production	Total number of resources	New criteria	A range of criteria have been added to better understand the suitability of wetlands in providing a suite of harvestable natural resources, typically used by rural communities.
Availability of reeds and grasses for thatching			
Availability of wood for construction / combustion			
Clay for building / pot production			
Presence of fish and game for harvesting			

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Presence of medicinal plants			
Score for supply:	**Average of criteria (but only for overall score)**	**New formula**	The supply score is based on an average of the three largest scores across all the criteria assessed.
Demand for benefits			
Demand for sedges for craft production	Location in rural communal area, Level of poverty, number of households depending on wetland, substitutability of wetland resources	New criteria	A range of criteria have been added to better understand the demand for harvestable natural resources.
Demand for reeds & grasses for thatching			
Demand for wood for construction / combustion			
Demand for clay for building / pot production			
Demand for fish and game			
Demand for medicinal plants			
Score for demand:	**Average of criteria (but only for overall score)**	**New formula**	The demand score is based on an average of the three largest scores across all the criteria assessed.
Food for livestock (New Service)			
Supply of benefits			
Hydrological zones	-	New criteria	A range of new criteria have been included to obtain an indication of grazing capacity.
Presence of palatable plant species			
Quality of forage during the winter months (Note: remains high if baled)			
Score for supply:	**-**	**New formula**	The supply score is based simply on an average of the above criteria.
Demand for benefits			
Use of wetland for grazing / hay making	-	New criteria	A range of new criteria have been included to obtain an indication of the demand for grazing.
Reliance on wetland vegetation during winter months			
Extent of wetland relative to grazing lands			
Score for demand:	**-**	**New formula**	The demand score is based simply on an average of the above criteria.
Cultivated foods			
Supply of benefits			
Ease of regulating (lowering) water table through drainage	-	New criteria	The suitability of wetlands for agriculture is largely dependent on the ability to manage and control water levels.
Relative suitability of soils for agriculture			

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Score for supply:	**-**	**New formula**	The supply score is based simply on an average of the above criteria.
Demand for benefits			
Level of poverty	Level of poverty	Retained - but included in "Demand" calculation	These criteria provide an indirect measure of demand
Location in rural communal area	Location in rural communal area	Retained - but included in "Demand" calculation	
Extent of cultivation in the wetland	Total number of different crops cultivated in the HGM unit	New criterion, but similar to original concept, and moved to "Demand" calculation	This provides a direct measure of current use as a surrogate for demand.
Substitutability of the crops cultivated in the wetland	Substitutability of the crops cultivated in the wetland	Retained - but included in "Demand" calculation	
Score for demand:	**Average of criteria**	**New formula**	The score for demand is based initially on the maximum score for (i) an indirect measure of demand (average of first two criteria) and (ii) a direct measure of use (third criterion). This score is then adjusted downwards for situations in which crops produced in the wetlands can be substituted by crops grown outside the wetland. It is also important to note that the criterion "Number of households who depend on the crops cultivated in the HGM unit" has been excluded and replaced by "extent of cultivation" criterion.

Tourism & recreation			
Supply of benefits			
Scenic beauty of the HGM unit	Scenic beauty of the HGM unit	Retained	These criteria include a range of aspects that influence the suitability of a site for recreation and tourism.
Presence of "charismatic" species	Presence of "charismatic" species	Retained	
Recreational hunting and fishing and birding opportunities	Recreational hunting and fishing and birding opportunities	Retained	
Extent of open water	Extent of open water	Retained	
Accessibility of site	-	New criterion	Accessibility is critically important for most tourism and recreational activities.
Security risk	-	New criterion	Security risk is a key factor affecting the suitability of a site for recreational and tourism activities.
Score for supply:	**Average of criteria (but for overall functional score)**	**New formula**	The suitability of a site for tourism and recreation is influenced by both wetland attributes and factors affecting access and use. To account for this interaction, the suitability of the site is initially calculated by averaging the top two scores from the first four criteria. This score is then down weighted based on limitations associated with access and risk (average of last two criteria).
Demand for benefits			
Location within a tourism route	Location within a tourism route	Retained	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al.*, 2007)	Action relative to Kotze *et al.* (2007)	Rationale for changes made
Currently use for recreation & tourism	Currently use for recreation & tourism	Retained	
Availability of other natural areas providing similar experiences	-	New criterion	If many similar sites are available and are being used for recreation / tourism, then the importance / demand for such spaces is reduced.
Score for demand:	**Average of criteria (but for overall functional score)**	**New formula**	The score for demand is based initially on the maximum score for (i) an indirect measure of demand (first criterion) and (ii) a direct measure of use (second criterion). This score is then adjusted downwards for situations in which a range of other natural areas provide similar experiences.
Education and research			
Supply of benefits			
Reference site suitability	Reference site suitability	Retained	
Availability of unique learning opportunities	-	New criterion	Sites providing interesting or unique learning opportunities are particularly valuable for education and research purposes.
Accessibility of site	Accessibility of site	Retained	
Security risk	-	New criterion	Security risk is a key factor affecting the suitability of a site for education and research purposes.
Score for supply:	**Average of criteria (but for overall functional score)**	**New formula**	The suitability of a site for education and research is influenced by both wetland attributes and factors affecting access and use. To account for this interaction, the suitability of the site is initially calculated by assessing the maximum value for the top two scores. This score is then down weighted based on limitations associated with access and risk (average of last two criteria).
Demand for benefits			
Location in relation to education, research and community outreach facilities	-	New criterion	The availability of alternative sites increases with distance from such facilities.
Current use for education/research purposes	Current use for education/research purposes	Retained	
Existing long term research & data collected	Existing long term research & data collected	Retained	
Score for demand:	**Average of criteria (but for overall functional score)**	**New formula**	The score for demand is based on the maximum score for (i) an indirect measure of demand (first criterion) and (ii) a direct measure of use (max of second two criteria).
Cultural significance			
Supply of benefits			
Registered SAHRA site	Registered SAHRA site	Retained	

Revised criteria (Macfarlane & Edwards, 2015)	WET-EcoServices criteria (Kotze *et al*., 2007)	Action relative to Kotze *et al*. (2007)	Rationale for changes made
Location in a communal rural area	Location in a communal rural area		
Known cultural practices	Known cultural practices		
Known taboos/beliefs	Known taboos/beliefs		
Score for supply:	**Average of criteria (but for overall functional score)**	**Average of criteria**	The supply score is based simply on an average of the above criteria.
Demand for benefits			
As above			It is difficult to differentiate between supply and demand in this case. Since both aspects determine use, supply and demand scores are rated the same unless there is a compelling reason to rate them differently.
Score for demand:			

A STRATEGIC WETLAND OFFSET ASSESSMENT FOR THE DEVELOPMENT OF A RESILIENCE FRAMEWORK FOR LANDHOLDINGS IN ETHEKWINI MUNICIPALITY'S NORTHERN SPATIAL DEVELOPMENT PLAN AREA

Revision No. 0.3

Date: December 2015

Author: Ryan Edwards, Scott Haworth, Douglas Macfarlane & Craig Cowden

Report No: EP181-04

Prepared for:

Tongaat Hulett DEVELOPMENTS

dube tradePORT SOUTHERN AFRICA'S PREMIER AIR LOGISTICS PLATFORM

ETHEKWINI MUNICIPALITY ENVIRONMENTAL PLANNING & CLIMATE PROTECTION DEPARTMENT BIODIVERSITY | CLIMATE | PEOPLE

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Suggested report citation:

Edwards, R. J., Haworth, S., Macfarlane, D. M. & Cowden, C. 2015. A Strategic Wetland Offset Assessment for the development of a resilience framework for landholdings in eThekwini Municipality's Northern Spatial Development Plan Area. Specialist Report prepared by Eco-Pulse Environmental Consulting Services & Ground-Truth: Wetlands for the Dube TradePort Corporation, Tongaat Hulett Developments and eThekwini Municipality: Environmental Planning and Climate Protection Department. Version 0.3. December 2015.

SPECIALIST ASSESSMENT REPORT DETAILS AND DECLARATION OF INDEPENDENCE

This is to certify that the following report has been prepared as per the requirements of Appendix 6 (1) of the NATIONAL ENVIRONMENTAL MANAGEMENT ACT, 1998 (Act No. 107 OF 1998) ENVIRONMENTAL IMPACT ASSESSMENT REGULATIONS 2014 as per Government Notice No. 38282 GOVERNMENT GAZETTE, 04 DECEMBER 2014.

Document Title:	A Strategic Wetland Offset Assessment for the development of a resilience framework for landholdings in eThekwini Municipality's Northern Spatial Development Plan Area.
Report prepared by:	Ryan Edwards, Scott Haworth, Douglas Macfarlane and Craig Cowden
Field of study/Expertise:	Wetland Ecology
Date:	17 December 2015
Version Number:	0.3
Reviewed by:	Douglas Macfarlane (Pr. Sci. Nat.)
Approved by:	Douglas Macfarlane (Pr. Sci. Nat.)
Signature:	
Date:	17 December 2015
Client:	Dube TradePort Corporation, Tongaat Hulett Developments and eThekwini Municipality: Environmental Planning and Climate Protection Department

I, Ryan Edwards, hereby declare that this report has been prepared independently of any influence or prejudice as may be specified by the Department of Environmental Affairs.

Signed: ______________________ Date: 17 December 2015

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1. INTRODUCTION

1.1 Background

A strategic framework for improved wetland management has recently been developed for eThekwini Municipality's Northern Spatial Development Plan Area (Macfarlane, 2015), and has received in-principle buy-in from the key landowners involved, namely the Dube TradePort Corporation (DTPC), Tongaat Hulett Developments (THD) and the eThekwini Environmental Planning and Climate Protection Department (EPCPD). This framework clearly articulates the initial proposed policy objectives and implementation framework for wetland management in the study area. This includes specific goals for wetland offsets that cater for a full spectrum of functions and values provided by wetlands (Figure 1).

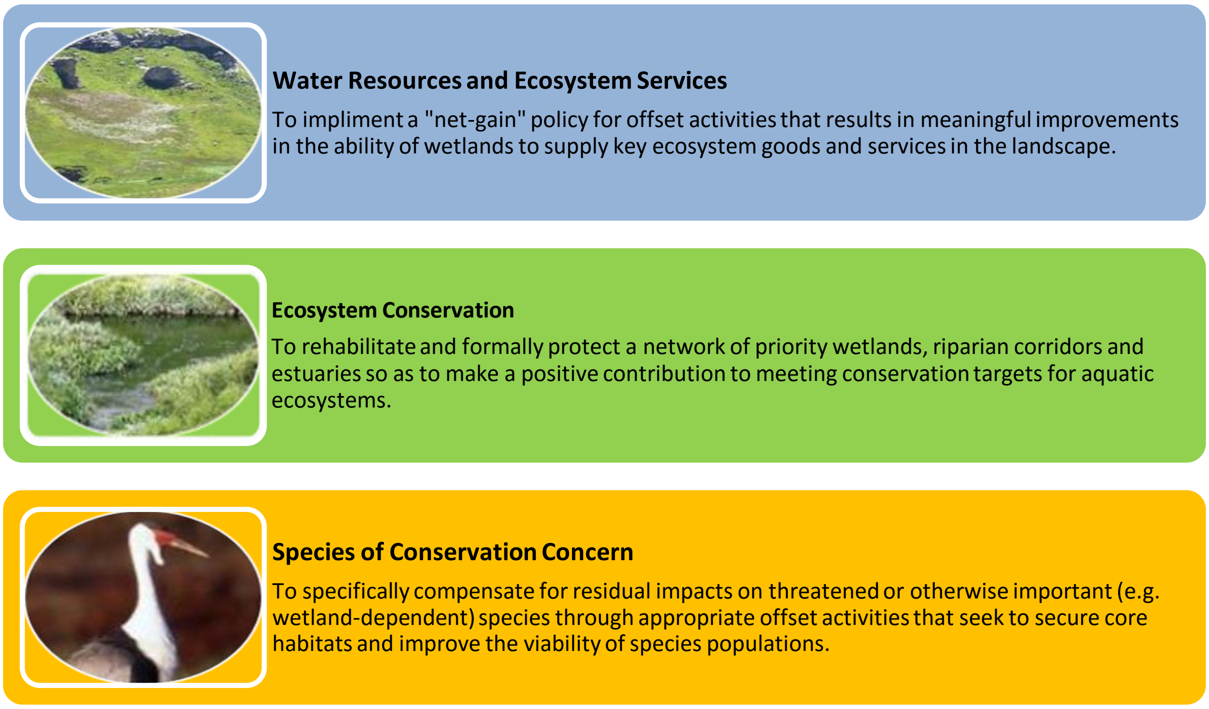


Figure 1 Goals for wetland offsets in the study area

DTPC and THD are in the process of finalising various development proposals for the study area. Priority projects which were included as part of this assessment are detailed in Table 1, with spatial locations indicated in Figure 2. In each instance, the proposed developments are set to have some impact on wetland ecosystems which will need to be addressed through appropriate wetland offset activities.

Table 1 Summary of the development projects considered as part of this assessment[1].

Development	Applicant	River Catchment
Inyaninga Farm Development	THD	oHlanga River (U30B)
Sibaya Node 4 Development	THD	Mdloti River (U30C)
AgriZone 2	DTPC	Mdloti & Tongaat Rivers (U30C & U30D)
TradeZone 2	DTPC	Tongaat River (U30D)
Dudley Pringle Farm Development	THD	Tongaat River (U30D)
uShukela	THD	Tongaat River (U30D)
Lindokuhle Housing Project	THD	Tongaat River (U30D)

Given the importance of maximizing potential offset gains, an opportunity to take a landscape view and to direct offset activities towards strategically placed wetland offset receiving areas was identified by project partners. This led to the identification of preliminary focal areas for offset implementation (Figure 2). A detailed assessment of anticipated gains and losses is however required in order to determine the potential to meet offset requirements within these focal areas.

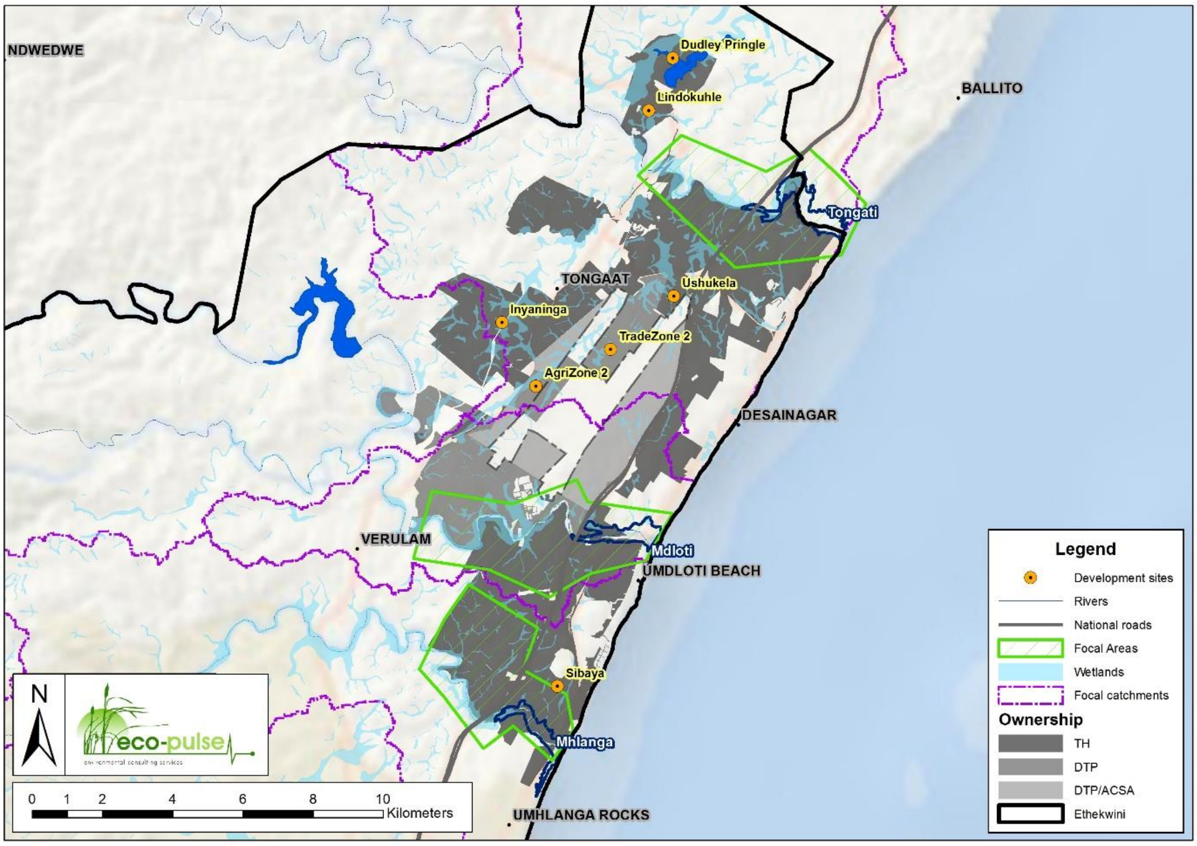


Figure 2 Preliminary focal areas identified to meet wetland offset requirements.

[1] Note: A range of additional developments are being planned for this region but have not specifically been considered as part of this assessment. An assessment of these areas and the potential of earmarked offset receiving areas in meeting any offset requirements will therefore need to be undertaken on a case-by-case basis.

1.2 Purpose of Document and Scope of Work

As part of the implementation of the strategic wetland management framework for the eThekwini Northern Spatial Development Plan (Macfarlane, 2015), Eco-Pulse Environmental Consulting Services were appointed to undertake a strategic wetland offset assessment in line with the new wetland offset framework proposed for the study area. The scope of work for this assessment involved the following tasks:

- Calculation of the revised and up-to-date wetland offset targets for the selected developments within the study area according to the new wetland offset framework;
- Identification of strategic wetland priorities within the study area and delineation of the proposed offset receiving areas for the OHlanga, Mdloti and Tongaat focal areas; and
- Assessment of the potential gains that could be achieved through rehabilitation and protection of wetlands and associated buffer zones in each focal area.

The results of this assessment will then be used as a basis for evaluating the feasibility of meeting offset targets for the proposed developments and to inform further development and offset planning.

2. APPROACH AND METHODS

2.1 Assessment of development sites

Potential wetland offset requirements were assessed for each development site based on the "Wetland Offset Framework" for the study area as detailed in the strategic framework for improved wetland management in eThekwini's Northern Spatial Development Plan Area (Macfarlane, 2015). Individual assessments were carried out for each development site and were based on the latest development plans provided by DTPC and THD[2]. Detailed findings from each of these assessments are included in a range of supporting reports as outlined in Table 2, below.

[2] It is important to note that the development layouts assessed were based on those provided by THD and DTPC and may need to be refined during the environmental authorization process.

Table 2 Supplementary reports for each development site.

Development project	Applicant	Report	Author
AgriZone 2	DTPC	Edwards, R. J. 2015. KwaZulu-Natal. Proposed Dube Tradeport AgriZone 2 Development in the eThekwini Municipality, KwaZulu-Natal: Wetland Offset Targets. Specialist Report prepared by Eco-Pulse Environmental Consulting Services for the Dube TradePort Corporation. December 2015.	Eco-Pulse Consulting
TradeZone 2	DTPC	Edwards, R. J. 2015. KwaZulu-Natal. Proposed Dube Tradeport TradeZone 2 Development in the eThekwini Municipality, KwaZulu-Natal: Wetland Offset Targets. Specialist Report prepared by Eco-Pulse Environmental Consulting Services for the Dube TradePort Corporation. December 2015.	Eco-Pulse Consulting
Inyaninga	THD	GroundTruth 2015. Tongaat Hulett Developments: Inyaninga. Wetland Study: Functional Equivalents. Report No GTW535-281015-01. Unpublished Specialist Report. December 2015.	GroundTruth
Sibaya	THD	GroundTruth 2015. Tongaat Hulett Developments: Sibaya. Wetland Study: Functional Equivalents. Report No GTW535-231015-01. Unpublished Specialist Report. October 2015.	GroundTruth
Dudley Pringle	THD	GroundTruth 2015. Tongaat Hulett Developments: Dudley Pringle. Wetland Study. Report No GTW557-261015-01. Unpublished Specialist Report. October 2015.	GroundTruth
uShukela	THD	GroundTruth 2015. Tongaat Hulett Developments: uShukela. Wetland Study. Report No GTW551-301015-01. Unpublished Specialist Report. October 2015.	GroundTruth
Lindokuhle	THD	GroundTruth 2015. Tongaat Hulett Developments: Lindokuhle. Wetland Study. Report No GTW557-301015-01. Unpublished Specialist Report. October 2015.	GroundTruth

The results of each of these assessments were then consolidated in order to define potential offset requirements for (i) Water Resources and Ecosystem Services and (ii) Ecosystem Conservation for DTPC and THD. It is important to note that targets for species of conservation concern were not established through this process. The need for such targets will need to be established on a site-by-site basis.

2.2 Assessment of Offset Receiving Areas

Delineation and classification of water resources

For most of the focal areas, formal wetland delineations and assessments had not been undertaken and as such infield delineations and associated GIS shapefiles of the wetland areas were not available to the authors. Thus, the wetland and riparian areas within each focal area was mapped at a desktop level by the authors using 2013 colour aerial photography and 2m contours in QGIS 2.8. Rapid site visits of selected areas were the undertaken to refine the desktop mapping[3]. The desktop wetland areas were then subdivided into distinct HGM units as per the *Classification System for Wetlands and other Aquatic Ecosystems in South Africa* (Ollis et al., 2013).

[3] The following assumptions and limitations of this mapping and classification are applicable:

- All mapping of wetland and riparian zones within the offset receiving areas is based on an analysis of aerial photography and 2m contours with limited infield verification, as well as the authors' experience with similar wetland types in the area. Thus, the accuracy of the boundaries and extent of the wetland areas is based on the authors' interpretations of visual features and the accuracy of the 2m contours.

Prioritization of areas for inclusion within offset receiving areas

Wetland areas mapped within each focal area were screened at a desktop level in terms of the potential contributions to functional and ecosystem conservation targets. Given that the assessment was undertaken at quite a broad level, wetlands were grouped according to similar HGM Process Units[4] and associated characteristics (Table 3). This allowed wetlands with potentially good offset contributions (Priority 1: high) to be differentiated from those with low anticipated contributions (Priority 3: low).

Table 3 Summary of sample HGM process units within the offset receiving areas and their defining characteristics.

HGM Process Units	Defining Characteristics	Generic Priority Rating
S1 - Moderately-steep Seep (Un-drained)	Slope 2-5%,Un-drained	• Rehab potential: Low (Priority 3) • Ecological importance: Moderate (Priority 2)
S2 - Moderately-steep Seep (Partially drained)	Slope 2-5%, Partially drained	• Rehab potential: Moderate (Priority 2) • Ecological importance: Moderate (Priority 2)
S3 - Moderately-steep Seep (Drained)	Slope 2-5%, Drained	• Rehab potential: Moderate (Priority 2) • Ecological importance: Moderate (Priority 2)
S4 - Steep Seep (Un-drained)	Slope >5%, Un-drained	• Rehab potential: Low (Priority 3) • Ecological importance: Moderate (Priority 2)
S5 - Steep Seep (Partially Drained)	Slope >5%, Partially drained	• Rehab potential: Low (Priority 3) • Ecological importance: Low (Priority 3)
S6 - Steep Seep (Drained)	Slope >5%, Drained	• Rehab potential: Low (Priority 3) • Ecological importance: Low (Priority 3)
VB1 - Gentle UCVB	Slope <1%	• Rehab potential: High (Priority 1) • Ecological importance: High (Priority 1)
VB2 - Moderate UCVB	Slope 1-2%	• Rehab potential: High (Priority 1) • Ecological importance: High (Priority 1)
VB3 - Moderately-steep CVB	Slope 2-5%	• Rehab potential: Moderate (Priority 2) • Ecological importance: Moderate (Priority 2)
VB4 - Steep CVB	Slope >5%	• Rehab potential: Low (Priority 3) • Ecological importance: Low (Priority 3)
F1 - Floodplain wetland – Backwamp depression (vegetated)	Backwamp setting, vegetated	• Rehab potential: Low (Priority 3) • Ecological importance: High (Priority 1)
F2 - Floodplain wetland – Backwamp depression (under cane & drained)	Backwamp setting, under cane cultivation, drained	• Rehab potential: High (Priority 1) • Ecological importance: High (Priority 1)
F3 – Low lying floodplain wetland (vegetated with incoming tributary)	Low lying relative to channel bed, vegetated, incoming tributary	• Rehab potential: High (Priority 1) • Ecological importance: High (Priority 1)
F4 – Low lying floodplain wetland (vegetated with no incoming tributary)	Low lying relative to channel bed, vegetated	• Rehab potential: Low (Priority 3) • Ecological importance: High (Priority 1)
RF1 – Elevated riparian floodplain terrace (vegetated)	Vegetated	• Rehab potential: Low (Priority 3) • Ecological importance: Moderate (Priority 2)
RF2 – Elevated riparian floodplain terrace (under cane / plantations / fields – with incoming tributary)	Under cane cultivation / plantation/recreation, incoming tributary	• Rehab potential: High (Priority 1) • Ecological importance: Moderate (Priority 2)
RF3 – Elevated floodplain terrace (under cane / plantations / fields – with no incoming tributary)	Under cane cultivation / plantation / recreation	• Rehab potential: Low (Priority 3) • Ecological importance: Moderate (Priority 2)

- Similarly to above, the subdivision of the wetland areas into distinct HGM units is based on an analysis of aerial photography and 2m contours, as well as the authors' experience with similar wetland types in the area.

[4] These units were defined with reference to the new functional assessment methodology (Macfarlane & Edwards, 2015) and aimed to differentiate between wetland systems with different functional values.

HGM Process Units	Defining Characteristics	Generic Priority Rating
AW1 – Artificial Wetland	Artificial wetland	• Rehab potential: Moderate (Priority 2) • Ecological importance: Moderate (Priority 2)
R1- Riparian areas	Vegetation associated with a stream / river channel, non-wetland	• Rehab potential: Low (Priority 3) • Ecological importance: Low (Priority 3)

Riparian areas were also included in the offset receiving areas where they provided important ecological linkages or were located within important terrestrial patches. Where low priority wetlands and/or riparian areas were found to be providing important (or potentially important) ecological linkage services between habitat patches of value, priority ratings were manually adjusted up (Priority 2). Only those wetland (and riparian) units screened as being of moderate and high importance were then included in potential offset receiving areas and were assessed in terms of potential offset contributions. The location and extent of different HGM process units included within earmarked offset receiving areas are included in Annexure A.

Buffer zones may also contribute towards ecosystem conservation targets. For the purposes of this assessment, a standard 50m buffer was applied to each of the wetlands included within earmarked offset receiving areas. While the width of this buffer zone will need to be refined at a site-level, this buffer width was selected over a narrower width in order to enhance opportunities for species movement, secure terrestrial habitat for key semi-aquatic species[5] and reduce the potential negative edge-effects of linear habitats that could reduce the suitability of these areas to use by biota. Where this linked with areas identified as potentially important terrestrial habitat (e.g. intact forest remnants & largely intact grasslands), the preliminary buffer zone width was expanded to accommodate these features. It is important to note however that the extent to which largely intact terrestrial areas will be incorporated into offset sites requires further consideration as it may be preferable to secure such areas as terrestrial offset areas.

Assessing potential offset contributions

Water Resources and Ecosystem Services

A rapid assessment of present state and potential rehabilitated state was undertaken for each of the wetland HGM groupings in order to assess the potential functional gains that could be realised. This assessment was undertaken using the Eco-Pulse functional offset methodology (Macfarlane and Edwards, 2015) and associated assessment tool (Eco-Pulse, 2015)[6]. For standardisation purposes, the scores for key assessment criteria were finalised upfront for each of the HGM groups based on a clear set of assumptions (Annexure B). The preliminary offset contributions for each grouping were then calculated as the difference between the expected rehabilitated state and present state functional equivalents (Change in functional value). These results were

[5] The presence of the Pickersgill's Reed Frog (*Hyperolius pickersgilli*) is particularly important in this landscape. Compared with many other faunal groups, frogs are relatively poor dispersers, given their small size, generally low agility and requirement of moist microhabitats. As a result, the availability of sufficient non-breeding habitat in order to disperse and forage is vital to ensure the long-term viability of populations. Connectivity should be maintained between breeding sites and other wetlands, drainage lines and areas of untransformed habitat.

[6] It is important to note that this assessment tool ideally requires further testing and refinement. The results provided in this report should therefore be viewed as providing only a first approximation of potential gains and losses.

then adjusted based on the functional importance ratio. The functional gains were then summed across all HGM groupings to provide an indication of the potential total functional gains for each offset receiving area.

Ecosystem Conservation

An assessment of the hypothetical rehabilitated state of wetland vegetation was undertaken for each of the wetland HGM groupings within targeted offset receiving areas using the vegetation module of the Level 1 WET-Health tool (Macfarlane *et al*., 2007). The expected habitat value and associated wetland habitat contribution provided by each wetland grouping under a realistic rehabilitation scenario was then calculated (in habitat equivalents. The contribution of non-wetland habitat included within offset sites in the form of riparian zones, terrestrial habitat and buffer zones was also assessed under a post-rehabilitation scenario based on a generic assumption of habitat condition (See assumptions below). The contribution of these habitats towards ecosystem conservation targets was restricted in line with the offset calculator published as part of the national wetland offset guidelines (SANBI & DWA, 2014). The ecosystem conservation contributions were then summed across all HGM groupings by adding wetland habitat and buffer zone contributions to provide an indication of the potential contributions of each offset receiving area to ecosystem conservation targets.

Assumptions and Limitations

The following key assumptions and limitations of this assessment are applicable:

- Delineation and classification of wetlands was largely undertaken at a desktop scale. Inaccuracies in the type and extent of wetlands can therefore be expected and will need to be refined during detailed assessments.
- The hypothetical post-rehabilitation state of the wetlands was assessed based on reasonable practical rehabilitation interventions and not a best case or bare minimum scenario. In terms of hydrology, it is assumed that drained wetland units with longitudinal gradients of <2% could be fully reinstated and that rehabilitation potential decreases considerably with every degree of steepness beyond 2%. In terms of re-vegetation, reasonable and practical re-vegetation is assumed that looks to establish an indigenous vegetation cover for functional ecological purposes rather than biodiversity but which consists largely of non-weedy, locally occurring indigenous species. It is important to note however that significant opportunities for wetland enhancement exist in the landscape and should be investigated further during detailed planning.
- The assessment of functional gains was undertaken using the newly developed functional assessment methodology for wetland offsets in eThekwini Municipality's Northern Spatial Development Plan Area (Macfarlane & Edwards, 2015). Changes in the approach and calculations can be expected with further refinement and testing of this methodology.
- Buffer zone contributions have been calculated based on a compatibility score of 0.75 (75%). This is based on the assumption that basic rehabilitation of these areas will be undertaken but not to the extent that a diverse assemblage of natural vegetation characteristic of benchmark vegetation is reintroduced. It is also

important to note that the extent of largely intact terrestrial vegetation to be included as buffer zone habitat requires further consideration.

- It is important to note that this assessment was undertaken at a largely desktop level and was not informed by detailed site investigations or the development of detailed rehabilitation plans. Refinements to these assessments will therefore need to be made following the completion of detailed rehabilitation and management plans for each site.
- Further discussions will be required with respect to the contributions of wetlands within estuary zones to offset contributions, particularly given potential like-for-like concerns. The involvement of an estuarine ecologist as part of any further rehabilitation planning and detailed functional assessments within estuarine zones is therefore recommended.

3. RESULTS AND DISCUSSION

3.1 Calculation of Offset Targets

A summary of the functional and ecosystem conservation offset targets calculated for each of the development projects, and the total targets across development sites are summarised in Table 4, below. Whilst details of each assessment are captured in individual site reports, the extent of wetlands that will be impacted on each site are included in Annexure C whilst further details of offset calculations are included in Annexure D.

The results of these assessments show that selected developments are expected to result in the transformation of some 151.05 hectares of wetland habitat. Most of these wetlands are classified as hillslope seeps and have a relatively low functional value, even in a realistic rehabilitation state (Figure 3). As a consequence, the development impact on key ecosystem services was calculated as 61.58 functional hectare equivalents. The offset target is slightly lower than this owing to the generally low local demand scores and associated functional importance ratios (Table 4).

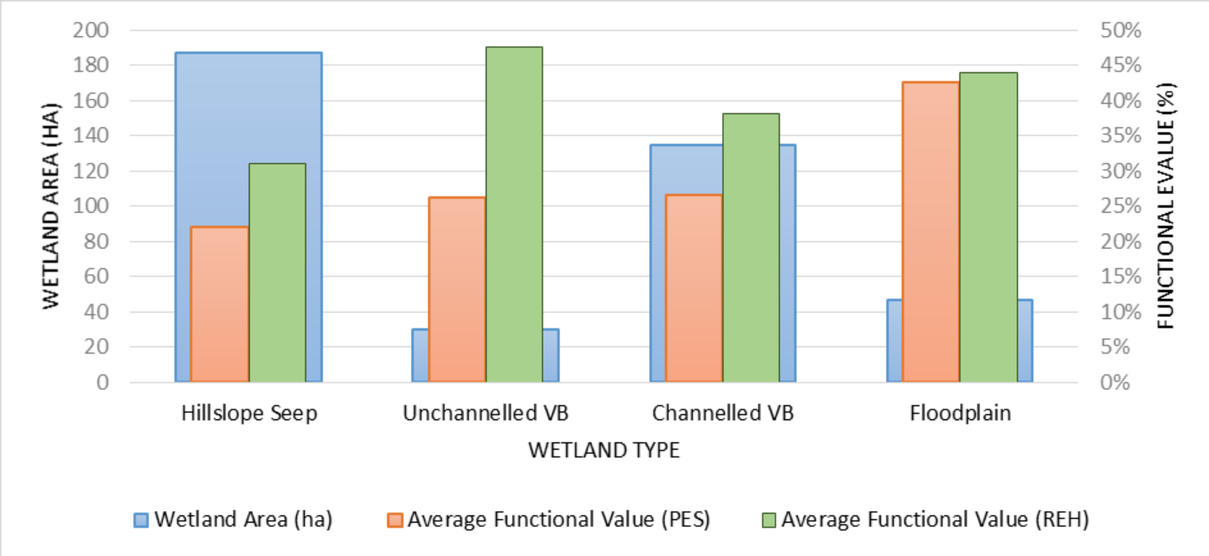


Figure 3 Distribution of impacts across wetland types and showing the variability in average functional values currently provided (PES) and under a realistic potential rehabilitation state (REH).

The implication is that THD and DTPC are required to identify, secure and rehabilitate wetlands within earmarked offset receiving areas such that **59.08 functional equivalents** are gained and **775.53 habitat equivalents** are rehabilitated and secured in the landscape through appropriate offset mechanisms. The individual targets for THD and DTPC are also provided.

Table 4 Summary of the functional and ecosystem conservation offset targets (in hectare equivalents) calculated for selected development projects in the study area.

		Water Resources and Ecosystem Services		Ecosystem Conservation	
Development	**Impacted Area (Ha)**	**Development Impact [7]**	**Functional Offset Target**	**Development Impact**	**Ecosystem Conservation Target**
DTPC					
AgriZone 2	13.2	6.56	6.52	6.6	6.6
TradeZone 2	29.4	10.11	10.11	15.1	15.1
Sub-Total	***42.64***	***16.67***	***16.63***	***21.69***	***21.69***
THD					
Inyaninga	34.6	15.23	13.50	16.9	16.9
Sibaya	0.2	0.05	0.05	0.1	0.1
Dudley Pringle	30.2	11.95	11.64	15.1	15.1
uShukela	25.9	9.96	9.55	12.9	12.9
Lindokuhle	17.6	7.70	7.70	8.8	8.8
Sub-Total	***108.41***	***47.54***	***44.90***	***53.83***	***53.83***
Combined					
Grand Total	**151.05**	**61.58**	**59.08**	**75.53**	**75.53**

[7] Note: This assessment was based on a hypothetical realistic rehabilitation state of impacted wetlands.

Box 1: Comparison of targets with those calculated using the wetland offset guidelines (DWS & SANBI, 2015)

The Wetland Offset Guidelines (DWS & SANBI, 2015) were also applied for comparison purposes. Under this approach, offset requirements are based on the existing values of wetlands prior to development (PES). A range of modifiers are also used to define the ecosystem conservation ratios for each wetland.

Water Resources and Ecosystem Services: In this instance, targets are essentially calculated simply based on the residual impacts assessed using the new functional assessment methodology. Without applying the functional importance ratio, the required target would be slightly higher at 64.21 functional hectare equivalents.

Ecosystem Protection Targets: Given the degraded nature of most of the wetlands targeted, the development impact across all sites was calculated as 18.02 habitat hectare equivalents. The average ecosystem conservation ratio applied across sites was 3.8:1 which is significantly lower than the starting ecosystem conservation ratio of 15:1 for Indian Ocean Coastal Belt Group 2 wetland types. This is attributed to the site attributes that are not conducive to biodiversity maintenance (low biodiversity value, moderate buffer zone compatibility and generally low connectivity) which in turn has resulted in these wetlands not being flagged as important in regional or national conservation plans. Based on this approach, the Ecosystem Conservation target was calculated as 67.60 habitat hectare equivalents. This is comparable to the target calculated using the new approach.

3.2 Offset Receiving Areas and Anticipated Gains

Identification of Offset Receiving Areas

The extent of proposed offset receiving areas are shown in Figures 5-7. These maps specifically identify wetlands, riparian zones and buffer zones that have been included in the assessment (delineated by way of a dashed blue line)[8]. Additional desirable terrestrial vegetation and estuarine habitat that should ideally be incorporated into these conservation zones has also been included at this stage.

Anticipated Functional Gains

An assessment of different wetland types within earmarked offset receiving areas revealed considerable variability in the functional gains that could be achieved through standard rehabilitation activities (Figure 4). Predicted gains are lowest in hillslope seepage and floodplain wetlands. In the case of hillslope seeps, this is linked to the lower potential of such sites to deliver benefits (linked to their position in the landscape) while in the case of floodplain wetlands, topographical constraints (e.g. elevation above typical water levels) reduce the effectiveness of these areas in providing key water quality enhancement services. Greater improvements can be expected in channelled valley bottoms and unchannelled systems with an average 23% improvement expected through the rehabilitation of unchannelled valley bottom wetlands.

[8] It is important to note that some changes to the final extent of offset receiving areas is anticipated. This will include a reduction in the extent of terrestrial habitat included in "buffer zones" and an adjustment in boundaries to account for existing rehabilitation and protection requirements stipulated in existing environmental authorizations.

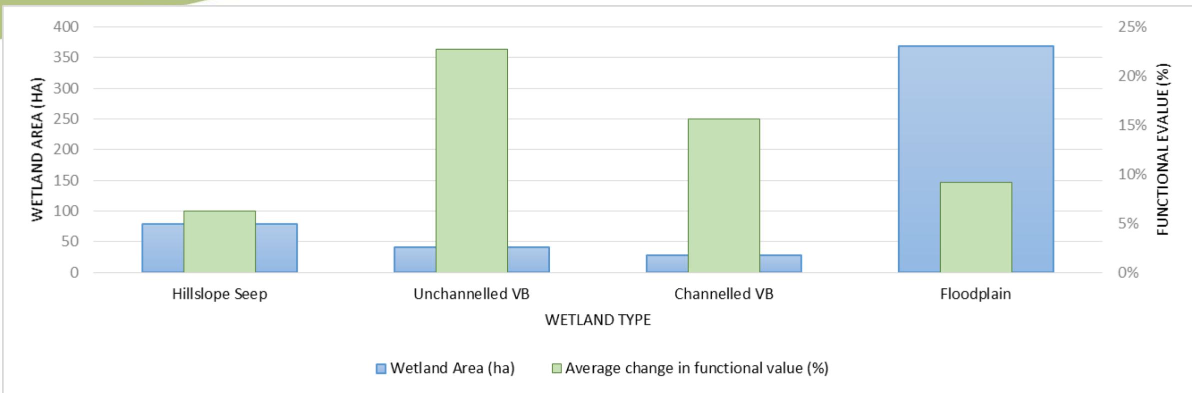


Figure 4 Area and expected gains in functional values across wetland types within earmarked offset receiving areas.

The total gains in functional equivalents resulting from the reasonable and practical rehabilitation of the wetland units within the three proposed offset receiving areas was calculated to be **90.3 functional hectare equivalents** with the biggest contributions coming from the Mdloti and Tongaat receiving areas (Table 5). This assessment shows that rehabilitation of proposed offset receiving areas is likely to deliver gains in wetland functions well in excess of the estimated losses from proposed developments included in this assessment (see Table 4). The implication is that a smaller area could be targeted for rehabilitation or that additional gains could potentially be "banked" to address wetland offset requirements linked to future developments in the region.

Table 5 Predicted functional gains associated with proposed offset receiving areas.

Offset Site	Wetland Area (ha)	Change in functional value (%)	Preliminary Offset Contribution	Weighted Demand Score	Functional Importance Ratio	Functional Gains
Mdloti system	164.4	10%	27.4	2.5	1.25	34.2
oHlanga system	128.1	11%	15.6	2.6	1.33	22.4
Tongaat system	226.2	11%	27.0	2.4	1.25	33.7
Grand Total	**518.6**		**70.0**			**90.3**

When proposed offset activities are considered together with the functional gains expected through on-site rehabilitation efforts, it is clear the proposed developments could make a meaningful net contribution towards improving key wetland functions in the landscape.

Anticipated Ecosystem Conservation Gains

The total ecosystem conservation gains resulting from the reasonable and practical rehabilitation of the wetland units and associated buffer zones within the three proposed offset receiving areas was calculated to be **204.6 habitat hectare equivalents** with the biggest contributions coming from the Mdloti and Tongaat receiving areas (Table 6). The figures indicate that the gains would more than meet the developers' ecosystem conservation offset requirements with a significant surplus over-and-above that required. Further details including calculations for each offset receiving area are included In Annexure E.

It is worth noting that these calculations are based on the assumption that offset receiving areas will be secured through the minimum acceptable means (conservation servitude) for a 30 year period. According to the national wetland offset guidelines, gains could improve significantly if longer-term protection measures were put in place but would need to be discussed further with regulating agencies. The calculations integrate a range of terrestrial areas that occur beyond the 50m buffer zone. While these areas should ideally be included within any protected area established, the calculations suggest that they could potentially be excluded from this assessment and rather be used to account for any terrestrial offset requirements should they arise.

Table 6 Total and per catchment ecosystem conservation gains associated with the offset receiving areas.

Offset Site	Wetland Area (ha)	REH Habitat Condition	Wetland habitat contribution	Buffer extent (Ha)	Buffer zone compatibility	Buffer zone contribution	Ecosystem Conservation Contribution
Mdloti system	164.4	47%	48.1	560.2	0.8	24.0	72.1
oHlanga system	128.1	46%	29.0	378.2	0.8	14.5	43.5
Tongaat System	226.2	48%	59.3	296.0	0.8	29.7	89.0
Grand Total	**518.6**		**136.4**	**1234.4**		**68.2**	**204.6**

When considered together with improvements in wetland habitat anticipated as a result of on-site rehabilitation efforts, planned developments could help to significantly enhance wetland conservation values in the landscape. This is in line with the vision for wetland management in the area and would undoubtedly also create opportunities for range expansion of threatened species that already occur in the area[9].

Box 1: Comparison of targets with those calculated using the wetland offset guidelines (DWS & SANBI, 2015)

The Wetland Offset Guidelines (DWS & SANBI, 2015) were also applied for comparison purposes. Under this approach, offset requirements are based on the existing values of wetlands prior to development (PES). A range of modifiers are also used to define the ecosystem conservation ratios for each wetland.

Water Resources and Ecosystem Services: In this instance, targets are essentially calculated simply based on the residual impacts assessed using the new functional assessment methodology. Without applying the functional importance ratio, the required target would be slightly higher at 64.21 functional hectare equivalents.

Ecosystem Protection Targets: Given the degraded nature of most of the wetlands targeted, the development impact across all sites was calculated as 18.96 habitat hectare equivalents. The average ecosystem conservation ratio applied across sites was 3.8:1 which is significantly lower than the starting ecosystem conservation ratio of 15:1 for Indian Ocean Coastal Belt Group 2 wetland types. This is attributed to the site attributes that are not conducive to biodiversity maintenance (low biodiversity value, moderate buffer zone compatibility and generally low connectivity) which in turn has resulted in these wetlands not being flagged as important in regional or national conservation plans. Based on this approach, the Ecosystem Conservation target was calculated as 71.2 habitat hectare equivalents. This is comparable to the target calculated using the new approach.

[9] Given the potential benefits for threatened frog species, consideration could also be given to generating credits for threatened species as part of the offset area.

Figure 5 Proposed offset receiving area for the oHlanga Focal Area.

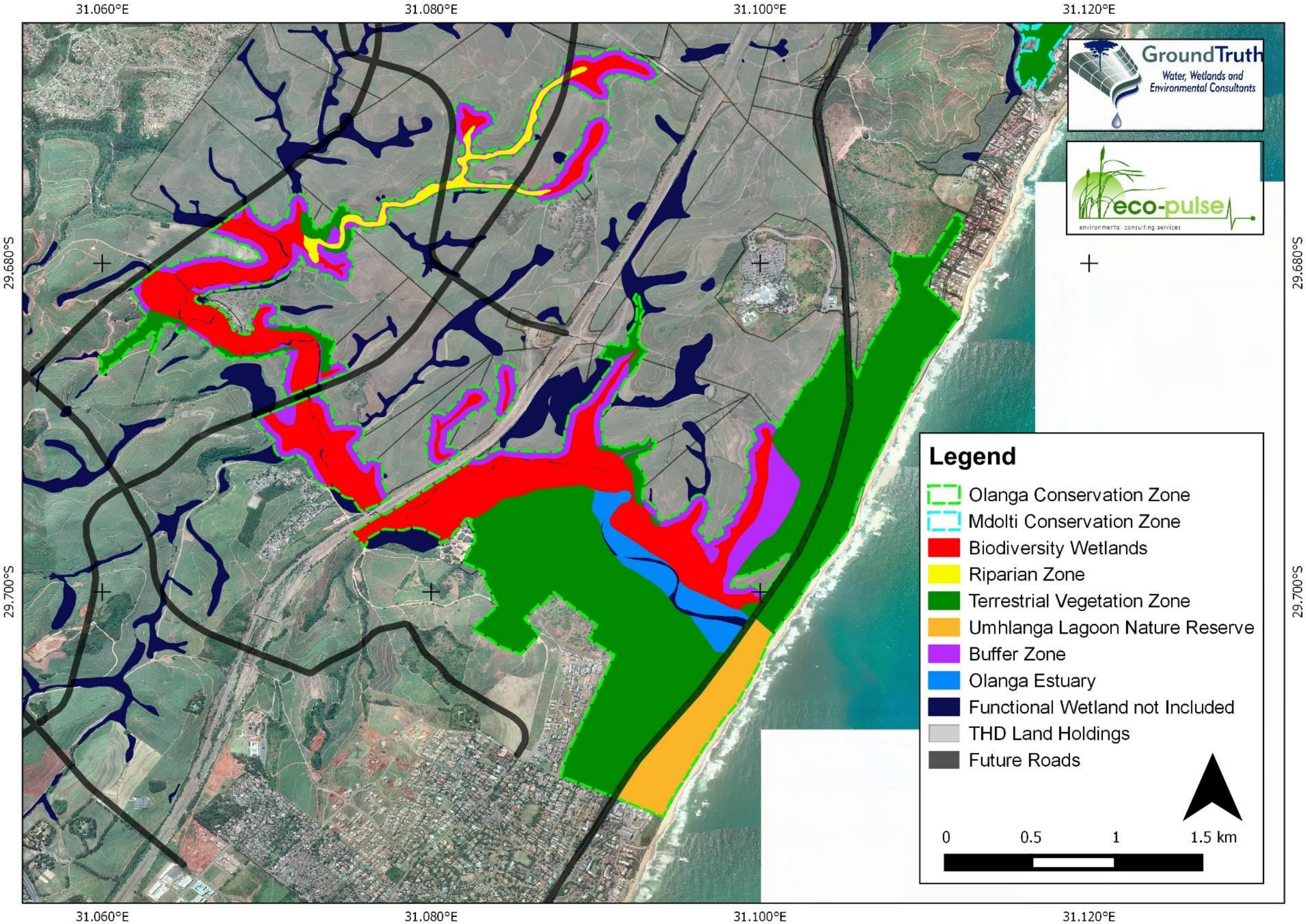


Figure 6 Proposed offset receiving area for the Mdloti Focal Area.

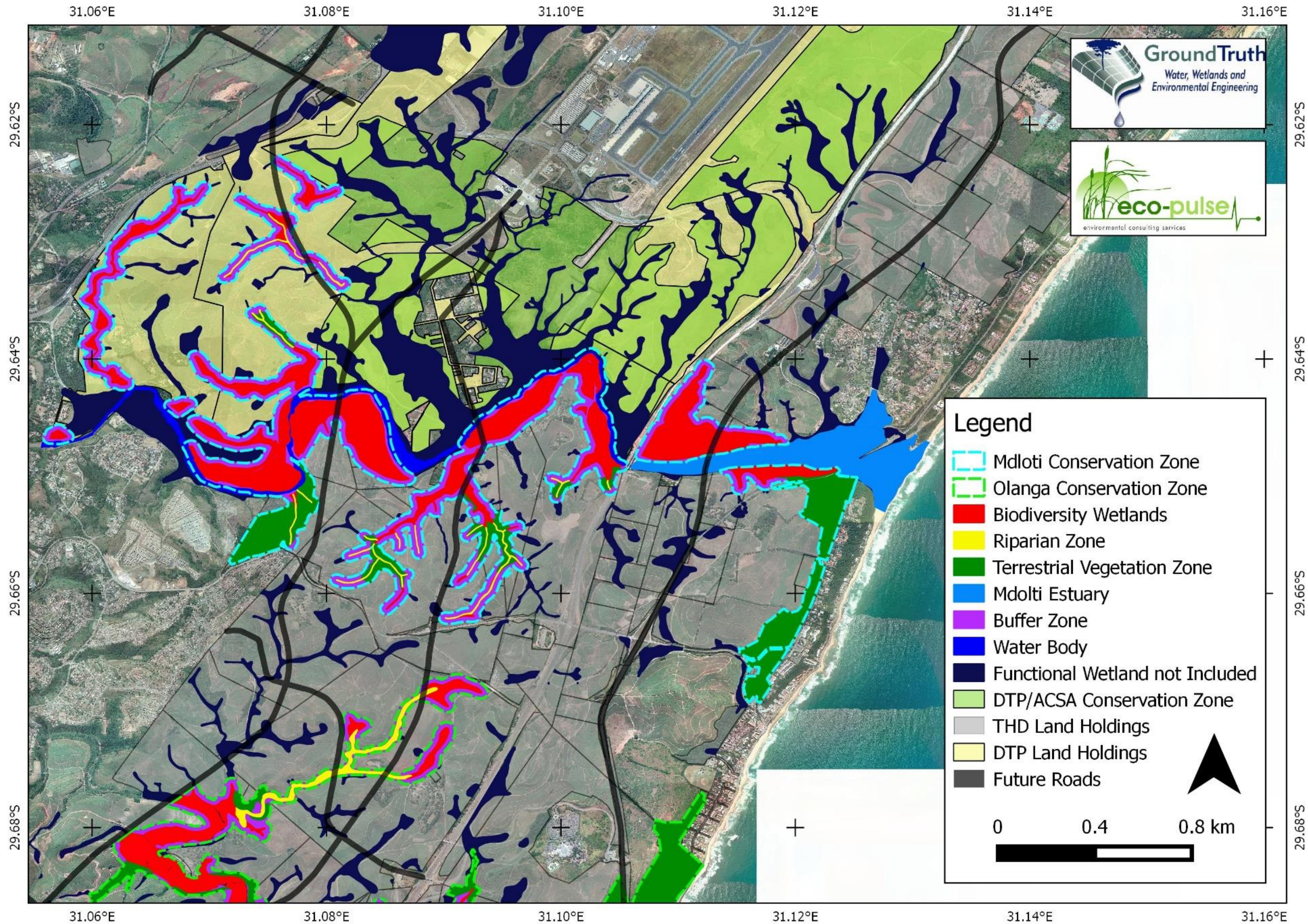
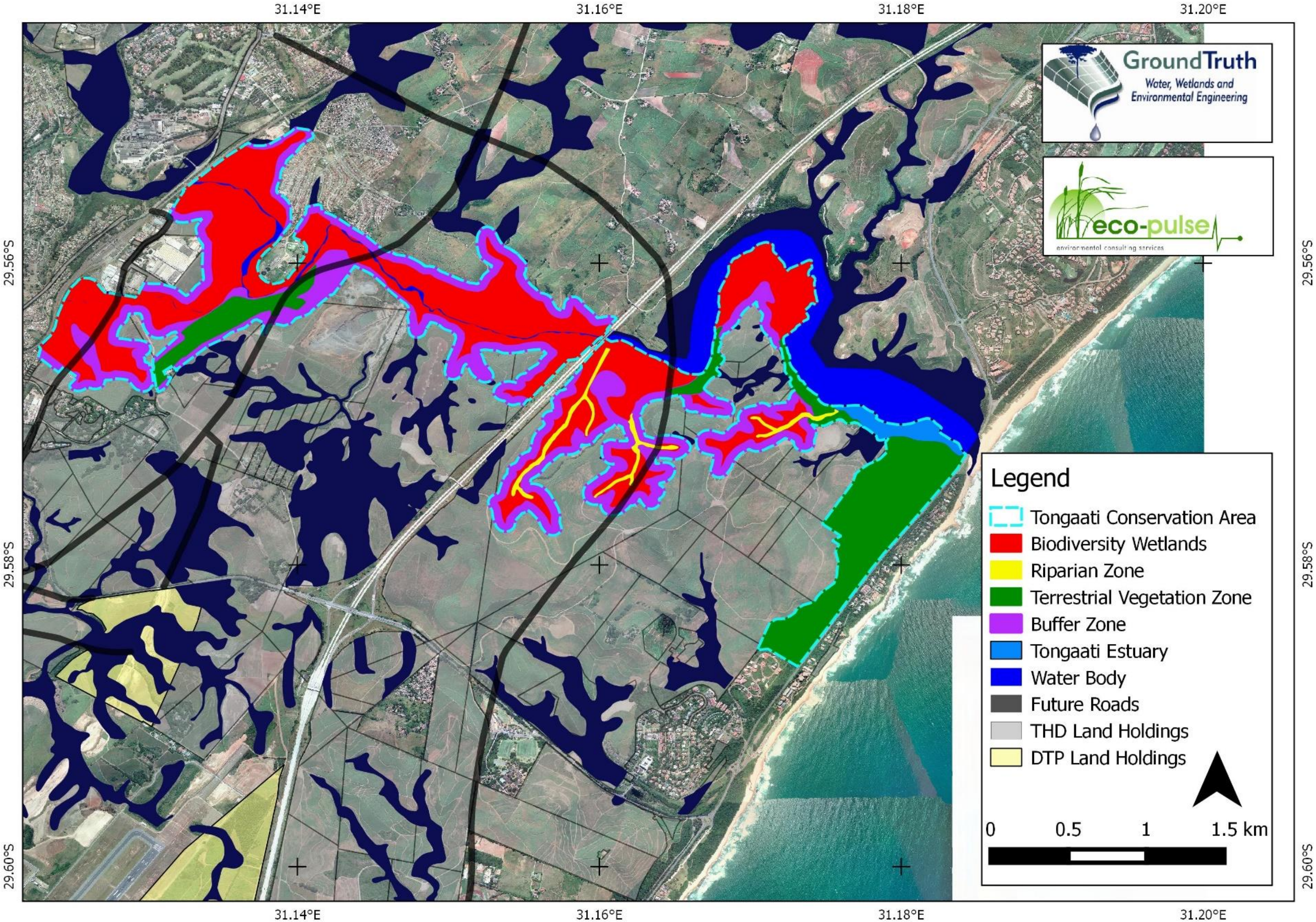


Figure 7 Proposed offset receiving area for the Tongaat Focal Area.



4. CONCLUSION AND WAY FORWARD

This assessment has served to quantify potential wetland offset targets linked with the planned development of seven sites in eThekwini Municipality's Northern Spatial Development Plan Area. This assessment was based on the revised offset framework for the study area which forms an integral part of the strategic framework for improved wetland management in this area. Based on current development proposals, targets for "water resources and ecosystem services" and "ecosystem protection" have been calculated as 59.08 functional hectare equivalents and 75.53 habitat hectare equivalents, respectively. This essentially accounts for lost opportunities associated with on-site rehabilitation if impacts were avoided.

Figure 8 Summary of expected gains and losses in wetland benefits as a result of proposed developments and proposed offset activities[10].

An assessment of three composite wetland offset receiving areas linked with the Tongaat, Mdloti and oHlanga estuaries suggests that offset activities could conservatively deliver gains in "water resources and ecosystem services" and "ecosystem protection" to the order of 90.3 functional hectare equivalents and 204.6 habitat hectare equivalents respectively. Thus whilst the planned developments will have a significant negative impact on wetland ecosystems, this strategic assessment has shown that rehabilitation and protection of the three composite wetland offset receiving areas could more than meet anticipated offset obligations (Figure 7). Given the high aspirations outlined in the vision and policy objectives for wetland management in the region (Macfarlane, 2015), this implies that a suitable trade-off between development and conservation

[10] It is important to note that rehabilitation of wetlands and buffer zones within development sites (on-site) have not been accounted for in these calculations. If included, this would significantly increase the net gain achieved through wetland restoration and management activities.

could be achieved which sees development proceed in a manner that results in a net positive contribution to the environment and broader society.

It is important to point out however that planning has only been undertaken at a conceptual level and detailed planning will be required to better quantify the expected outcomes of proposed offset activities. Before further work is initiated however, it is important that the strategic framework and potential solutions to address wetland impacts are presented to key stakeholders including regulating authorities. If this approach is accepted, a number of key questions will then need to be addressed through further work including:

- The integration of offset planning and commitments into the various development application processes;
- Formalising institutional arrangements and responsibilities for implementation and oversight of offset activities;
- Exploring and adopting appropriate financial mechanisms to fund offset activities including a potential conservation banking model;
- Developing detailed rehabilitation plans for development sites and offset receiving areas.

5. REFERENCES

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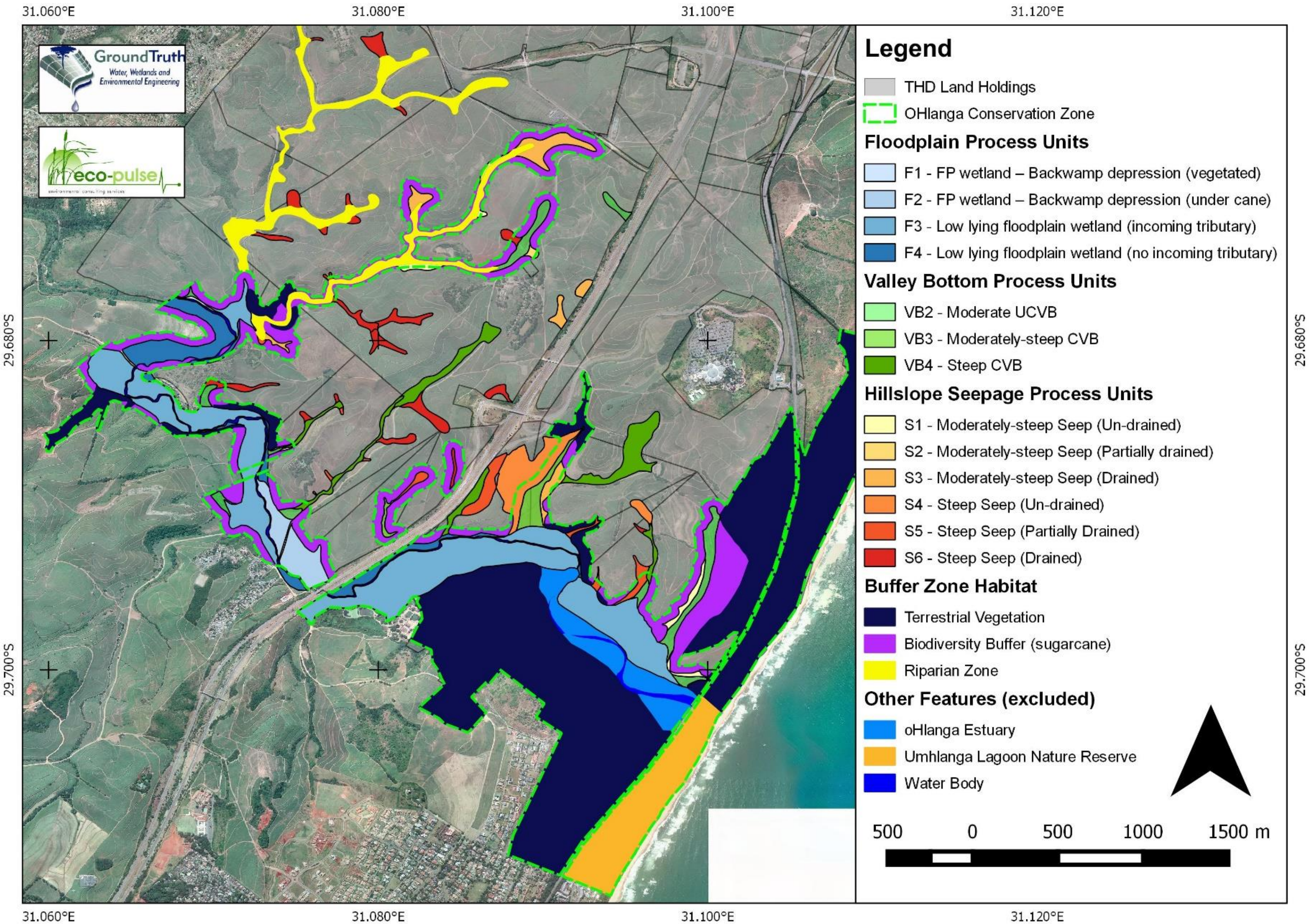
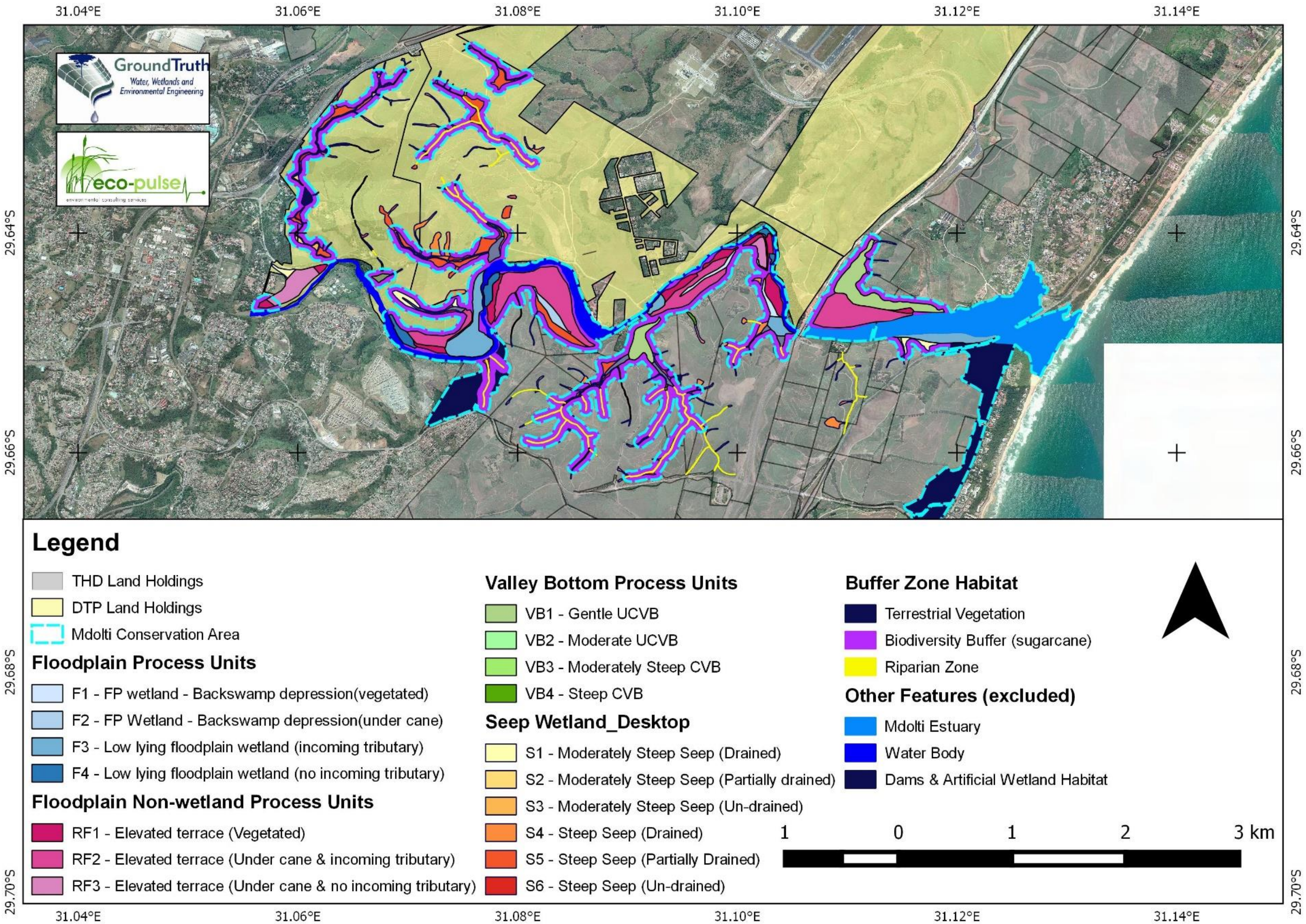
Annexure A: The location and extent of different HGM process units included within earmarked offset receiving areas.

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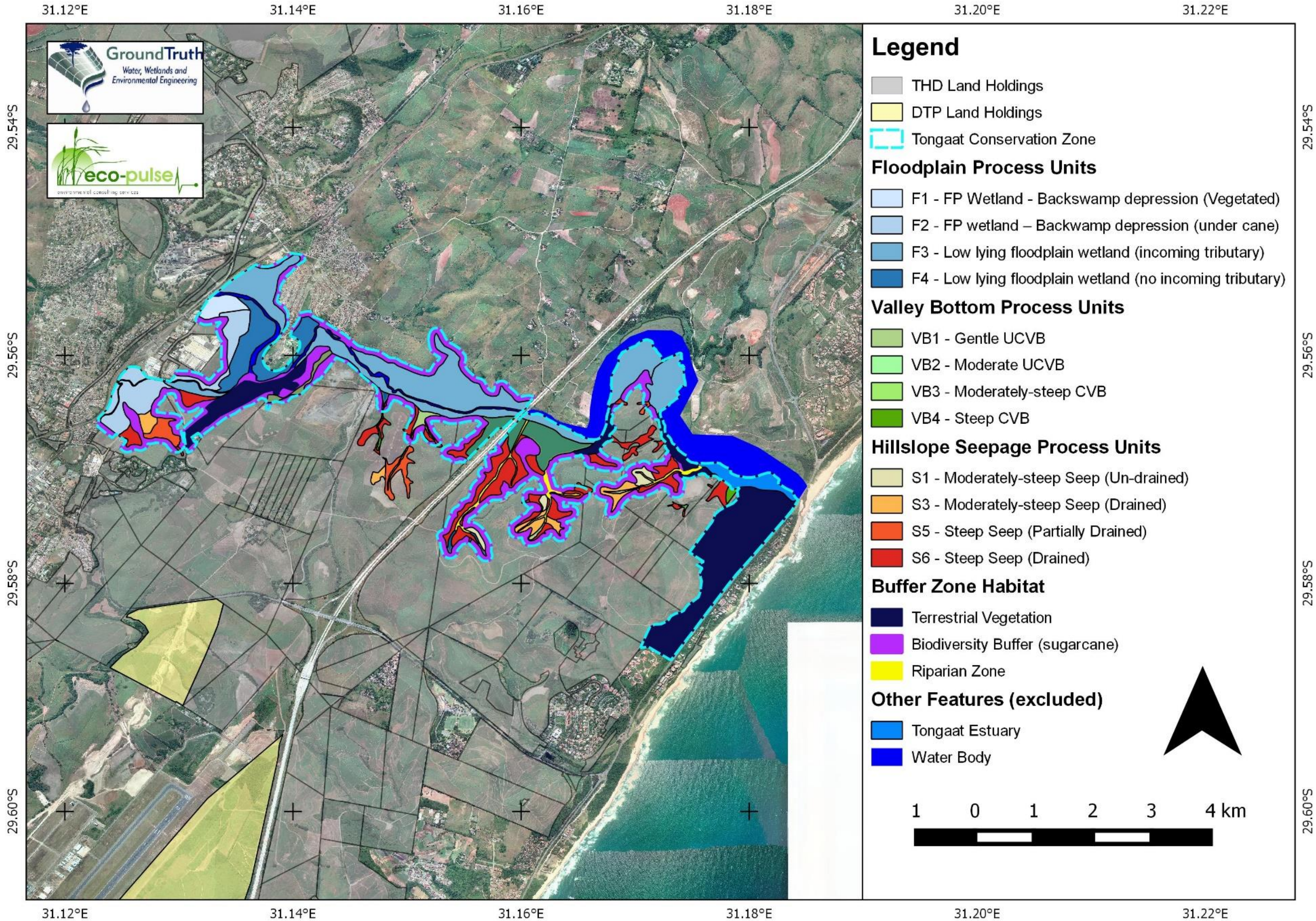
29.66°S
29.68°S
29.70°S
GroundTruth
Water, Wetlands and Environmental Engineering
eco-pulse
Legend
THD Land Holdings
DTP Land Holdings
Mdolti Conservation Area
Floodplain Process Units
F1 - FP wetland - Backswamp depression(vegetated)
F2 - FP Wetland - Backswamp depression(under cane)
F3 - Low lying floodplain wetland (incoming tributary)
F4 - Low lying floodplain wetland (no incoming tributary)
Floodplain Non-wetland Process Units
RF1 - Elevated terrace (Vegetated)
RF2 - Elevated terrace (Under cane & incoming tributary)
RF3 - Elevated terrace (Under cane & no incoming tributary)
Valley Bottom Process Units
VB1 - Gentle UCVB
VB2 - Moderate UCVB
VB3 - Moderately Steep CVB
VB4 - Steep CVB
Seep Wetland_Desktop
S1 - Moderately Steep Seep (Drained)
S2 - Moderately Steep Seep (Partially drained)
S3 - Moderately Steep Seep (Un-drained)
S4 - Steep Seep (Drained)
S5 - Steep Seep (Partially Drained)
S6 - Steep Seep (Un-drained)
Buffer Zone Habitat
Terrestrial Vegetation
Biodiversity Buffer (sugarcane)
Riparian Zone
Other Features (excluded)
Mdolti Estuary
Water Body
Dams & Artificial Wetland Habitat
1 0 1 2 3 km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31.18°E
31.20°E
31.22°E
29.54°S
29.56°S
29.58°S
29.60°S
GroundTruth
Water, Wetlands and Environmental Engineering
eco-pulse
Legend
THD Land Holdings
DTP Land Holdings
Tongaat Conservation Zone
Floodplain Process Units
F1 - FP Wetland - Backswamp depression (Vegetated)
F2 - FP wetland – Backwamp depression (under cane)
F3 - Low lying floodplain wetland (incoming tributary)
F4 - Low lying floodplain wetland (no incoming tributary)
Valley Bottom Process Units
VB1 - Gentle UCVB
VB2 - Moderate UCVB
VB3 - Moderately-steep CVB
VB4 - Steep CVB
Hillslope Seepage Process Units
S1 - Moderately-steep Seep (Un-drained)
S3 - Moderately-steep Seep (Drained)
S5 - Steep Seep (Partially Drained)
S6 - Steep Seep (Drained)
Buffer Zone Habitat
Terrestrial Vegetation
Biodiversity Buffer (sugarcane)
Riparian Zone
Other Features (excluded)
Tongaat Estuary
Water Body
1 0 1 2 3 4 km

Annexure B: Wetland Process Units sampled and assumptions used to inform functional offset calculations.

HGM Process Units	Present State Assumptions	Post Rehab Assumptions
Valley Bottom Wetlands		
VB1 – Gentle UCVB	• Catchment size 100-1000ha • Wetland: catchment ratio 1-2% • Substantially drained (Low flow pattern score = 1 & hydrological zones = 2) • Under cane cultivation (Surface roughness & extent of vegetation cover = 2)	• Catchment size 100-1000ha • Wetland: catchment ratio 1-2% • Totally un-channelled due to effective plugging of all drains (Low flow pattern & hydrological zones scores = 4) • Total reinstatement of wetland vegetation (Surface roughness & extent of vegetation cover = 4)
VB2 – Moderate UCVB	• Catchment size 10-100ha • Wetland: catchment ratio 1-2% • Substantially drained (Low flow pattern score = 0 and hydrological zones score = 1) • Under cane cultivation (Surface roughness & extent of vegetation cover = 2)	• Catchment size 10-100ha • Wetland: catchment ratio 1-2% • Totally un-channelled due to effective plugging of all drains (Low flow pattern & hydrological zones scores = 4) • Total reinstatement of wetland vegetation (Surface roughness & extent of vegetation cover = 4)
VB3 – Moderately-steep CVB	• Catchment size 10-100ha • Wetland: catchment ratio <1% • Substantially drained / eroded (Low flow pattern score = 0 and hydrological zones score = 0) • Under cane cultivation (Surface roughness = 1 & extent of vegetation cover = 2)	• Catchment size 10-100ha • Wetland: catchment ratio <1% • 50% un-channelled due to plugging of channels to create un-channelled wetland (Low flow pattern & hydrological zones scores = 2) • Partial establishment of dense wetland vegetation above structures (Surface roughness & extent of vegetation cover scores = 3)
VB4 – Steep CVB	• Catchment size 10-100ha • Wetland: catchment ratio <1% • Substantially drained / eroded (Low flow pattern score = 0 and hydrological zones score = 0) • Under cane cultivation and eroded out (Surface roughness score = 1 & extent of vegetation cover score = 2)	• Catchment size 10-100ha • Wetland: catchment ratio <1% • Totally channelled (Low flow pattern & hydrological zones scores = 0) • Bank re-vegetation for channel (Surface roughness & extent of vegetation cover scores = 2)
Seeps		
S1 – Moderately-steep Seep (Un-drained)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Undrained and un-channelled (Low flow pattern score = 4 and hydrological zones score = 1) • Under cane cultivation (Surface roughness & extent of vegetation cover = 2)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Undrained and un-channelled (Low flow pattern score = 4 and hydrological zones score = 1) • Re-vegetated (Surface roughness score = 3 & extent of vegetation cover = 4)
S2 – Moderately-steep Seep (Partially drained)	• Catchment size <10ha • Wetland: catchment ratio 3-5%	• Catchment size <10ha • Wetland: catchment ratio 3-5%

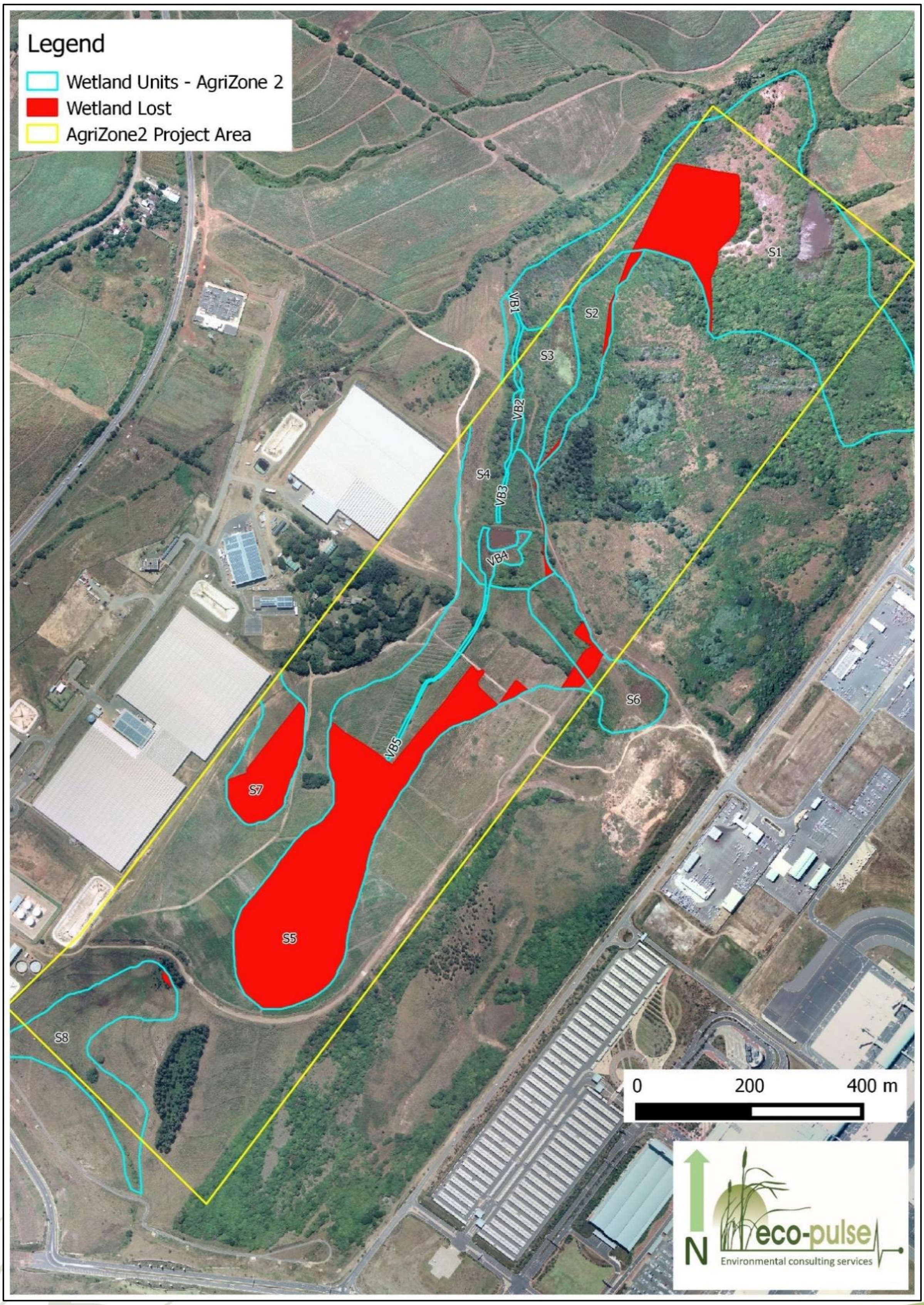
HGM Process Units	Present State Assumptions	Post Rehab Assumptions
	• Partially drained (Low flow pattern score = 2 and hydrological zones score = 0) • Under cane cultivation (Surface roughness & extent of vegetation cover = 2)	• Plugging of drains (Low flow pattern score = 3 and hydrological zones score = 1) • Re-vegetated (Surface roughness score = 3 & extent of vegetation cover = 4)
S3 – Moderately-steep Seep (Drained)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Substantially drained (Low flow pattern score = 0 and hydrological zones score = 0) • Under cane cultivation (Surface roughness = 1 & extent of vegetation cover = 2)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Plugging of drains (Low flow pattern score = 3 and hydrological zones score = 1) • Re-vegetated (Surface roughness score = 3 & extent of vegetation cover = 4)
S4 – Steep Seep (Un-drained)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Undrained (Low flow pattern score = 4 and hydrological zones score = 0) • Under cane cultivation (Surface roughness & extent of vegetation cover = 2)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Un-drained & un-channelled (Low flow pattern score = 4 and hydrological zones score = 0) • Re-vegetated (Surface roughness score = 3 & extent of vegetation cover = 4)
S5 – Steep Seep (Partially Drained)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Partially drained (Low flow pattern score = 2 and hydrological zones score = 0) • Under cane cultivation (Surface roughness & extent of vegetation cover = 2)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Stabilisation of drains (plugging impractical) (Low flow pattern score = 2 and hydrological zones score = 0) • Re-vegetated (Surface roughness score = 3 & extent of vegetation cover = 4)
S6 – Steep Seep (Drained)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Substantially drained (Low flow pattern score = 0 and hydrological zones score = 0) • Under cane cultivation (Surface roughness = 1 & extent of vegetation cover = 2)	• Catchment size <10ha • Wetland: catchment ratio 3-5% • Stabilisation of drains (plugging impractical) (Low flow pattern score = 0 and hydrological zones score = 0) • Re-vegetated (Surface roughness score = 2 & extent of vegetation cover = 3)
Floodplain Wetlands		
FW1 – Floodplain wetland – Backwamp depression (vegetated)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained – Low flow pattern score = 4 and hydrological zones score = 2) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained – Low flow pattern score = 4 and hydrological zones score = 2) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4)

HGM Process Units	Present State Assumptions	Post Rehab Assumptions
	• Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 2)	• For Mdloti River catchment, frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 2)
FW2 – Floodplain wetland – Backwamp depression (under cane & drained)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Drained – Low flow pattern score = 0 and hydrological zones score = 0) • Under cane cultivation (Surface roughness = 1 & extent of vegetation cover = 2) • Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 1)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Plugging of drains (Low flow pattern score = 4 and hydrological zones score = 2) • Re-vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • For Mdloti River catchment, frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 2)
FW3 – Low lying floodplain wetland (vegetated with incoming tributary)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 2) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 2)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Enhancement of diffuse flows through the spreading out of incoming tributary flow across floodplain using interventions (Low flow pattern score = 3 and hydrological zones score = 3 • Re-vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • Increase in frequency of wetland flooding by the spreading out of incoming tributary flows (Frequency of wetland flooding score = 3)
FW4 – Low lying floodplain wetland (vegetated with no incoming tributary)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 2) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 2)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 2) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • For the Mdloti River catchment, frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of wetland flooding score = 2)

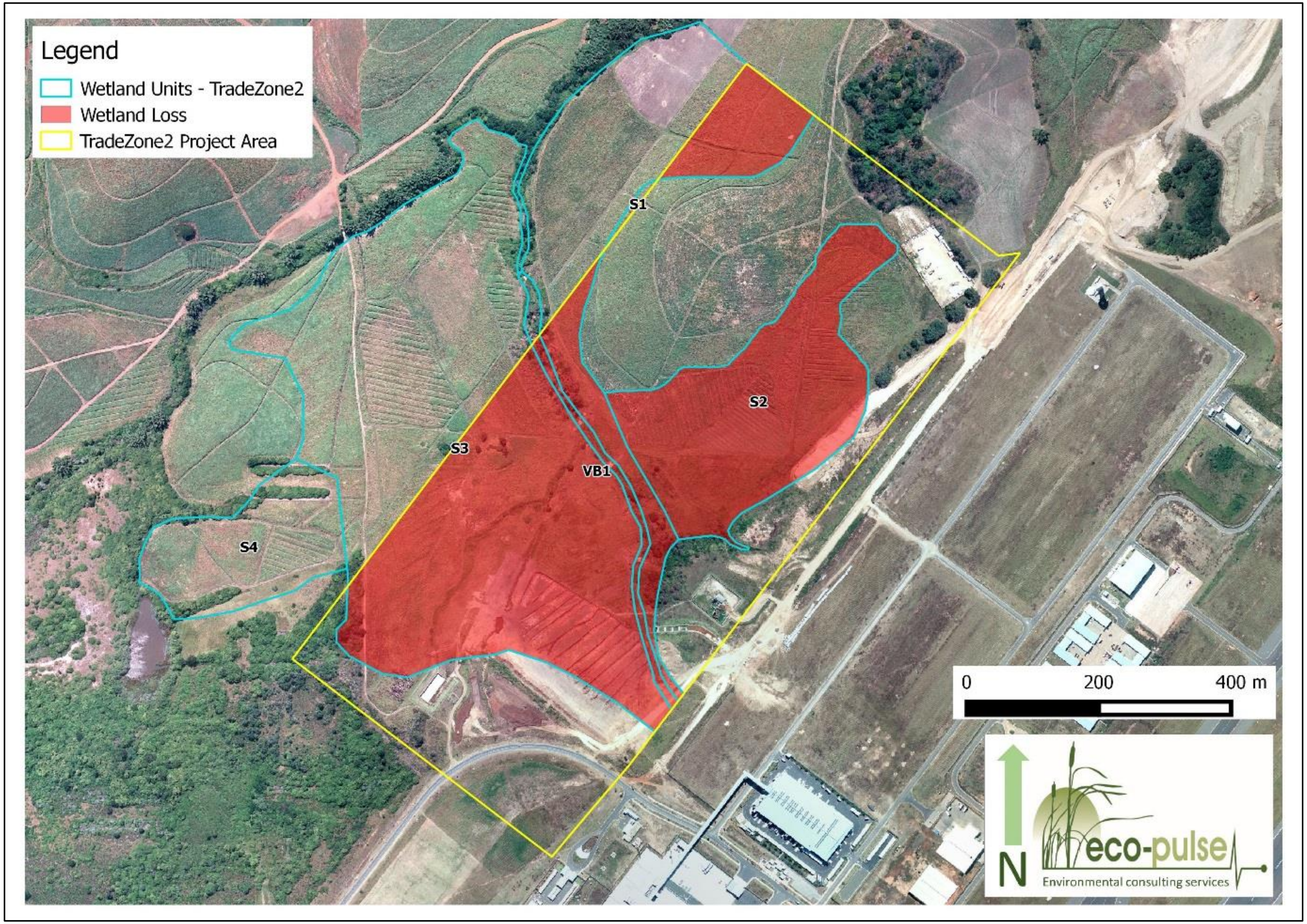
HGM Process Units	Present State Assumptions	Post Rehab Assumptions
Riparian Floodplain Terraces (Non-wetland)		
RF1 – Elevated floodplain terrace (vegetated & no incoming tributary)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 0) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of flooding score = 1)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Undrained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 0) • Vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • For the Mdloti River catchment, frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of flooding score = 1)
RF2 – Elevated floodplain terrace (under cane / plantations / fields & with incoming tributary)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Partially drained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 0) • Under cultivation or recreation (Surface roughness = 1 & extent of vegetation cover = 2) • Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of flooding score = 1)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Enhancement of diffuse flows through the spreading out of incoming tributary flow across floodplain using interventions (Low flow pattern score = 3 and hydrological zones score = 3 • Re-vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • Increase in frequency of wetland flooding by the spreading out of incoming tributary flows (Frequency of wetland flooding score = 2)
RF3 – Elevated floodplain terrace (under cane / plantations / fields – with no incoming tributary)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Limited to partially drained but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 0) • Under cultivation or recreation (Surface roughness = 1 & extent of vegetation cover = 2) • Frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of flooding score = 1)	• Catchment size >1000ha • Wetland: catchment ratio <1% • Substantial catchment hardening (moderate increase in runoff intensity) • Wetland slope 0.5 – 0.9% • Plugging of drains but low flow flows confined to main channel (Low flow pattern score = 0 and hydrological zones score = 0) • Re-vegetated (Surface roughness = 3 & extent of vegetation cover = 4) • For the Mdloti River catchment, frequency of flooding substantially reduced by Hazelmere Dam and associated abstraction (Frequency of flooding score = 1)
Artificial Wetland Habitat		

HGM Process Units	Present State Assumptions	Post Rehab Assumptions
Aw1 – Dams (Deep flooding and wetland fringe)	• Catchment size 10-100ha • Wetland: catchment ratio <1% • Wetland slope 1-2% • Channel loses confinement and flow spreads out (Low flow pattern score and hydrological zones score = 3) • Dense fringe vegetation and open water (Surface roughness & extent of vegetation cover = 2)	• Catchment size 10-100ha • Wetland: catchment ratio <1% • Wetland slope 1-2% • Dam wall re-designed to promote permanent wetland establishment upstream (Low flow pattern score = 4 and hydrological zones score = 4) • Dense vegetation establishment (Surface roughness = 4 & extent of vegetation cover = 4)

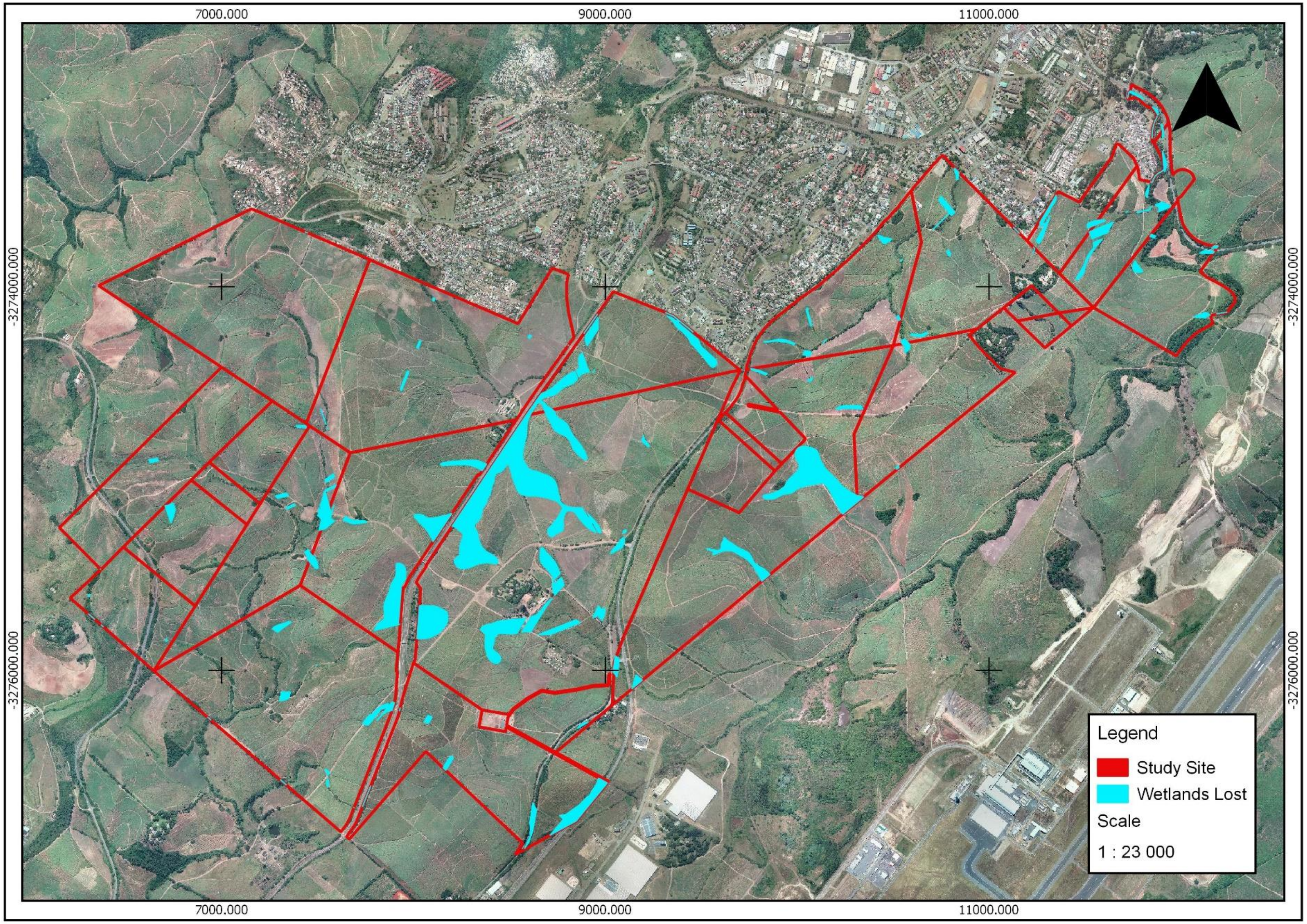
Annexure C1. Map indicating the extent of expected wetland loss associated with the proposed **AgriZone 2** development.



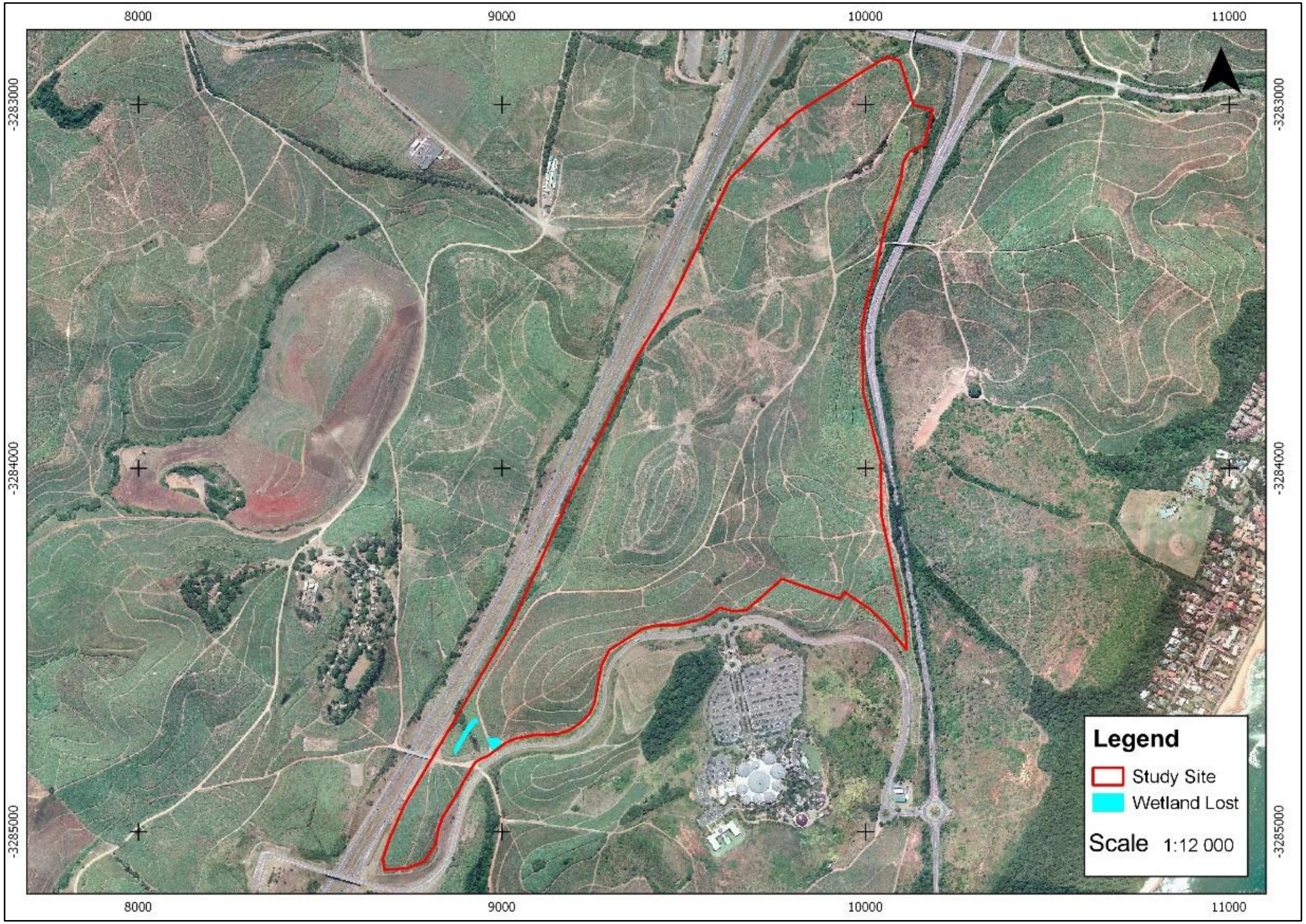
Annexure C2. Map indicating the extent of expected wetland loss associated with the proposed **TradeZone 2** development.



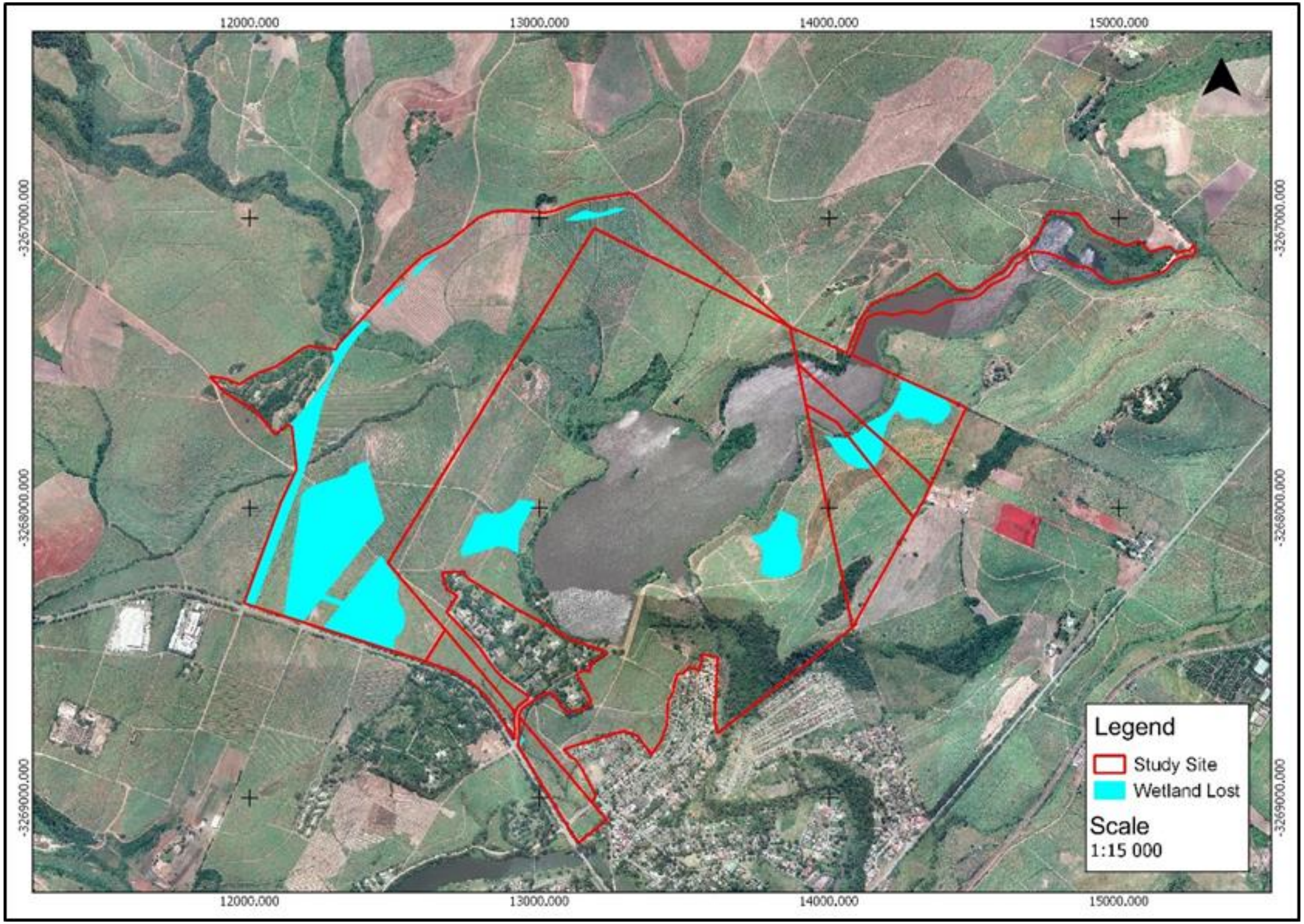
Annexure C3. Map indicating the extent of expected wetland loss associated with the proposed **Inyaninga** development.



Annexure C4. Map indicating the extent of expected wetland loss associated with the proposed **Sibaya** development.

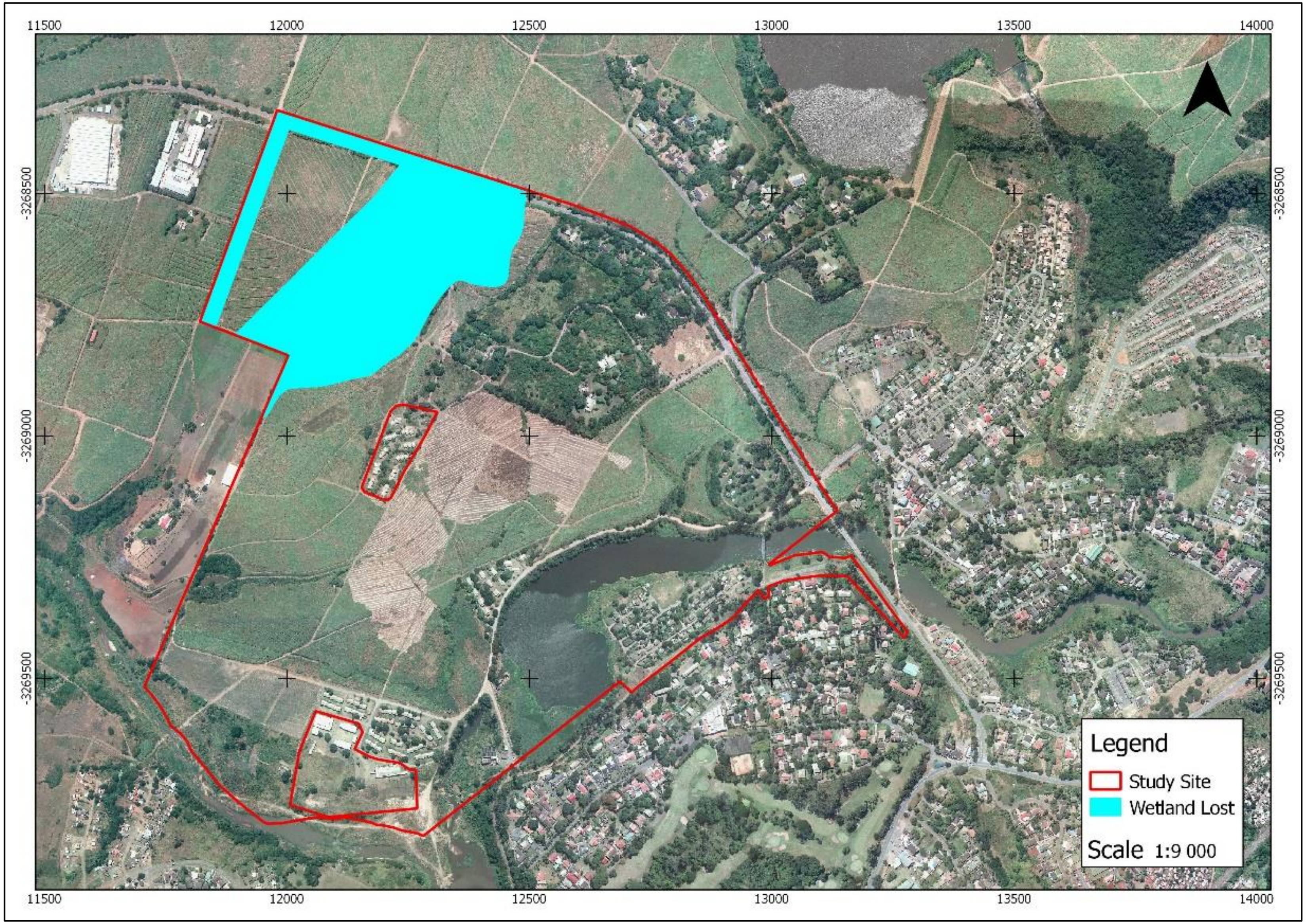


Annexure C5. Map indicating the extent of expected wetland loss associated with the proposed **Dudley Pringle** development.



Annexure C6. Map indicating the extent of expected wetland loss associated with the proposed **uShukela** development.

Annexure C7. Map indicating the extent of expected wetland loss associated with the proposed **Lindokuhle** development.



Annexure D1: Evaluation of functional offset targets for proposed developments[11]

HGM Unit	Impacted Area (Ha)	PES Functional Value (%)	REH Functional Value (%)	Development Impact	Weighted Demand Score	Functional Importance Ratio	Functional Target
AgriZone2	**13.2**			**6.56**			**6.5**
S1	2.6	40%	61%	1.55	1.7	1.00	1.6
S2	0.1	24%	31%	0.04	0.9	0.75	0.0
S3	0.0	37%	39%	0.00	0.9	0.75	0.0
S4	0.1	28%	31%	0.02	1.4	1.00	0.0
S5	8.7	26%	50%	4.30	1.5	1.00	4.3
S6	0.2	40%	50%	0.12	1.0	0.75	0.1
S7	1.5	21%	33%	0.51	1.5	1.00	0.5
S8	0.0	42%	49%	0.01	1.9	1.00	0.0
VB1	0.0	16%	20%	0.00	1.1	1.00	0.0
VB2	0.0	37%	46%	0.00	1.0	0.75	0.0
VB3	0.0	20%	39%	0.00	1.0	0.75	0.0
VB4	0.0	45%	47%	0.00	1.2	1.00	0.0
VB5	0.0	15%	39%	0.00	1.5	1.00	0.0
TradeZone2	**29.4**			**10.11**			**10.1**
S1	4.4	17%	23%	1.03	1.5	1.00	1.0
S2	9.4	25%	47%	4.42	1.6	1.00	4.4
S3	14.9	29%	29%	4.29	1.5	1.00	4.3
S4	0.0	20%	28%	0.00	1.5	1.00	0.0
VB1	0.7	27%	51%	0.38	1.8	1.00	0.4
Inyaninga	**34.6**			**15.23**			**13.5**
CVB1	0.5	30%	39%	0.18	0.9	0.75	0.1
CVB2	0.0	27%	38%	0.02	0.9	0.75	0.0
CVB3	1.8	31%	43%	0.76	1.3	1.00	0.8
HS1	0.0	29%	33%	0.00	1.0	1.00	0.0
HS10	0.1	20%	25%	0.02	1.2	1.00	0.0
HS11	0.9	21%	31%	0.28	1.0	0.75	0.2
HS12	0.3	23%	33%	0.09	1.0	0.75	0.1
HS13	2.0	15%	24%	0.50	1.2	1.00	0.5
HS14	2.0	22%	33%	0.66	1.2	1.00	0.7
HS15	0.4	17%	24%	0.10	1.2	1.00	0.1

[11] Further detailed calculations used to assess functional values and weighted demand scores can be obtained from Eco-Pulse Consulting and Ground-Truth upon request.

HGM Unit	Impacted Area (Ha)	PES Functional Value (%)	REH Functional Value (%)	Development Impact	Weighted Demand Score	Functional Importance Ratio	Functional Target
HS16	0.1	21%	30%	0.02	1.2	1.00	0.0
HS17	1.2	17%	24%	0.29	1.2	1.00	0.3
HS18	0.6	16%	23%	0.14	1.2	1.00	0.1
HS19	0.0	22%	33%	0.00	1.2	1.00	0.0
HS2	0.0	30%	37%	0.00	1.0	1.00	0.0
HS20	0.0	18%	25%	0.00	1.2	1.00	0.0
HS3	0.0	26%	35%	0.00	1.0	1.00	0.0
HS4	0.2	18%	25%	0.05	1.0	1.00	0.1
HS5	0.2	19%	25%	0.04	1.0	1.00	0.0
HS6	0.2	18%	26%	0.05	1.0	0.75	0.0
HS7	0.0	17%	23%	0.00	1.0	0.75	0.0
HS8	0.1	21%	26%	0.02	1.0	0.75	0.0
HS9	0.2	21%	26%	0.05	1.0	0.75	0.0
U30D 110 HS1	0.0	26%	31%	0.00	1.1	1.00	0.0
U30D 112 HS 2	0.0	22%	27%	0.00	1.1	1.00	0.0
U30D 112 HS1	0.2	30%	35%	0.07	1.1	1.00	0.1
U30D 114 CVB1	0.4	24%	36%	0.16	1.1	1.00	0.2
U30D 114 CVB2	0.6	26%	38%	0.22	0.9	0.75	0.2
U30D 114 HS1	0.1	20%	33%	0.04	1.1	1.00	0.0
U30D-102 CVB1	0.0	22%	34%	0.00	1.3	1.00	0.0
U30D-102 HS1	0.0	19%	29%	0.01	1.3	1.00	0.0
U30D-105 HS1	0.1	18%	28%	0.01	1.1	1.00	0.0
U30D-106 HS1	1.2	22%	38%	0.44	1.0	0.75	0.3
U30D-107 HS1	5.2	26%	43%	2.25	1.0	0.75	1.7
U30D-108 CVB2	0.3	27%	43%	0.11	1.1	1.00	0.1
U30D-108 HS1	0.0	20%	33%	0.01	1.1	1.00	0.0
U30D-108 HS3	0.0	16%	23%	0.01	1.1	1.00	0.0
U30D-108 HS4	0.4	20%	31%	0.12	1.1	1.00	0.1
U30D-108 HS5	0.1	18%	26%	0.03	1.1	1.00	0.0
U30D-108 HS6	0.0	18%	26%	0.01	1.1	1.00	0.0
U30D-108 HS7	0.0	17%	26%	0.01	1.1	1.00	0.0
U30D-108 HS8	0.2	24%	37%	0.07	1.1	1.00	0.1
UVB1	2.5	25%	47%	1.15	0.7	0.75	0.9
UVB2	2.2	18%	39%	0.86	0.9	0.75	0.6
UVB4	1.3	16%	36%	0.48	0.9	0.75	0.4

HGM Unit	Impacted Area (Ha)	PES Functional Value (%)	REH Functional Value (%)	Development Impact	Weighted Demand Score	Functional Importance Ratio	Functional Target
UVB5	7.5	30%	68%	5.08	1.2	1.00	5.1
U30D 104 UCVB 1	1.6	0.2	53%	0.84	1.0	0.75	0.6
Sibaya	**0.2**			**0.05**			**0.1**
CVB1	0.1	26%	31%	0.04	1.2	1.00	0.0
HS1	0.1	14%	18%	0.02	1.3	1.00	0.0
Dudley Pringle	**30.2**			**11.95**			**11.6**
CVB1	1.1	73%	77%	0.83	1.1	1.00	0.8
CVB2	2.1	30%	46%	0.95	1.0	1.00	1.0
CVB3	0.1	21%	22%	0.02	0.8	0.75	0.0
FLAT	17.0	43%	44%	7.55	1.3	1.00	7.5
HS1	3.9	23%	27%	1.06	0.7	0.75	0.8
HS2	2.5	22%	27%	0.66	1.4	1.00	0.7
HS3	2.5	22%	26%	0.65	1.4	1.00	0.6
HS4	0.6	22%	27%	0.16	1.0	0.75	0.1
HS6	0.2	17%	20%	0.04	1.0	1.00	0.0
HS7	0.1	13%	17%	0.02	1.1	1.00	0.0
HS8	0.1	17%	20%	0.01	1.1	1.00	0.0
uShukela	**25.9**			**9.96**			**9.6**
U30D-115 CVB1	1.5	29%	39%	0.59	1.1	1.00	0.6
U30D-115 CVB2	0.0	17%	26%	0.01	1.1	1.00	0.0
U30D-115 CVB4	0.0	17%	26%	0.00	1.1	1.00	0.0
U30D-115 HS1	1.5	18%	30%	0.45	1.1	1.00	0.5
U30D-115 HS2	0.0	25%	43%	0.00	1.1	1.00	0.0
U30D-115 HS3	10.8	25%	43%	4.62	1.1	1.00	4.6
U30D-115 HS4	2.8	25%	43%	1.19	1.1	1.00	1.2
U30D-115 HS5	0.0	16%	29%	0.01	1.1	1.00	0.0
U30D-116 HS1	1.0	24%	28%	0.27	1.1	1.00	0.3
U30D-117 HS1	5.1	16%	27%	1.39	1.0	0.75	1.0
U30D-117 UVB1	2.2	24%	49%	1.06	1.0	1.00	1.1
U30D-118 HS1	0.4	17%	30%	0.12	1.0	1.00	0.1
U30D-118 UVB1	0.6	21%	43%	0.24	1.0	0.75	0.2
Lindokuhle	**17.6**			**7.70**			**7.7**
FLAT	17.6	43%	44%	7.70	1.2	1.00	7.7
Grand Total		**0.24**		**61.58**			**59.1**

Annexure D2: Evaluation of offset requirements for ecosystem protection.[12]

HGM Unit	Impacted Area (Ha)	REH Habitat Condition	Development Impact	Ecosystem Protection Target
AgriZone2	**13.2**	**52%**	**6.6**	**6.6**
S1	2.6	50%	1.3	1.3
S2	0.1	50%	0.1	0.1
S3	0.0	50%	0.0	0.0
S4	0.1	60%	0.0	0.0
S5	8.7	50%	4.3	4.3
S6	0.2	50%	0.1	0.1
S7	1.5	50%	0.8	0.8
S8	0.0	50%	0.0	0.0
VB1	0.0	50%	0.0	0.0
VB2	0.0	60%	0.0	0.0
VB3	0.0	50%	0.0	0.0
VB4	0.0	50%	0.0	0.0
VB5	0.0	50%	0.0	0.0
TradeZone2	**29.4**	**50%**	**15.1**	**15.1**
S1	4.4	60%	2.6	2.6
S2	9.4	50%	4.7	4.7
S3	14.9	50%	7.5	7.5
S4	0.0	50%	0.0	0.0
VB1	0.7	40%	0.3	0.3
Inyaninga	**34.6**	**51%**	**16.9**	**16.9**
CVB1	0.5	50%	0.2	0.2
CVB2	0.0	50%	0.0	0.0
CVB3	1.8	50%	0.9	0.9
HS1	0.0	50%	0.0	0.0
HS10	0.1	50%	0.0	0.0
HS11	0.9	50%	0.5	0.5
HS12	0.3	50%	0.1	0.1
HS13	2.0	50%	1.0	1.0
HS14	2.0	50%	1.0	1.0
HS15	0.4	50%	0.2	0.2

12 Further details regarding habitat condition scores and ecosystem conservation ratio calculations are obtainable from Eco-Pulse Consulting or Ground-Truth upon request.

HGM Unit	Impacted Area (Ha)	REH Habitat Condition	Development Impact	Ecosystem Protection Target
HS16	0.1	50%	0.0	0.0
HS17	1.2	50%	0.6	0.6
HS18	0.6	50%	0.3	0.3
HS19	0.0	50%	0.0	0.0
HS2	0.0	60%	0.0	0.0
HS20	0.0	50%	0.0	0.0
HS3	0.0	50%	0.0	0.0
HS4	0.2	50%	0.1	0.1
HS5	0.2	50%	0.1	0.1
HS6	0.2	50%	0.1	0.1
HS7	0.0	50%	0.0	0.0
HS8	0.1	50%	0.0	0.0
HS9	0.2	50%	0.1	0.1
U30D 110 HS1	0.0	60%	0.0	0.0
U30D 112 HS 2	0.0	50%	0.0	0.0
U30D 112 HS1	0.2	50%	0.1	0.1
U30D 114 CVB1	0.4	50%	0.2	0.2
U30D 114 CVB2	0.6	50%	0.3	0.3
U30D 114 HS1	0.1	50%	0.1	0.1
U30D-102 CVB1	0.0	50%	0.0	0.0
U30D-102 HS1	0.0	50%	0.0	0.0
U30D-105 HS1	0.1	60%	0.0	0.0
U30D-106 HS1	1.2	50%	0.6	0.6
U30D-107 HS1	5.2	50%	2.6	2.6
U30D-108 CVB2	0.3	50%	0.1	0.1
U30D-108 HS1	0.0	50%	0.0	0.0
U30D-108 HS3	0.0	60%	0.0	0.0
U30D-108 HS4	0.4	50%	0.2	0.2
U30D-108 HS5	0.1	50%	0.1	0.1
U30D-108 HS6	0.0	60%	0.0	0.0
U30D-108 HS7	0.0	50%	0.0	0.0
U30D-108 HS8	0.2	60%	0.1	0.1
UVB1	2.5	50%	1.2	1.2
UVB2	2.2	50%	1.1	1.1
UVB4	1.3	50%	0.7	0.7

HGM Unit	Impacted Area (Ha)	REH Habitat Condition	Development Impact	Ecosystem Protection Target
UVB5	7.5	50%	3.7	3.7
U30D 104 UCVB 1	1.6	25%	0.4	0.4
Sibaya	**0.2**	**50%**	**0.1**	**0.1**
CVB1	0.1	50%	0.1	0.1
HS1	0.1	50%	0.0	0.0
Dudley Pringle	**30.2**	**50%**	**15.1**	**15.1**
CVB1	1.1	50%	0.5	0.5
CVB2	2.1	50%	1.0	1.0
CVB3	0.1	50%	0.0	0.0
FLAT	17.0	50%	8.5	8.5
HS1	3.9	50%	1.9	1.9
HS2	2.5	50%	1.3	1.3
HS3	2.5	50%	1.3	1.3
HS4	0.6	50%	0.3	0.3
HS6	0.2	50%	0.1	0.1
HS7	0.1	50%	0.1	0.1
HS8	0.1	50%	0.0	0.0
uShukela	**25.9**	**50%**	**12.9**	**12.9**
U30D-115 CVB1	1.5	50%	0.7	0.7
U30D-115 CVB2	0.0	50%	0.0	0.0
U30D-115 CVB4	0.0	50%	0.0	0.0
U30D-115 HS1	1.5	50%	0.8	0.8
U30D-115 HS2	0.0	50%	0.0	0.0
U30D-115 HS3	10.8	50%	5.4	5.4
U30D-115 HS4	2.8	50%	1.4	1.4
U30D-115 HS5	0.0	50%	0.0	0.0
U30D-116 HS1	1.0	50%	0.5	0.5
U30D-117 HS1	5.1	50%	2.6	2.6
U30D-117 UVB1	2.2	50%	1.1	1.1
U30D-118 HS1	0.4	50%	0.2	0.2
U30D-118 UVB1	0.6	50%	0.3	0.3
Lindokuhle	**17.6**	**50%**	**8.8**	**8.8**
FLAT	17.6	50%	8.8	8.8
Grand Total	**151.05**		**75.53**	**75.5**

Annexure E1: Evaluation of expected functional offset gains for HGM Process Units in each proposed offset receiving area[13]

HGM Process Unit	Wetland Area (ha)	PES Functional Value (%)	REH Functional Value (%)	Functional Improvement (%)	Preliminary Offset Contribution	Weighted Demand Score	Functional Importance Ratio	Functional Gains
Mdloti system	**164.4**				**27.4**			**34.2**
AW1	1.1	33%	44%	10%	0.1	2.4	1.25	0.1
FW1	3.2	44%	44%	0%	0.0	2.6	1.25	0.0
FW2	2.9	22%	43%	21%	0.6	2.6	1.25	0.7
FW3	23.6	42%	52%	10%	2.4	2.6	1.25	3.1
FW4	5.5	42%	42%	0%	0.0	2.6	1.25	0.0
RF1	14.8	26%	26%	0%	0.0	2.6	1.25	0.0
RF2	52.1	18%	48%	30%	15.6	2.6	1.25	19.5
RF3	2.4	18%	25%	7%	0.2	2.6	1.25	0.2
S1	0.3	20%	25%	5%	0.0	2.6	1.25	0.0
S2	0.6	16%	24%	8%	0.0	2.6	1.25	0.1
S3	3.5	12%	24%	11%	0.4	2.6	1.25	0.5
S4	4.6	19%	24%	5%	0.2	2.6	1.25	0.3
S5	17.1	16%	21%	5%	0.9	2.6	1.25	1.1
S6	1.5	13%	15%	3%	0.0	2.6	1.25	0.1
VB1	19.8	37%	60%	23%	4.5	2.4	1.25	5.6
VB2	5.7	21%	46%	25%	1.4	2.4	1.25	1.8
VB3	5.4	15%	33%	18%	1.0	2.4	1.25	1.3
VB4	0.6	15%	16%	1%	0.0	2.6	1.25	0.0
oHlanga system	**128.1**	**28%**	**39%**	**11%**	**15.6**	**2.6**	**1.33**	**22.4**
FW1	0.3	0.5	0.5	0.0	0.0	3.0	1.25	0.0
FW2	9.7	0.2	0.5	0.2	2.1	3.1	1.50	3.2
FW3	83.3	0.4	0.5	0.1	8.6	3.1	1.50	12.9
FW4	14.3	0.4	0.5	0.0	0.7	3.1	1.50	1.1
S1	1.0	0.2	0.3	0.1	0.1	2.3	1.25	0.1
S3	2.8	0.2	0.3	0.1	0.2	2.3	1.25	0.3
S5	0.7	0.2	0.2	0.0	0.0	2.3	1.25	0.0
S6	0.4	0.2	0.2	0.1	0.0	2.3	1.25	0.0
VB2	10.8	0.2	0.5	0.3	2.8	2.3	1.25	3.5
VB3	4.8	0.2	0.4	0.2	1.0	2.3	1.25	1.3

[13] Further detailed calculations used to assess functional values and weighted demand scores can be obtained from Eco-Pulse Consulting and Ground-Truth upon request.

HGM Process Unit	Wetland Area (ha)	PES Functional Value (%)	REH Functional Value (%)	Functional Improvement (%)	Preliminary Offset Contribution	Weighted Demand Score	Functional Importance Ratio	Functional Gains
Tongaat System	**226.2**	**28%**	**39%**	**11%**	**27.0**	**2.4**	**1.25**	**33.7**
FW1	6.1	0.5	0.5	0.0	0.0	2.6	1.25	0.0
FW2	58.2	0.2	0.5	0.2	12.7	2.6	1.25	15.9
FW3	64.3	0.4	0.6	0.1	6.7	2.6	1.25	8.4
FW4	28.4	0.4	0.4	0.0	0.0	2.6	1.25	0.0
S1	4.0	0.2	0.3	0.0	0.1	2.3	1.25	0.2
S3	8.6	0.2	0.3	0.1	1.1	2.3	1.25	1.3
S4	19.2	0.2	0.3	0.0	0.7	2.3	1.25	0.9
S5	4.0	0.2	0.2	0.1	0.2	2.3	1.25	0.3
S6	11.4	0.2	0.2	0.0	0.5	2.3	1.25	0.6
VB1	1.9	0.4	0.6	0.3	0.5	2.3	1.25	0.6
VB2	2.6	0.2	0.5	0.3	0.7	2.3	1.25	0.8
VB3	17.6	0.2	0.4	0.2	3.8	2.3	1.25	4.7
Grand Total	**518.6**				**70.0**			**90.3**

Annexure E2: Evaluation of expected Ecosystem Protection gains for HGM Process Units in each proposed offset receiving area[14]

HGM Process Unit	Wetland Area (ha)	PES Habitat Condition (%)	REH Habitat Condition (%)	Habitat Improvement (%)	Wetland habitat contribution	Buffer Area (Ha)	Buffer zone compatibility	Buffer zone hectare equivalents	Buffer zone contribution (capped)	Ecosystem Conservation Contribution
Mdloti system	**164.4**				**48.1**	**560.2**		**105.0**	**24.0**	**72.1**
AW1	1.1	20%	50%	30%	0.3	3.7	0.8	0.7	0.2	0.5
FW1	3.2	50%	60%	10%	0.3	10.9	0.8	2.0	0.2	0.5
FW2	2.9	10%	50%	40%	1.1	9.7	0.8	1.8	0.6	1.7
FW3	23.6	40%	60%	20%	4.7	80.3	0.8	15.1	2.4	7.1
FW4	5.5	40%	50%	10%	0.5	18.6	0.8	3.5	0.3	0.8
RF1	14.8	40%	50%	10%	1.5	50.5	0.8	9.5	0.7	2.2
RF2	52.1	10%	50%	40%	20.8	177.6	0.8	33.3	10.4	31.3
RF3	2.4	10%	50%	40%	1.0	8.2	0.8	1.5	0.5	1.4
S1	0.3	10%	50%	40%	0.1	1.0	0.8	0.2	0.1	0.2
S2	0.6	10%	50%	40%	0.2	2.0	0.8	0.4	0.1	0.4
S3	3.5	10%	30%	20%	0.7	11.9	0.8	2.2	0.3	1.0
S4	4.6	10%	50%	40%	1.8	15.6	0.8	2.9	0.9	2.7
S5	17.1	10%	40%	30%	5.1	58.3	0.8	10.9	2.6	7.7
S6	1.5	10%	20%	10%	0.1	5.0	0.8	0.9	0.1	0.2
VB1	19.8	30%	60%	30%	5.9	67.4	0.8	12.6	3.0	8.9
VB2	5.7	10%	50%	40%	2.3	19.3	0.8	3.6	1.1	3.4
VB3	5.4	15%	40%	25%	1.4	18.4	0.8	3.5	0.7	2.0
VB4	0.6	20%	30%	10%	0.1	2.0	0.8	0.4	0.0	0.1
oHlanga System	**128.1**			**26%**	**29.0**	**378.2**		**70.9**	**14.5**	**43.5**
FW1	0.3	50%	60%	10%	0.0	0.9	0.8	0.2	0.0	0.0
FW2	9.7	10%	50%	40%	3.9	28.7	0.8	5.4	1.9	5.8
FW3	83.3	40%	60%	20%	16.7	246.0	0.8	46.1	8.3	25.0
FW4	14.3	40%	50%	10%	1.4	42.2	0.8	7.9	0.7	2.1
S1	1.0	10%	50%	40%	0.4	3.0	0.8	0.6	0.2	0.6
S3	2.8	10%	30%	20%	0.6	8.2	0.8	1.5	0.3	0.8
S5	0.7	10%	50%	40%	0.3	2.0	0.8	0.4	0.1	0.4
S6	0.4	10%	20%	10%	0.0	1.2	0.8	0.2	0.0	0.1
VB2	10.8	10%	50%	40%	4.3	31.8	0.8	6.0	2.2	6.5
VB3	4.8	10%	40%	30%	1.4	14.1	0.8	2.6	0.7	2.1

[14] Further detailed calculations used to assess ecosystem conservation gains can be obtained from Eco-Pulse Consulting and Ground-Truth upon request.

HGM Process Unit	Wetland Area (ha)	PES Habitat Condition (%)	REH Habitat Condition (%)	Habitat Improvement (%)	Wetland habitat contribution	Buffer Area (Ha)	Buffer zone compatibility	Buffer zone hectare equivalents	Buffer zone contribution (capped)	Ecosystem Conservation Contribution
Tongaat System	**226.2**			**27%**	**59.3**	**296.0**		**55.5**	**29.7**	**89.0**
FW1	6.1	50%	60%	10%	0.6	7.9	0.8	1.5	0.3	0.9
FW2	58.2	10%	50%	40%	23.3	76.2	0.8	14.3	11.6	34.9
FW3	64.3	40%	60%	20%	12.9	84.1	0.8	15.8	6.4	19.3
FW4	28.4	40%	50%	10%	2.8	37.2	0.8	7.0	1.4	4.3
S1	4.0	10%	50%	40%	1.6	5.2	0.8	1.0	0.8	2.4
S3	8.6	10%	30%	20%	1.7	11.2	0.8	2.1	0.9	2.6
S4	19.2	10%	50%	40%	7.7	25.1	0.8	4.7	3.8	11.5
S5	4.0	10%	50%	40%	1.6	5.3	0.8	1.0	0.8	2.4
S6	11.4	10%	20%	10%	1.1	14.9	0.8	2.8	0.6	1.7
VB1	1.9	30%	60%	30%	0.6	2.5	0.8	0.5	0.3	0.9
VB2	2.6	10%	50%	40%	1.0	3.4	0.8	0.6	0.5	1.5
VB3	17.6	15%	40%	25%	4.4	23.0	0.8	4.3	2.2	6.6
Grand Total	**518.6**				**136.4**	**1234.4**		**231.4**	**68.2**	**204.6**