Aquatic Rehabilitation Plan for George Rex Wetland, Knysna.

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confluent
environmental

DECLARATION OF CONSULTANTS INDEPENDANCE

This report was compiled by Jacqueline (Jackie) Dabrowski, the Director of Confluent Environmental (Pty) Ltd. Jackie holds a Ph.D. in Veterinary Science and her post-graduate studies were in the field of freshwater ecology. She has conducted research and published scientific articles on a range of topics including aquatic food webs, fish health, and trends in water quality, branchiopod diversity, and land-use impacts on water quality. Her consulting work has focussed on a range of environmental assessments of dams, rivers, ephemeral watercourses and wetlands at various locations in South Africa.

At the time of conducting this study, I declare that:

- I am an independent specialist consulting in the field of Aquatic Science;
- I do not have any financial interest in the undertaking of the activity, apart from remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014;
- I do not have any vested interest in the proposed activity proceeding;
- I will not engage in any conflicting interests in the undertakings of the activity;
- I undertake to disclose to the competent authority any relevant information with the potential to influence the decision of the competent authority or the objectivity of the report; and,
- I will provide the competent authority with access to all information at my disposal regarding the application, whether this information is favourable to the applicant or not.

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1. INTRODUCTION

1.1 Background

Confluent Environmental (Pty) Ltd. were appointed to provide aquatic specialist inputs to a rehabilitation plan required as part of a Water Use License Application for the development of a sports complex on George Rex Wetland in Knysna, Western Cape. The George Rex wetland is located on Erf 12403.

1.2 Description of George Rex Wetland

Erf 12403 is located adjacent to the Knysna Estuary in the K50B quaternary catchment. The George Rex Wetland is a classified as a wetland flat, located on a very low gradient slope, and is mostly dependent on groundwater. The wetland was historically more directly linked with Knysna Estuary where it was associated with the floodplain. The entire wetland is located between 2 and 3 m above mean sea level (WSP Environmental, 2006), meaning that it lies within the Estuarine Functional Zone (EFZ). The site has a very shallow water table. The mostly flat terrain drains slowly into the Knysna Estuary in a south-westerly direction.

The entire site is 19.406 ha in extent, and the extent of the wetland at the site is 71% which is equal to 13.8 ha (Rountree and Scherman, 2017).

1.3 Condition of the Wetland

The Present Ecological State (PES) of the George Rex Wetland was classified as C (Moderately Modified) by the Department of Water Affairs and Forestry (DWAF, 2008) and C/D by Rountree and Scherman (2017) who also determined the Ecological Importance of the wetland to be Moderate. The latter classification is due to the historic combination of freshwater and estuarine wetlands which increase the complexity and biodiversity associated with the site. Although *Phragmites australis* reed beds are common throughout South Africa, they are locally uncommon with most areas having been transformed around Knysna. Therefore this habitat type is locally important. Vegetation at the site has been modified from a more estuarine / brackish plant community to a more freshwater-adapted community over time (Figure 1). This is due to increased freshwater inputs related to stormwater runoff from adjacent developments (Hunters Estate) and surface and sub-surface flows emanating from the wastewater treatment works adjacent to the site.

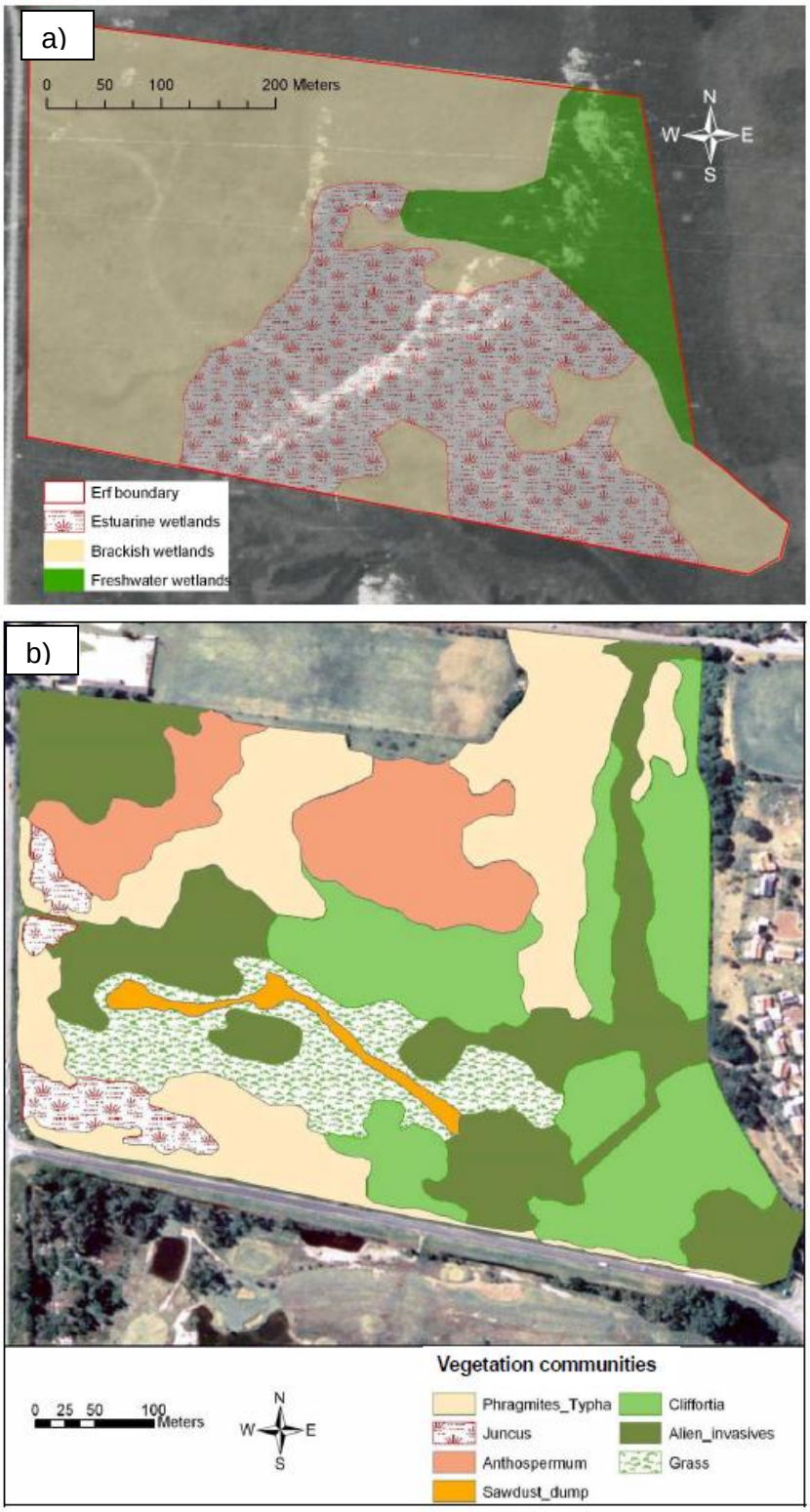

Figure 1. Wetland vegetation mapped on a photo from 1936 (a) compared to a survey conducted at the site in 2003 by Bornman and Adams (b; 2004).

1.4 Layout of the Proposed Development

The recommended development option proposed by Rountree and Scherman (2017) was a 40% development footprint, which would allow for rehabilitation of 60% of the wetland remaining at the site. The proposed 40% development plan produced by Vreken is shown in

Figure 2. In addition to housing retail and sports facilities, the development will have access via George Rex Drive and a road is proposed to be built through the wetland from Howard Street to the south.

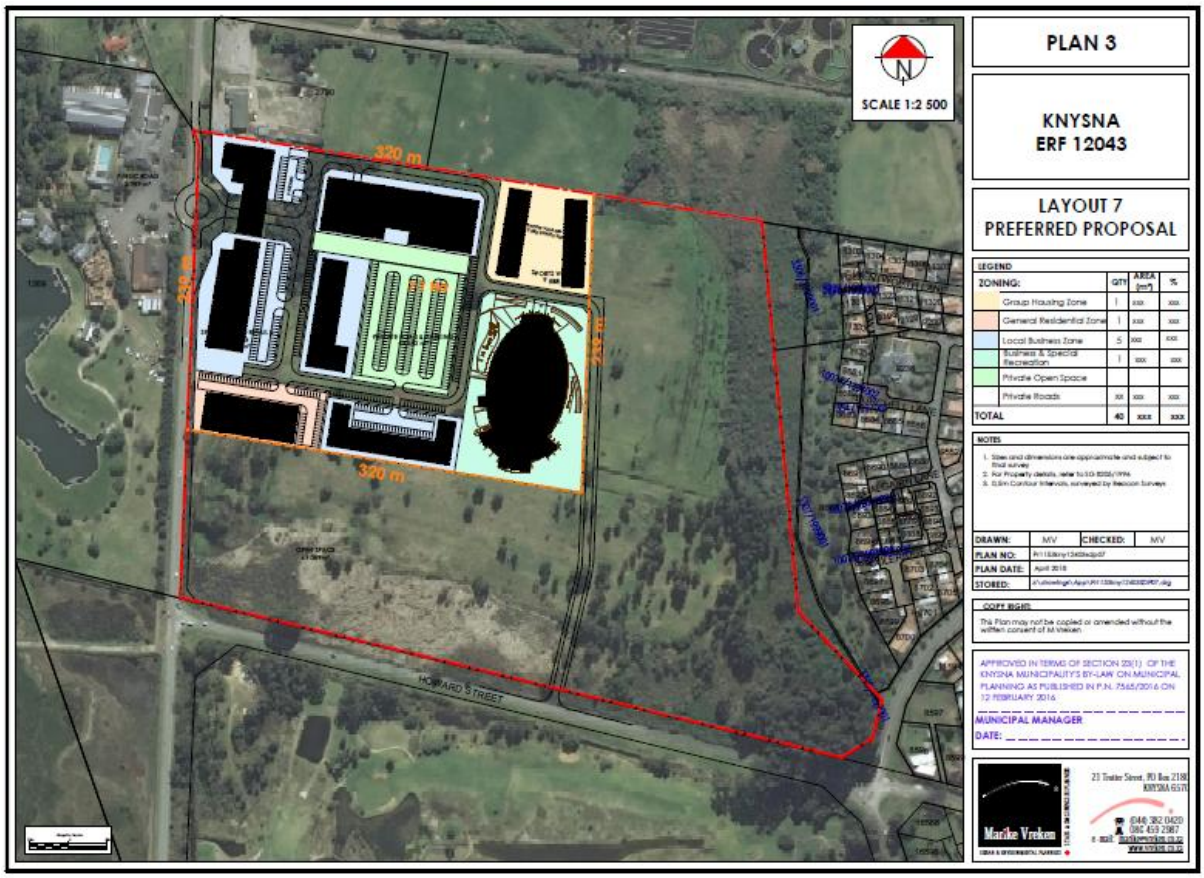

Figure 2. Proposed layout of the development at George Rex wetland which has a footprint of 40% of the wetland area.

2. REHABILITATION PLANNING

2.1 Managing Urban Wetlands

Urbanisation is a world-wide trend which frequently results in the loss and transformation of wetlands through draining and infill, and as such represents one of the biggest threats to the integrity of wetlands. However, urban environments are greatly enhanced by the presence of ecologically functional wetlands which also provide a range of benefits for people. These benefits include flood attenuation, soil erosion control, pollution control, noise reduction, carbon sequestration, micro-climate control, and opportunities for recreation and education. In addition wetlands provide refuge and habitat for a diverse range of plants and animals, and can enhance ecological connectivity. Urban wetlands help make cities liveable. However, wetland losses in urban areas globally are an ongoing trend, reflecting the lack of understanding and value placed on the benefits provided by wetlands.

While it is recognised that the restoration (return to pre-impacted state) of most urban wetlands is difficult to attain, the rehabilitation of wetlands towards the provision of a wide range of ecological functions is achievable. While the modified system may not be exactly the same as the pristine version, substantial benefits can be derived and maintained from a

social and ecological perspective (Box 1). Given the magnitude of losses, wetlands are often the only systems supporting wildlife in urban environments.

Box 1: Sydney Olympic Park Case Study

There are a number of similarities between George Rex Wetland and the Sydney Olympic Park (SOP) in Australia. The SOP has already been developed, and provides an excellent example of what can be achieved through imaginative management of urban wetlands and embracing the connection between wetlands and urban development. Both developments involve sports and recreation complexes embedded within a natural environment that happens to include wetland habitat. These wetland habitats both include a matrix of freshwater and brackish / saltwater habitats. The rehabilitation of wetlands at both sites was a condition for development consent. In both cases, the land area was split between the development and wetland areas. At SOP the split was 60/40 and at George Rex it is 40/60 respectively. In both cases, freshwater had become more dominant than saltwater over time and increased tidal exchange was recommended.

SOP is marketed as an urban oasis for people and wildlife. It incorporates bike trails, walking trails and boardwalks with interpretive information en route. Wetland habitat in the park supports endangered frog species' and provides information about how to protect amphibians. Migratory birds breed and feed in the wetland, providing bird-watching opportunities and enhancing the experience of seeing 'wild' animals and experiencing 'wild' spaces in urban settings. The wetland and associated natural areas are legally protected. About 30 000 school children tour the wetland each year and there is a wetland education centre on site that caters for workshops and training.

The wetland area in SOP is approximately 200 ha which is far greater than the 13.8 ha in George Rex Wetland. However, Knysna is proportionally smaller than Sydney, and George Rex Wetland is one of the few remaining urban wetlands that could provide similar opportunities to the wildlife and communities of Knysna and the Garden Route once rehabilitated.




2.2 The Planning Process

In order to compile an effective rehabilitation plan, it is necessary to have a good understanding of the causes of degradation as the aim of rehabilitation is to treat the underlying causes and not just symptoms of degradation. To gain an understanding of George Rex Wetland the site was visited on a number of occasions during the first half of 2019 and available literature on the site was reviewed with particular emphasis on the Reserve Determination study compiled by Rountree and Scherman (2017). Wetland rehabilitation refers to the process of assisting in the recovery of a degraded wetland's ecosystem health, service delivery and function, and halting the further decline in wetland health.

2.3 Aims for Rehabilitation

The Reserve Determination study set the Target Ecological Category for the site as *C, Moderately Modified*. Wetlands in this category have experienced the loss and change of natural habitat and biota, but the basic ecosystem functions are still predominantly unchanged. While it is acknowledged that the wetland can never be fully restored to a pristine state, the causes of degradation can be mitigated to a large extent, greatly improving the resilience and functions of the wetland ecosystem for wildlife and humans alike.

3. CAUSES OF DEGRADATION AT GEORGE REX WETLAND

A summary of the primary causes of degradation and loss of ecological function at George Rex Wetland are provided in this section with a visual reference in Figure 4.

3.1.1 Stormwater Drainage

A drainage channel has been excavated along the eastern and southern boundary of the wetland in order to concentrate stormwater flows and reduce flooding over the site (Figure 3). Infill dumped along the edge of the channel has had the effect of reducing soil saturation for wetland plants and reducing dispersive flows across the wetland (also discussed in the following section on dumping). Seepage from the WWTW also enters the drainage channel impacting on water quality.

3.1.2 Reduced Estuarine Connectivity and Increased Freshwater Dominance

A culvert located on the corner of George Rex Drive and Howard Street was constructed to help drain stormwater out of the wetland under the road and into the estuary. Presently the land is higher on the estuary side of the road meaning that freshwater does not drain out of the wetland well, and saltwater cannot drain into the wetland except under high water levels. This is one of the factors leading to increased dominance of freshwater (and associated plant communities) in the wetland. Inflows of stormwater from neighbouring land (ie. Hunters Estate) and the WWTW have increased the amount of freshwater entering the wetland, which is mostly retained on site due to the blocked culvert (Figure 4).

3.1.3 Dumping and Infilling

Large quantities of wood waste and sawdust (30 000 to 40 000 m^3) were historically dumped on the southern half of the wetland, although the location of this dump is difficult to locate as most of it has decomposed. This represents a type of infilling. Spoil material was dumped along the western bank of the artificial canal that was excavated to channel stormwater (Figure 3 and red outline in Figure 4). This had the effect of providing disturbed soil that was easily colonised by alien plants and altered the local topography through reducing the water table, preventing wetland plants from colonising this area. There are areas where soil material has been stockpiled which also has an infilling effect (orange outline in Figure 4), but these are largely located within the development footprint and therefore do not require rehabilitation.

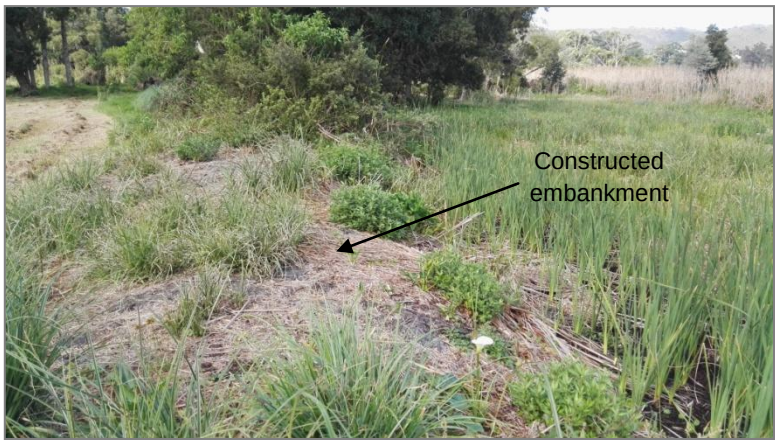

Figure 3. Drainage channel embankment separating wetland vegetation (right) from mown wetland vegetation (left).

3.1.4 Mowing

Large areas of the site are mowed on a regular basis by the land-owner as the vegetation growth was viewed as a fire hazard. This has reduced the extent of obligate wetland plants such as *Phragmites australis* and *Typha capensis*. The extent of mowing can be seen in Figure 4.

3.1.5 Sewage

The Knysna 2 SBR wastewater treatment works (WWTW) is located approximately 100 m to the north of the site and consists of a number of lined sludge ponds. Polluted water from the WWTW enters the wetland via surface water discharge as well as sub-surface seepage (WSP Environmental, 2006). The wetland provides an important scrubbing function because nitrogen levels and faecal coliforms in water originating from the plant have frequently exceeded General and Special limits. A continuous supply of nutrient-rich water has resulted in the establishment of beds of *Phragmites australis* and *Typha capensis* which play an important role in the uptake of nutrients. Were it not for the scrubbing function provided by the wetland, polluted water from the WWTW would enter the Knysna estuary.

3.1.6 Alien Vegetation

Alien plant species have invaded all of the disturbed areas of the wetland, including the soil stockpile (orange outline in Figure 4), drainage channel banks, along roads and around the old farm house. Extensive alien vegetation corresponds with the red outline of the drainage channel shown in Figure 4. More isolated alien trees (as well as indigenous trees) are located in the extensively mown area.

Figure 4. Aerial drone image (2018) of the George Rex Wetland showing degraded features. Blue arrows show the stormwater channel, the red area is the stormwater channel embankment, the orange area is the historical soil stockpile which has been colonised by alien trees (in the footprint of the sports complex), and all open areas are mown.The blocked culvert in the south-western corner is indicated by the blue rectangle.

4. REHABILITATION RECOMMENDATIONS

According to the Reserve Determination (Rountree and Scherman, 2017) the following actions should form part of the rehabilitation plan:

- The blocked outlet point between Erf 12403 and the estuary should be re-opened in an effort to improve the connectivity of the site with the estuary.
- Removal of alien invasive vegetation;
- Cease mowing the wetland vegetation;
- Removal of infill material within selected areas to bring the water table back in line with the original soil level;
- Replanting of selected wetland species;
- Promotion of diffuse flows through closure of the excavated canals and berms;
- Incorporate walkways and recreational / educational areas.

All of these actions will be considered as options for rehabilitating the major aspects of degradation in the wetland. These measures each address one or multiple causes of degradation. An additional factor that will be considered is the protection of fauna which may be increasingly attracted to the wetland which will increasingly serve as valuable habitat in the urban environment.

4.1 Stormwater Management

The proposed stormwater management plan for Erf 12403 produced by Nieuwoudt and Kie (2018) shows where stormwater will be discharged from open areas, parking and roads into the wetland. According to the plan there are 4 points where this will occur, and each point has been circled in red on Figure 5. According to this plan, all the stormwater is discharged on Erf 12403 and none is diverted under George Rex Avenue. This water will aid in recharging the aquifer.

The plan proposes to store rainwater collected from roofs in a lined surface water dam, and re-use it as part of the potable water supply for the development. The proopsed storage dam is located in the wetland to the south of the development and it is recommended that 4000 m^2 be set aside for this. There are two inlets to the storage dam which are circled in blue on Figure 5 for clarity.

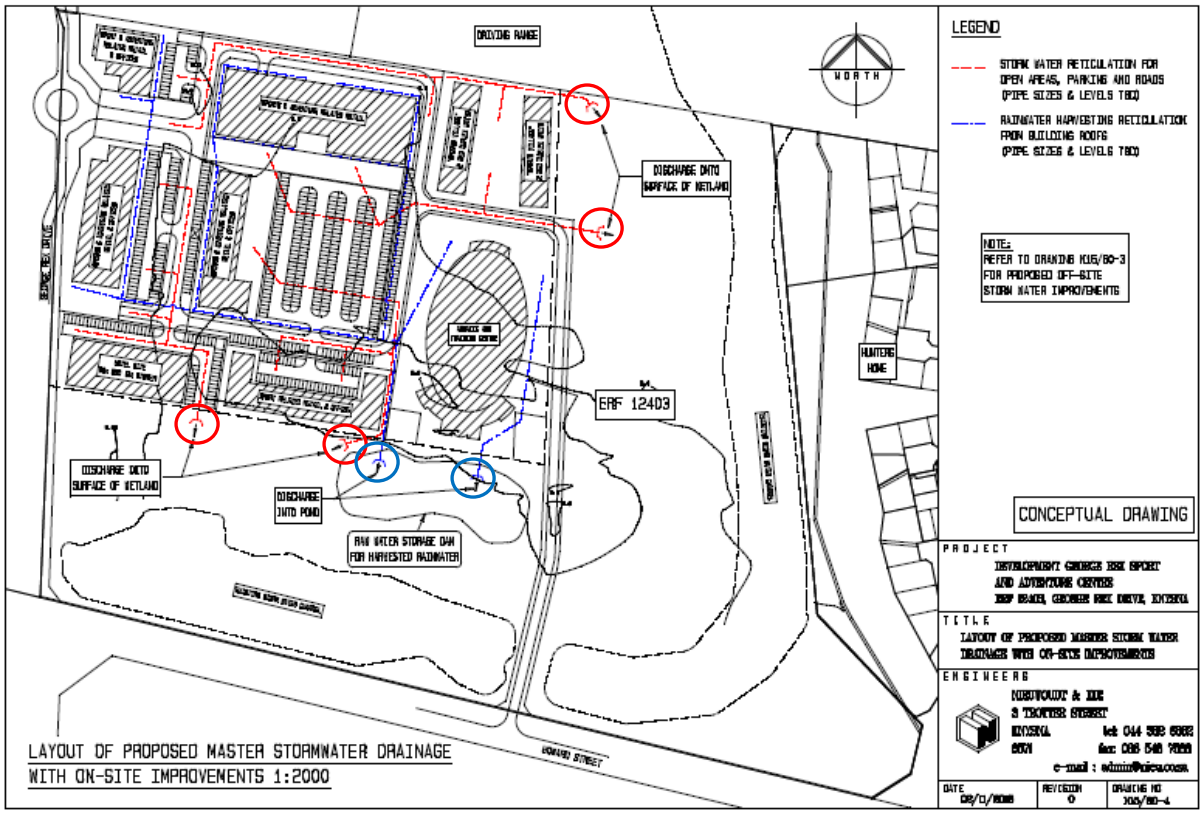

Figure 5. Stormwater drainage plan for Erf 12403 (Niewoudt & Kie, 2018)

The proposed stormwater management plan for draining stormwater from Erf 12403 into the Knysna Estuary is shown in Figure 6. Stormwater flow has been shown using red arrows for clarity. The plan shows water drained from the catchment as flowing through the existing drainage channel, through box culverts under Howard Street (new culvert) to a drainage channel along the northern and western boundary of the golf course, discharging into the estuary through enlarged box culverts as shown in the inset with the car in Figure 6. It has been proposed by the engineers involved that the drainage channel will provide opportunity for enhanced connectivity with the estuary as seawater can flow up the channel into the wetland.

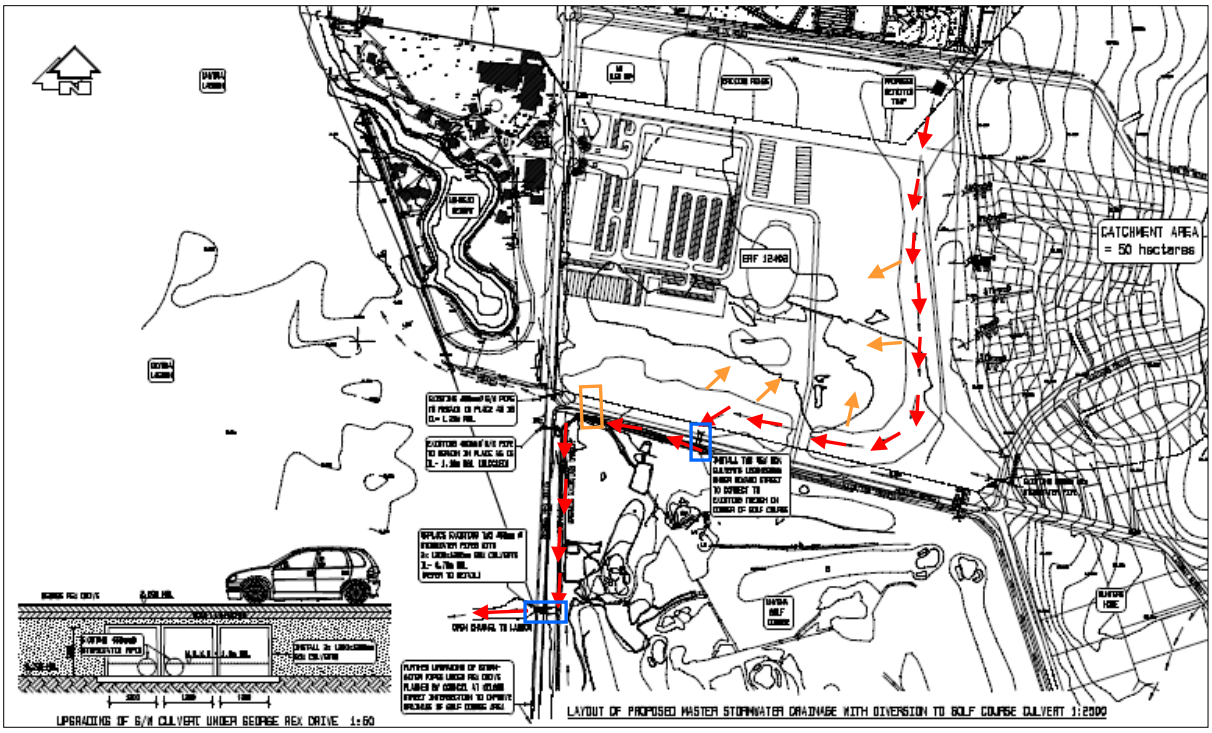

Figure 6. Stormwater drainage plan from Erf 12403 to Knysna Estuary (Niewoudt & Kie, 2018). Red arrows indicate proposed movement of stormwater through existing drainage channel; blue rectangles indicate proposed new culvert or culvert upgrades; and the orange rectangle is an additional culvert recommended in this rehabilitation plan. Orange arrows are locations of 'slots' in the drainage channel embankment proposed in this rehabilitation plan.

Rehabilitation measures concerning the management of stormwater took into consideration the recommendations made in the Reserve Determination study, along with measures proposed by Niewoudt and Kie (2018).

4.1.1 Drainage Channel

Recommendations regarding the drainage channel in the stormwater management plan and those made by Rountree and Scherman (2017) are somewhat opposed. The stormwater plan continues to view the drainage channel as the best conduit for transferring water off the site to reduce the risk of flooding, and suggests the drainage channel should be rehabilitated (Niewoudt and Kie, 2018). A discussion with the engineer about the meaning of rehabilitation confirmed that the intention would be to reduce clogging by vegetation and increase the conveyance potential of the drainage channel. This scenario compounds negative impacts associated with the drainage channel. However, it is acknowledged that large volumes of water enter the drainage channel from Hunters Estate and may provide an overwhelming volume of water that the wetland cannot attenuate in its current degraded state.

In contrast, Rountree and Scherman (2017) recommended that the drainage channel be 'closed' to allow dispersive flows through the wetland. While this could be the ultimate goal, the reality is that a lot more surface water is entering the site than under natural conditions, and the wetland may not have the attenuation capacity for safely dispersing flows. Especially once the sports complex has been built. Furthermore, the goal of reducing freshwater inputs relative to saltwater inputs to the wetland will not be achievable if high volumes of stormwater are widely dispersed.

Therefore, a precautionary approach is recommended. Approximately 5 'slots' measuring 5 m across could be removed from the embankment to allow floodwaters to disperse into the wetland (orange arrows on Figure 6), while a large volume of water would still be conveyed through the channel and discharged through the new culvert proposed under Howard Street. Openings in the embankment must be made level with the surrounding wetland.

The combination of stormwater runoff from the sports complex development at 4 points and overflow from the drainage channel at 5 points would provide opportunity for sheet flow to disperse across large areas of the wetland.

Water flow from the 'slots' must be monitored following high rainfall to ensure no channelization or other negative impacts result in the wetland as a result of opening up these sections of the drainage channel embankment. As vegetation regenerates across the wetland (providing flood attenuation functions) the option to open up more of the embankment could be explored, provided there is no risk of flooding infrastructure.

4.1.2 Culverts and Connectivity

It is widely recognised that the George Rex Wetland has become more dominated by freshwater and associated plant communities when compared to its historical state, which was a functional extension of the estuarine floodplain. Most ecological studies of the wetland, including the Reserve Determination, have advocated the establishment of a stronger connection to the estuary. Rountree and Scherman (2017) suggested unblocking the existing 450 mm diameter outlet pipe on the south-western corner of Erf 12403. However, the stormwater plan from Niewoudt and Kie (2018) identifies an important caveat to this approach, as the Invert Level of the pipe requires that a trench be dug across a section of the estuary in order to ensure that seawater enters the wetland.

An alternative plan was proposed which is to divert stormwater out of Erf 12403 via a new culvert beneath Howard Street into an existing drainage channel that runs along the north and western boundary of the golf course (blue rectangle in Figure 6). Stormwater would then flow into the estuary via an upgraded box culvert on George Rex Drive. During high tides, seawater pushes up this channel and would enter the estuary via the Howard Street culvert, to an extent.

This option represents a feasible alternative but the amount of tidal inflow could be restricted by the distance required for the water to reach the wetland (approximately 600 m). This also represents only a single point where seawater could enter the once estuarine-dominated site. Therefore an additional culvert beneath Howard Street between the south-west corner and the golf course drainage channel is recommended (orange rectangle in Figure 6). This would provide an additional point where seawater can enter the southern portion of the wetland. The different respective salinities that are likely to occur in the vicinity of both culverts would add complexity, potentially providing conditions to support a greater diversity of plant communities.

4.1.3 Water Harvesting Storage Dam

The stormwater plan proposes that water from rooftops at the development be channelled into a storage dam for re-use and treatment as a potable water supply. The dam is technically related to the development and requires an additional 4000 m^2 be put aside

within the wetland, thus increasing the development footprint within the wetland. Furthermore, the proposal is that the dam should be lined, so it would not facilitate recharge of groundwater.

There are some positive elements however. The dam could provide additional open water habitat that could be utilised by a range of wetland-associated taxa. The dam would play an important role in flood mitigation, retaining some of the water that might otherwise run off into the wetland under heavy rainfall conditions. Overall the dam is considered in a mostly positive light provided some criteria are met which will ensure that it makes a positive contribution to the ecological function and diversity of the wetland.

Abstraction from the dam for use by the development must not draw the water level down below 30% in order to protect habitat that will be colonised by various aquatic fauna. Consider using an alternative to a plastic liner that will provide a more natural substrate, such as a compacted clay liner. The habitat could be further enhanced through construction of small islands in the middle of the dam that could provide refuge for nesting waterfowl (Figure 7). The edge of the pond should be sloped to a gradient of 1: 6 or 8, or even flatter, as many water birds find a large portion of their food in water that is shallower than their leg length (Russell, 2009). In the event of flooding, overflow from the dam must not be channelled into the wetland as this will cause erosion. Overflow needs to be dispersed evenly avoiding channelling, and high energy flows must be dissipated.

Finally, under no circumstances must the dam be stocked with alien fish such as Mosquitofish (*Gambusia affinis).* The open water will provide ideal habitat for amphibians, but Mosquitofish are highly predatory on tadpoles and can significantly impact food webs. Any decision to introduce fish into the dam must be made with prior knowledge of the restrictions of the National Environmental Management: Biodiversity Act (NEMBA, 2004). The act lists invasive species including freshwater fish (List 7) that may or may not be introduced to various catchments in South Africa.

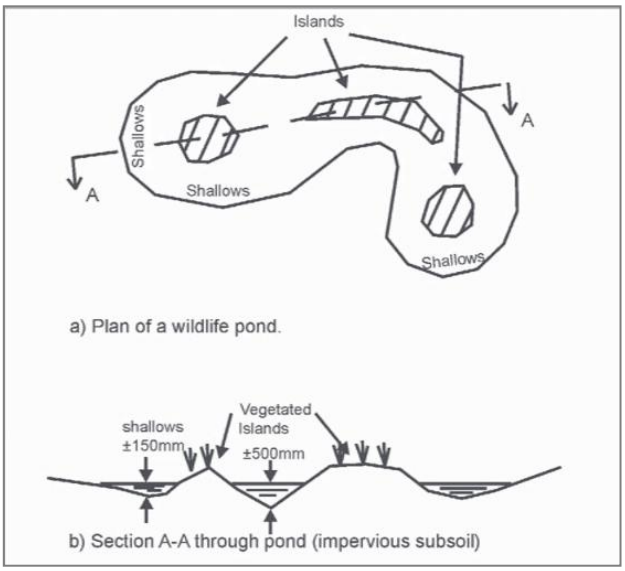

Figure 7. Suggested design of a wildlife pond including islands made from excavated soil (from Russell, 2009)

4.1.4 Impervious Surfaces Runoff

The stormwater plan proposes to discharge stormwater from roads, car parks and other open areas into the wetland at 4 points (Figure 5). There are two points on the eastern side and two on the southern side of the development. This will support the recharge of groundwater, and provide surface flow into the wetland during periods of rainfall. This is considered a positive approach but must ensure that channelled flow doesn't occur at the discharge points. Sheet flow must be maintained as far as possible so as not to further degrade the wetland.

4.1.5 Access Road from Howard Street

An access road connecting Howard Street through the wetland to the sports complex has been proposed as part of the traffic plan. The proposed design specifications of the road are presented by Niewoudt and Kie (2018) are shown in Figure 8. The road is approximately 180m long in the open wetland (excluding the length next to the sports complex), the road reserve is 12 m wide, and the actual road surface is 6 m wide.

It is unfortunate that the road needs to transect the wetland as this represents a significant reduction in connectivity of habitat. On the one hand the rehabilitation efforts will improve habitat to the extent that populations of wildlife increase, but this increases the risk of wildlife collisions on the road. Therefore extreme traffic calming measures such as speed bumps and signage are recommended for this road. Users must be made aware that they are crossing a sensitive ecological space and must adapt their driving behaviour accordingly.

Efforts have been made to minimise disruption to hydrological connectivity by proposing the road be constructed with 600 mm diameter stormwater pipes crossing the road in the open section of the wetland (indicated by blue arrows on Figure 8). Where the road crosses the drainage channel, water flow will be maintained through two box culverts with brick headwalls (blue rectangle in Figure 8).

Given the distance covered by the road through open wetland space, the three proposed stormwater pipe crossings are considered insufficient from a number of perspectives:

- Under-road crossings provide opportunities for the safe dispersal and movement of wildlife across the site. But the pipelines are limited in size (600 mm diameter) and number (three) resulting in increased likelihood that wildlife would cross over the road;
- The aim of rehabilitating the wetland is to increase dispersive sheet flow across the surface of the wetland. If dispersed water is channelled through three relatively narrow pipes it will result in erosion at the exit points.

It is therefore recommended that the stormwater pipes be upgraded to one larger box culvert at each of the three crossings. A stilling basin (or similar) needs to be installed at either end of the culvert in order to reduce the effects of channelling and erosion on the wetland.

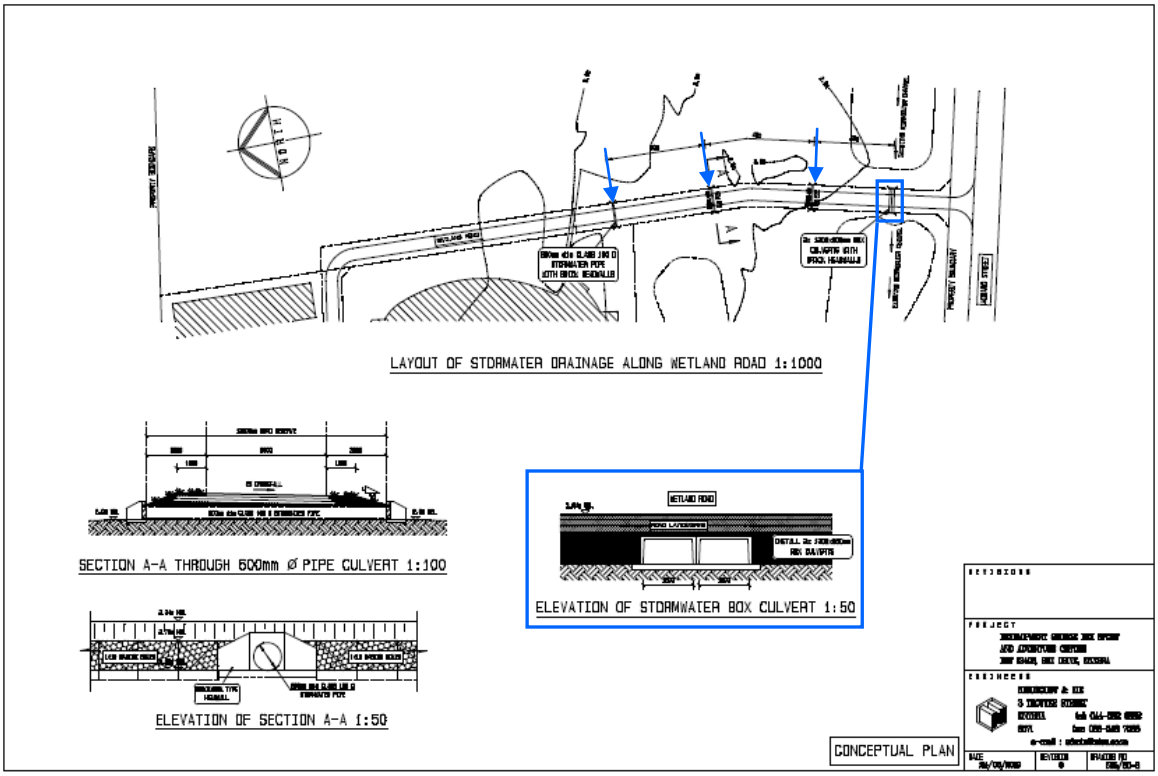

Figure 8. Proposed layout and cross-sections showing stormwater management of the access road from Howard Street to the sports complex.

Vegetation Rehabilitation

Three factors play a significant role in shaping the plant communities on Erf 12403. Mowing is the first, and is technically easy to rectify simply by stopping the practice and allowing plants to re-grow naturally. However, it is likely that a large number of alien plants will germinate and grow alongside indigenous species. The second factor is alien plants which are abundant at the site and are present in most disturbed areas. This means the site will be very susceptible to further encroachment by alien plants during high disturbance activities such as the construction phase of the development. Thirdly, the vegetation has become far more dominated by freshwater wetland species such as *Phragmites australis* and *Typha capensis*, than its historic more brackish and marine origins.

4.1.6 Alien Vegetation Management

The first priority for rehabilitation should be the initial removal of alien plants. There is diverse, and in some areas abundant alien vegetation that will constrain rehabilitation of the wetland in the long run if not effectively controlled from the start. Control implies initial clearing as well as ongoing follow up operations which will be ongoing for years to come.

Caution must be exercised along the embankment of the drainage channel, because large alien trees have colonised the entire area and provide some ecological functions that must not be disrupted. These include stabilisation of the banks of the channel (preventing erosion) and shading and temperature control in the stream to which indigenous under-storey plants and aquatic biota will be accustomed. It is therefore recommended that large trees (trunk diameter > 20 cm) along the channel be ring barked and locally treated with an appropriate herbicide so as to reduce disturbance to the environment. Smaller trees (trunk diameter < 20

cm) can be selectively cut, and the stump treated with herbicide to prevent regrowth and coppicing. Tree saplings and shrubs can be cleared using 'cut and paint' methods or tree poppers with minimal soil disturbance. Clearing must be done by hand, and no large machinery must be used in this area. Any cut vegetation must be removed from the site and dumped at a municipal waste site in order to reduce further dispersal opportunities.

Alien trees and shrubs in the remainder of the wetland area may be treated in a similar way to that described in the above paragraph, but limited access by light machinery may be used to remove trees and plant material. Pampas grass is common in the wetland and needs to be controlled as it replaces indigenous vegetation. Repeated applications of a systemic herbicide will be translocated to the roots and will eventually kill the entire plant. Removal by hand is difficult because of its large rhizomatous roots which all need to be removed for effective control.

Classified alien weed and invader species according to the National Environmental Management Biodiversity Act (NEMBA, 2014) commonly found at George Rex Wetland are listed in Table 1 with a description of relevant class categories provided in Table 2.

Table 1. List of declared weeds and invaders recorded in the George Rex Wetland.

Species Name	Common Name	Growth Form	NEMBA Category
Acacia mearnsii	Black wattle	Tree	2
Acacia melanoxylon	Australian blackwood	Tree	2
Cestrum laevigatum	Inkberry	Shrub/tree	1b
Cirsium vulgare	Spear thistle	Herb	1b
Cortaderia selloana	Pampas grass	Grass	1b
Eucalyptus grandis	Saligna gum	Tree	2
Paraserianthes lophantha	Australian albizia	Tree	1b
Rubus sp.	Bramble, Blackberry	Shrub	1b
Sambucus nigra	Elderberry	Shrub/tree	1b
Solanum elaeagnifolium	Silver-leaf bitter apple	Shrub	1b
Solanum mauritianum	Bugweed	Shrub	1b
Vinca major	Periwinkle	Herb	1b

Table 2. NEMBA categories for invasive alien plants at George Rex Wetland.

Invasive Status (category)	Description
Category 1b (Prohibited)	• Invasive species requiring compulsory control as part of an invasive species control program. • Remove and destroy. • Plants deemed to have such a high invasive potential that infestations can be placed under a government sponsored invasive species management program. • No permits can be issued.
Category 2 (Permit required)	• Invasive species regulated by area. • A demarcation permit is required to import, possess, grow, breed, move, sell, buy or accept as a gift any plants listed in Category 2. • No permits will be issued for these plants to exist in riparian zones.

4.1.7 Mowing

While mowing the wetland should ultimately be stopped, it has created the opportunity to access areas where alien plants need to be controlled, particularly along the drainage channel embankment running along the eastern and southern boundaries. Therefore it is recommended that mowing should be stopped across the majority of the site, except for mown paths which should be maintained to provide access to areas where alien plant control will require follow up and maintenance. Paths to these areas could continue to be cut and maintained. As alien vegetation will also appear in previously mown areas, paths should be cut inbetween manageable blocks of land so as to allow access for the control of alien plants as they appear.

As regeneration of the wetland advances along these areas, some of the mown paths may subsequently be used as scenic pathways for boardwalks through the wetland.

4.1.8 Establishment of Indigenous Wetland Plants

Despite the extensive alien plant community, there are diverse wetland-associated indigenous plants at the site. This is very positive because under the right conditions (no mowing, saturated soils, and variable salinities) these plants will thrive and colonise new areas. Therefore, active planting of wetland species is not required in areas where aliens are controlled and mowing has ceased.

However, there is a case for active planting where soil has been disturbed, such as where ‘slots’ are opened in the drainage channel, or banks of the water storage dam have been excavated. It is recommended that these areas are re-vegetated with suitable plants obtained from the site as a priority following the work. Where land surfaces are modified and cleared for the development, indigenous wetland plants should be rescued and kept in a nursery on site for use in rehabilitation. Given that *P. australis* and *T. capensis* are already abundant at the site, plant rescue efforts should focus on other wetland plant groups such as sedges, rushes and restios (Figure 9).


Carex aethiopica
Sedge


Eleocharis limosa (finger rush)

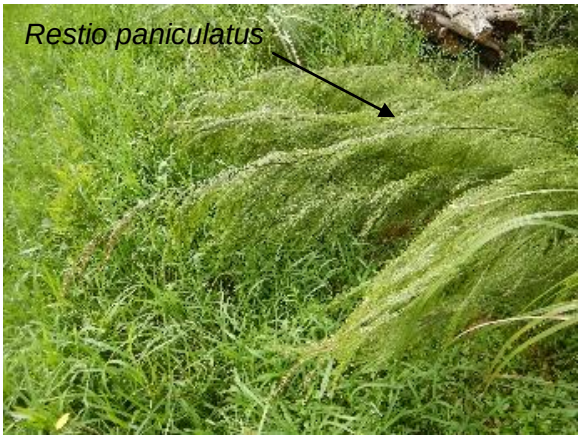

Figure 9. Examples of indigenous wetland plants found at George Rex Wetland that can be rescued and replanted in disturbed area.

4.1.9 Suitable Plants for the Sports Complex

Given the proximity of the sports complex to the area of wetland to be rehabilitated, only indigenous plants should be used for associated landscaping. In some areas, wet soils may still be present despite the degraded nature of the site due to infilling, in which case indigenous wetland plants from the site may be used if clearing them is deemed necessary. Where further infilling results from the development and soils will not be saturated, indigenous terrestrial plants that occur at the site should be planted. A list of identified plants on site that should serve as a basis for planting is presented in Table 3. Many of these plants can be obtained from wholesale nurseries and could also be rescued during clearing operations on site.

Table 3. Indigenous terrestrial plants suitable for use in planting around the sports complex.

Species name	Common Name	Growth Form
Asparagus asparagoides	Bridal creeper	Creeper
Chasmanthe aethiopica	Cobra lily	Herb
Ekebergia capensis	Cape ash	Tree
Gymnosporia buxifolia	Spikethorn	Shrub/hedge/small tree
Helichrysum petiolare	Silver bush	Shrub
Osterospermum moniliferum	Bietou	Shrub
Pterocelastrus tricuspidatus	Candlewood	Tree/shrub
Rapanea melanophloeos	Boekenhout	Tree
Senecio tamoides	Canary creeper	Creeper
Searsia lucida	Glossy crowberry	Tree/shrub
Vepris lanceolata	White ironwood	Tree/shrub

4.1.10 Extension of Brackish Wetlands

The wetland areas in the vicinity of the two proposed new culverts beneath Howard Street will undergo a change in dominant plant communities as the water chemistry changes from fresh to brackish. Plants intolerant of elevated salinities will die off and salinity-tolerant plants will become more dominant. Propagules of salt marsh and brackish estuarine plants will be washed into the wetland with the incoming tide allowing oppurtunities for the re-establishment of new plant species and the recovery of estuarine wetland conditions in this

area. This is an important process that requires monitoring to determine how effective the culvert system is and to monitor the change in plant communities over time.

4.2 Infill Removal

The three main areas subjected to infilling in the wetland are the soil stockpiling area, historical sawdust dump and embankment along the drainage channel.

The soil stockpiling area is located within the footprint of the sports complex and therefore does not require clearing as part of the rehabilitation plan.

The sawdust dump has decomposed over time to the point that it is barely distinguishable. The disturbance to vegetation and risk of alien plant invasion outweigh the benefits of its removal because it is in the final stage of decomposition.

The infill along the drainage channel has had a significant impact because it has resulted in an overgrowth of alien vegetation and terrestrialisation of the infill embankment. Despite these negative impacts, it is recognised that complete removal of the embankment may represent a flood risk to the property and would cause a drastic alteration in habitat that would negatively impact numerous plant and animal species accustomed to the conditions. Therefore the recommendation is to take a precautionary, phased approach to removal of the embankment infill by removing sections as per the explanation given in Section 4.1.1.

4.3 Wetland Fauna

No formal study of the fauna utilising the wetland in its current state has been conducted. However it is important to have a basic understanding of the animals that occur on site in order to better understand their habitat requirements. This may be achieved through monitoring with baited camera traps and scat observations at various points on the site. The purpose of this study is not to provide an extensive list of animals at the site, but relevant observations made during site visits should always be recorded. Based on animal droppings observed in the southern portion of the erf, both Porcupine (*Hystrix africaeaustralis*) and Cape Grysbok (*Raphicerus melanotis*) occur in the wetland.

4.4 Recreation and Tourism

There is definitely scope for the development of recreational facilities related to the wetland area of Erf 12403. This would be highly compatible with the values associated with sports recreation which promote a healthy body, and by extension, a healthy environment.

Recreation activities must not compromise the ecological structure and function of the wetland, and should include low impact activities and structures that provide the opportunity for visitors to appreciate and experience wetlands. Compatible activities include bird-watching, walking and nature talks. Compatible structures include wooden boardwalks, an Eco-information/education centre, bird hides, owl and bat boxes and interpretive information points.

As mentioned in Section 4.1.7 of this report which recommended mowing paths between regenerating vegetation to provide access for alien vegetation control, some of these paths may ultimately be used for wooden boardwalks at a later stage of the rehabilitation process.

This will reduce the impact of cutting through the wetland vegetation in order to construct boardwalks.

As the wetland is meant to be a natural area providing refuge for biota, the development footprint for recreation in this area should be light and restricted to a maximum limit. As a preliminary suggestion, this should be no more than 5% of the 13.8 ha wetland area. This is a total area not exceeding 6 900 m^2. Activities should also exclude possible disturbances such as loud music events, dog-walking and high speed activities like mountain biking (given the limited area).

As the primary aim is to restore the ecological functions and integrity of the wetland, the development of recreation activities and structures is seen as being in the second phase of rehabilitation. Detailed planning for recreation-related developments should include an aquatic ecologist.

5. REHABILITATION SUMMARY

Recommendations for rehabilitation have been broadly discussed in the preceding section and include specific actions in the discussion. For clarity, Table 4 provides a summarised list of these specific actions.

Table 4. Summary of actions required for each aspect of rehabilitation.

Stormwater Management Actions
1. Drainage Channel Outflows • Create 5 outflow points approximately 5 m wide in the drainage channel embankment. • Openings must be made using light machinery. • The infill must be removed to the same level as the surrounding wetland. • Fill material must be removed from the site. • Openings should be made in locations with abundant alien vegetation, causing minimal disturbance to indigenous plants. • Openings must not be made directly opposite stormwater inflows from Hunters Estate. • The embankment must be reshaped to a 1:3 slope on both sides of the opening to minimise erosion. • Disturbed areas must be revegetated with indigenous wetland plants. • Work on this aspect should be completed during the dry season. • Take photos of the outflows following completion of the work to provide a comparison following high flows.
2. Culverts and Connectivity • Add a second culvert linking the wetland to the golf course drainage channel under Howard Street, towards the intersection with George Rex wetland.
3. Water Harvesting Dam • Water levels must not be drawn down below 30% for human consumption. • Consider the use of a clay liner instead of plastic. • Construct small island(s) above the high water mark in the middle of the dam. • Edges of the dam must be sloped to a gradient of 1: 6 or flatter. • Ensure overflow from the dam during flood events will not cause erosion or channelled flows into the wetland. • Do not stock alien fish. • One viewpoint (e.g. bird hide) at the dam is permitted for recreation purposes, otherwise the

dam must be surrounded by wetland vegetation.
4. Impervious Surfaces Runoff • Ensure stormwater discharge points include energy dispersive measures such as stilling dams to prevent erosion and channelled flows.
5. Howard Street Access Road • Install traffic calming measures and signage to reduce the risk of wildlife collisions. • Upgrade the 3 proposed stormwater pipes to box culverts with energy dispersive structures on either side to reduce the risk of erosion and channelled flows.
Vegetation
1. Alien Vegetation Management • All work on alien vegetation along the drainage channel embankment must be done by hand, and no heavy machinery must be used in this area for clearing. • Large alien trees (trunk diameter > 20cm) along the drainage channel embankment must be ring-barked and treated with herbicide. The same applies to large trees elsewhere at the site, the *Eucalyptus* trees along the southern boundary for example. • Small alien trees (trunk diameter < 20 cm) along the drainage channel embankment must be cut down and removed, and the stumps treated with appropriate herbicide. • Tree saplings and shrubs along the embankment can be cleared using the 'cut and paint' method or a tree popper. • Pampas grass to be spot treated using an appropriate herbicide, with repeated applications if necessary. Because it is a grass, extreme care must be taken to keep herbicide away from surrounding vegetation. • Cleared vegetation must be removed from the site and dumped at a municipal waste site. • Within the more open wetland area, all alien trees must be cut down, stumps treated with an appropriate herbicide, and removed from the site.
2. Mowing • Cease mowing the wetland. • Retain a network of mown paths from which to access areas of regenerating vegetation as well as established vegetation to control alien plants. • Eventually consider using some of the mown paths as scenic pathways for boardwalks through the wetland.
3. Establishment of Indigenous Wetland Plants • Rescue indigenous plants from areas to be disturbed and maintain them in a nursery on site for planting at a later stage. • Disturbed land areas susceptible to erosion or alien plant colonisation should be revegetated using the above plants.
4. Planting at the Sports Complex • Only indigenous plants to be used for landscaping. • In terrestrial (non-wetland) areas, utilise indigenous plants listed in Table 3 or other indigenous plant species identified at the site.
Infill removal
• The only infill to be removed is from five locations within the drainage channel embankment as described in this table under the heading 'Drainage Channel Outflows'.
Recreation and Tourism
• The footprint for recreation-related infrastructure in the wetland should be no more than 5% (6 900 m^2). • Structures could include wooden boardwalks, Eco-information/education centre, bird hides, owl and bat boxes, and interpretive information points. • Activities could include bird-watching, walking and nature talks. • Loud music, dog walking and high speed activities should be excluded.

6. MONITORING

The Present Ecological State of the wetland must be monitored on an annual basis once the development begins and rehabilitation efforts have been initiated. The same method used by DWAF (2008) and Rountree and Scherman (2017) should be used to maintain consistency, and ensure that the Recommended Ecological Category of C, Moderately Modified is attained. The method utilised by both studies was the Vegetation Alteration module in the Wetland Index of Habitat Integrity (DWAF, 2007).

Some aspects associated with this rehabilitation plan require more frequent or event-specific monitoring in order to determine whether the recommended actions are having the desired effect, and are listed below.

6.1 Drainage Channel Outflows

The five proposed outflow points should be monitored during and following high rainfall events to determine a) whether erosion is occurring at the outflow points, and b) how the flow dynamics have changed across the wetland as a result of the intervention. Photographic evidence will suffice for monitoring purposes.

6.2 Culverts and Connectivity

The two new culverts proposed to link the wetland with the estuary should be visually inspected at high tide and low tide, and during spring high tide to determine the extent to which tidal exchange is occurring. Photographic evidence of this would suffice. Before construction activities commence on the site, baseline measurements of salinity should be made by an aquatic ecologist at a range of locations with standing water to provide a comparison once the culverts are installed.

6.3 Alien Vegetation

The control of alien vegetation is widely understood to be an ongoing task, requiring a long-term commitment to follow up control if it is to be successful. As time goes on the work-load reduces, but a once-off exercise will certainly not be successful if follow up control does not happen. Mown paths providing access to regenerating wetland vegetation and areas where aliens have previously been cleared must be walked every 4 months (3 times a year) in order to identify new plants or re-growth of old plants.

7. CONCLUSIONS

The Recommended Ecological Category for George Rex Wetland as determined by Rountree and Scherman (2017) is C, Moderately Modified. This rehabilitation plan addresses each aspect of degradation cited in the Reserve Determination study and provides a plan to rehabilitate as many of these impacts as possible within the constraints of the proposed sports centre development. In spite of the sports centre, the rehabilitation prospects for George Rex wetland are positive if this plan is followed, and the REC is quite achievable if the plan is well implemented and managed.

The rehabilitation plan represents a first phase approach, and it is quite likely (and recommended) that an adaptive management approach to rehabilitation of the site be embraced. As various elements of wetland health improve / decline, it is important to recognise changes and adapt strategies accordingly. Recognition of change is where the implementation of monitoring recommendations will be important.

The location and extent of the wetland at this site poses an excellent opportunity for recreation and tourism opportunities that are highly compatible with the values associated with a sports centre. However, this aspect of rehabilitation is viewed as a second phase with the primary concern being to improve the ecological status of the wetland.

8. REFERENCES

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