Maintenance Management Plan for the Bigai River Floodplain, Knysna, Western Cape.

Prepared for: Knysna Municipality

In terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended & Environmental Impact Regulations 2014 March 2023

May 2023 (updated September 2023)

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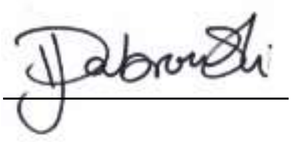
DECLARATION OF CONSULTANTS INDEPENDANCE

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, estuaries, 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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Qualifications: BSc, BSc Honours (Entomology), MSc & PhD (Veterinary Science)

Expertise: > 15 years' experience working on aquatic ecosystems across South Africa, with a focus on the Southern Cape in the last 7 years. Includes research and consulting expertise, having published > 10 water-related research articles and compiled > 150 aquatic specialist reports. Research and consulting have been in a range of sectors including agriculture, urban developments, linear structures, renewable energy, conservation, and mining.

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ACRONYMS

Alt.	Alternative
BGCMA	Breede-Gouritz Catchment Management Agency
BGIS	Biodiversity Geographic Information System
CARA	Conservation of Agricultural Resources Act (43 of 1983)
CBA	Critical Biodiversity Area
CDSM	Chief Directorate Surveys and Mapping
cm	Centimetre
DFFE	Department of Forestry Fisheries & Environment
DEA&DP	Department of Environmental Affairs & Development Planning (Western Cape)
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EAP	Environmental Impact Practitioner
ECO	Environmental Control Officer
EHS	Environmental, Health & Safety
EIA	Environmental Impact Assessment
ESA	Ecological Support Area
EMPr	Environmental Management Programme
GA	General Authorisation
GPS	Global Positioning System
ha	Hectare
I&APs	Interested and Affected Parties
L	Litre
m	Metre
m^2	Square metres
m^3	Cubic metres
NEMA	National Environmental Management Act (107 of 1998, as amended in 2006)
NEMBA	National Environmental Management: Biodiversity Act (10 of 2004)
NSBA	National Spatial Biodiversity Assessment
NWA	National Water Act (36 of 1998)
SANBI	South Africa National Biodiversity Institute
SDF	Spatial Development Framework
S&EIR	Scoping & Environmental Impact Reporting
WULA	Water Use Licence Application

1. BACKGROUND AND INTRODUCTION

Confluent Environmental (Pty) Ltd was appointed by Knysna Municipality to compile a Maintenance Management Plan (MMP) for the lower reaches of the Bigai River in Knysna. The purpose of the MMP is to consider maintenance actions required to alleviate flooding in the lower reaches of the Bigai River. A number of flood-prone areas are highlighted in this assessment along with recommended maintenance actions to improve their ability to convey flood waters.

This plan was compiled in conjunction with the Knysna Municipality and the Knysna Golf Course who proposed a range of maintenance actions to alleviate flooding at various points. These actions and others are presented in this plan along with other methods aimed at reducing flooding without causing excessive negative impacts to the aquatic environment. Several of the areas highlighted for maintenance involve historical channels which have been excavated to improve drainage in low-lying areas. Significant flooding occurs on a fairly regular basis in the area, frustrating residents, workers and business owners who cannot cross road sections due to flooding which can remain *in situ* for weeks at a time.

The Knysna Municipality is the main applicant and will implement all actions outside of the Knysna Golf Course. The Knysna Golf Course is located on municipal ground, but all maintenance actions will be carried out by groundsmen on their site.

No engineering solutions are proposed in this MMP, and specialist inputs are limited to those provided by the aquatic and biodiversity specialists, who is also the authors of the MMP (Dr J. Dabrowski and Ms Bianke Fouche).

Figure 1. Area covered by this Maintenance Management Plan in Knsyna, Western Cape.

1.1 Maintenance Management Principles

This MMP is prepared using the guiding principles for landowners and managers considering the development of a MMP as provided in the MMP template for a watercourse (2017). These are summarised as follows:

- Avoid and reduce unnecessary maintenance.
- The condition of physical and ecological processes that drive and maintain aquatic ecosystems in a catchment must inform a MMP relative to the desired state of the affected system.
- Management actions must aim to prevent further deterioration to the condition of affected watercourses and, overall, be guided by a general commitment to improving and maintaining ecological infrastructure for the delivery of ecosystem services; and
- Managers and organs of state must identify, address and, where feasible, eliminate the factors that necessitate intrusive, environmentally damaging maintenance.

1.2 Relevant Legislation

The maintenance work proposed in this MMP is mostly located at sites which are either terrestrial or located within the Estuarine Functional Zone. Refer to Figure 2 for locations of culverts, channels and berm where maintenance is required. The definition of estuarine habitat in terms of listing Notice 3 (GN R 985) published under the NEMA EIA regulations (2014), defines an estuary as the Estuarine Functional Zone (EFZ) as defined in the National Biodiversity Assessment: Estuary Component (van Niekerk & Turpie, 2012). The EFZ is delimited by the 5 m topographical contour surrounding an estuary.

The proposed maintenance includes excavation of sediment and vegetation that has accumulated around existing infrastructure along the Bigai Wetland and within the Knysna Golf Course. The excavation of material from an estuary/watercourse triggers listed activity 19, activity 19A (Listing Notice 1) and Listing Notice 3 (Activity 12) of NEMA for the removal of vegetation (if classified as endangered/critically endangered, unless it is for maintenance purposes undertaken in accordance with an approved Maintenance Management Plan (National Environmental Management Act (NEMA).

This MMP considers regulations in the National Environmental Management: Protected Areas Act (Act 57 of 2003), specifically Regulations for the Proper Administration of the Knysna Protected Environment (GN R1175). The Knysna Estuary is located within the SANParks Protected Area and is listed as the most important estuary in South Africa. The regulating authority would be the national Department of Forestry, Fisheries and Environment (DFFE).

As affected areas of the Bigai Wetland are mostly freshwater in nature, the proposed maintenance actions to remove sediment and vegetation from culverts are defined as Section 21 c) and i) water uses in terms of the National Water Act (NWA, Act 36 of 1998). It is therefore necessary to consider the risk posed by the maintenance actions to the receiving aquatic ecosystem in the form of a Risk Matrix which is compiled by a SACNASP-registered aquatic scientist (as required by GN509 of 2016). If the risk of actions in their mitigated state is considered ‘Low’, then the MMP can be Generally Authorised. But if the risk is considered ‘Medium’ or ‘High’ then a Water Use License would be applicable. The regulating authority in for water use is the Breede Olifants Catchment Management Agency (BOCMA).

1.3 Scope of Work

The scope of work covered by this MMP incorporates aspects assessed during both desktop and field assessments. The following points were covered for each:

Desktop Assessment

- Review of flood-prone areas in the lower reaches of the Bigai River known to cause access problems for the local community.
- Review of methods proposed to alleviate flooding by the Knysna Municipality and the Knysna Golf Club. Reports listing infrastructure requiring maintenance were provided along with proposed methods to improve flood conveyance.
- Review previous reports compiled by engineering / environmental consultants on flooding in the Bigai River.
- Desktop assessment of affected areas using spatial data such as contours, mapped watercourses, conservation plans and historical aerial images.

Field Assessment

- Visually inspect flood-prone areas and problematic infrastructure where maintenance actions are proposed.
- Collect and analyse water samples to determine baseline water quality at key points.
- Consider proposed maintenance actions in the context of existing impacts affecting watercourses.

Report Compilation

- Compile a Maintenance Management Plan which provides clear, measurable and time framed maintenance measures to address flooding within the ambit of an MMP.
- Where work in Regulated Area of a watercourse is undertaken (as defined in the National Water Act) a Risk Matrix will be compiled to determine the level of risk posed by the maintenance actions to the watercourse concerned.

This MMP excludes the expansion and/or relocation of any structures and infrastructure as per the definitions provided in NEMA.

2. DESKTOP ASSESSMENT

2.1 Geographic Scope

The geographical scope of this assessment covers the lower reaches of the Bigai River which is predominantly wetland habitat where it enters the Knysna Estuary. The work proposed will all take place on land owned by the Knysna Municipality which includes the Knysna Golf Course, although the groundskeepers at the golf course would implement the work on that property (Figure 2). Where question marks are indicated on Figure 2, this is where culverts are suspected, but could not be confirmed due to the extent of overgrown vegetation. The following areas are covered:

- Lower reaches of the Bigai Wetland in the vicinity of Thesen, Howard, Kennet and Wilson Streets.

- All existing culverts beneath roads in the suburbs of Hunters Home and Rexford that lead to the Bigai Wetland and Knysna Estuary.
- Existing drainage channels on the Knysna Golf Course which drain from the Bigai Wetland to the Knysna Estuary.
- An artificial berm constructed between the Knysna Golf Course and the Bigai Wetland to reduce the impact of flooding on the 9th hole.

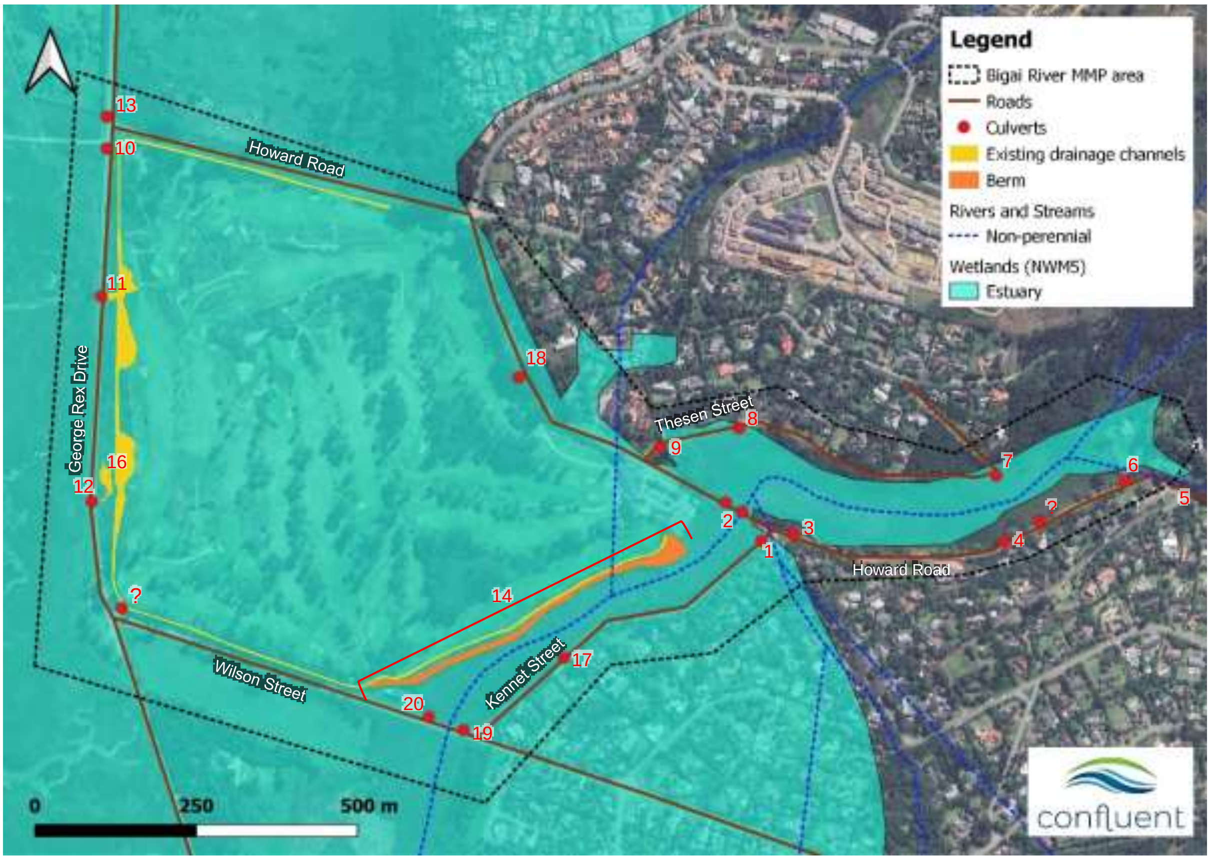

Figure 2. Area covered by this MMP indicating infrastructure and areas where maintenance is required.

2.2 Catchment Features

The Bigai River is in quaternary catchment K50B (Table 1). The Mean Annual Precipitation is 882 m and the Mean Annual Runoff is 239 mm. Rainfall occurs year-round with seasonal peaks in spring and autumn (Figure 3). Rainfall can occur at a high intensity which has the potential to exacerbate the erosion potential of the site which is mapped as High.

The project area is located within the southeastern coastal belt (Ecoregion Level 2:20.02). The terrain is described as closed hills of moderate and high relief and moderately undulating plains. Altitude ranges between 0 - 1300 m.a.m.s.l.

Table 1. Summarised environmental features of the Bigai River and catchment.

Feature	Description
Quaternary catchment	K50B
Mean Annual Runoff	239 mm
Mean Annual Precipitation	882 mm
Rainfall intensity	High (60.05)
Inherent erosion potential of soils (K-factor)	0.57, High
Mapped Soil types	Podzolic soils: soils with a sandy texture, leached with a subsurface accumulation of organic matter, iron and aluminium oxides.
Ecoregion Level II	20.02, South eastern coastal belt
NFEPA area	Sub-quaternary reach 9117, FEPA
Mapped Vegetation Type	FFh9: Garden Route Shale Fynbos (Endangered; Vegmap, 2018)
Conservation	Protected Area: Garden Route National Park Critical Biodiversity Area 1: Aquatic, Wetland (CBA1; WCBSP) Garden Route Biosphere Reserve Outeniqua Strategic Water Source Area

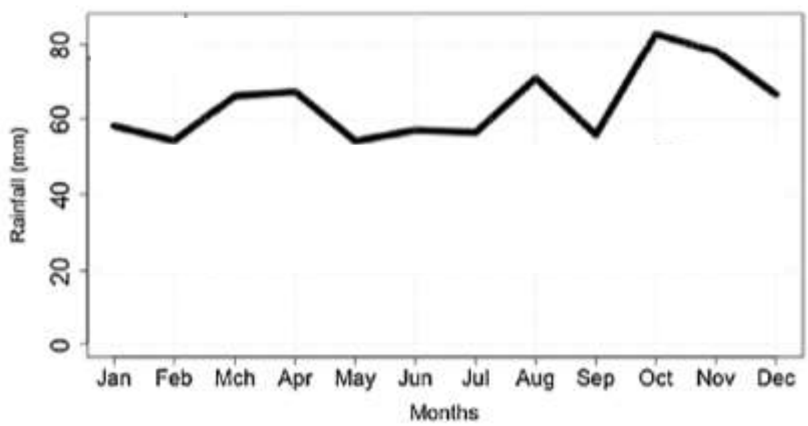

Figure 3. Area-averaged monthly rainfall for the coastal Southern Cape indicating peaks in Mar-Apr, Aug, and Oct. Data averaged between 1979 and 2011 (Engelbrecht *et al*., 2015).

According to SANBI Vegmap (2018) the mapped vegetation type in the project area is Garden Route Shale Fynbos. The conservation status of this vegetation type was revised from Vulnerable to Endangered in the gazetted revision of nationally listed ecosystems in need of protection (GN 2747of the National Environmental Management Act: Biodiversity Act; Act No. 10 of 2004).

2.2.1 Mapped Vegetation Types

Areas to the west of George Rex Drive and the golf course are mapped as Non-terrestrial estuarine vegetation, salt marsh, which has no conservation status. The vegetation on Erf 12403 is partially mapped as Non-terrestrial estuarine vegetation, reeds and sedges which reflects a more fresh water influence at the site.

In reality, vegetation types do not follow a straight line, and the low-lying reaches of the Bigai River within the Estuarine Functional Zone were likely more saline in nature with estuarine vegetation. Historical photos of the golf course for instance, indicate vegetation similar to that in the larger estuarine area in 1936 (Figure 8). Parts of the golf course adjacent to George Rex Drive are presently dominated by saltmarsh as well as reeds and sedges. Vegetation within most of the project area has been significantly modified is no long representative of the mapped vegetation type. The area mapped as Garden Route Shale Fynbos which is an Endangered vegetation type has been completely transformed to create the Knysna golf course and surrounding suburbs.

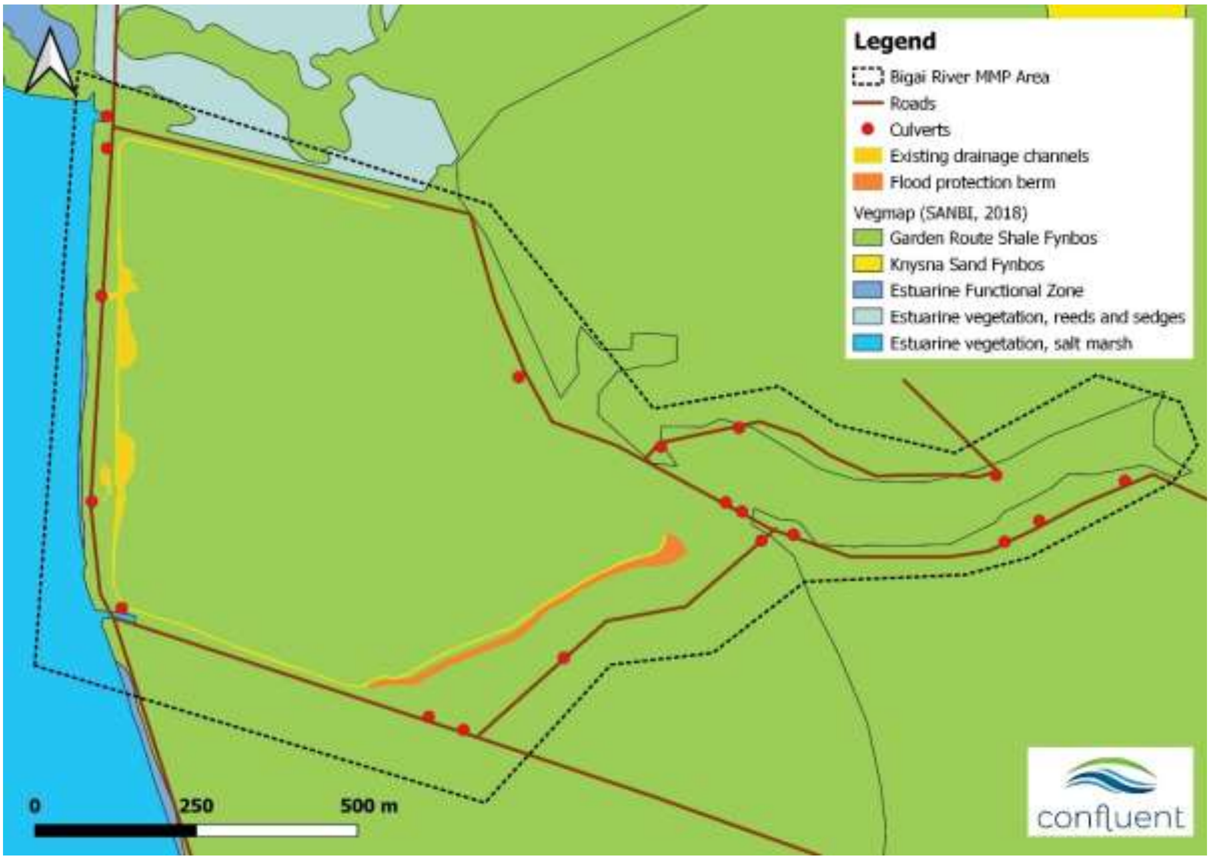

Figure 4. Mapped vegetation of the area covered by the MMP according to VegMap (2018).

The conservation importance of the Knysna Estuary is highly significant, and as it is the final sink for pollutants, litter, and sediment from the town of Knysna it is imperative that any maintenance of watercourses takes this into account. The Knysna Estuary is a unique estuarine system that has been ranked as the most important estuary in South Africa in terms of conservation importance. Preservation of its fauna and flora alone would ensure that 42% of South Africa's estuarine biodiversity would be conserved (Turpie *et al*., 2002). The estuary is home to a number of critically endangered invertebrate species including the Knysna seahorse (*Hippocampus capensis*), the pulmonate limpet (*Siphonaria compressa*) and the pansy shell (*Echinodiscus bisperforatus*; Angel *et al*., 2006).

2.2.2 Western Cape Biodiversity Spatial Plan

According to the Western Cape Biodiversity Spatial Plan (WCBSP; 2017) some of the proposed maintenance sites (culverts, drainage channels, dumping sites) are located in Critical Biodiversity Area 1 and Protected Areas (Figure 5). The lower Bigai Wetland area is categorised as CBA1: Aquatic, and the Knysa Estuary up to and including sections of the Knysna Golf Course are part of the SANParks Protected Area (Garden Route National Park).

While this highlights the need to take a precautionary approach to maintenance considering local sensitivities, all proposed maintenance is to existing infrastructure.

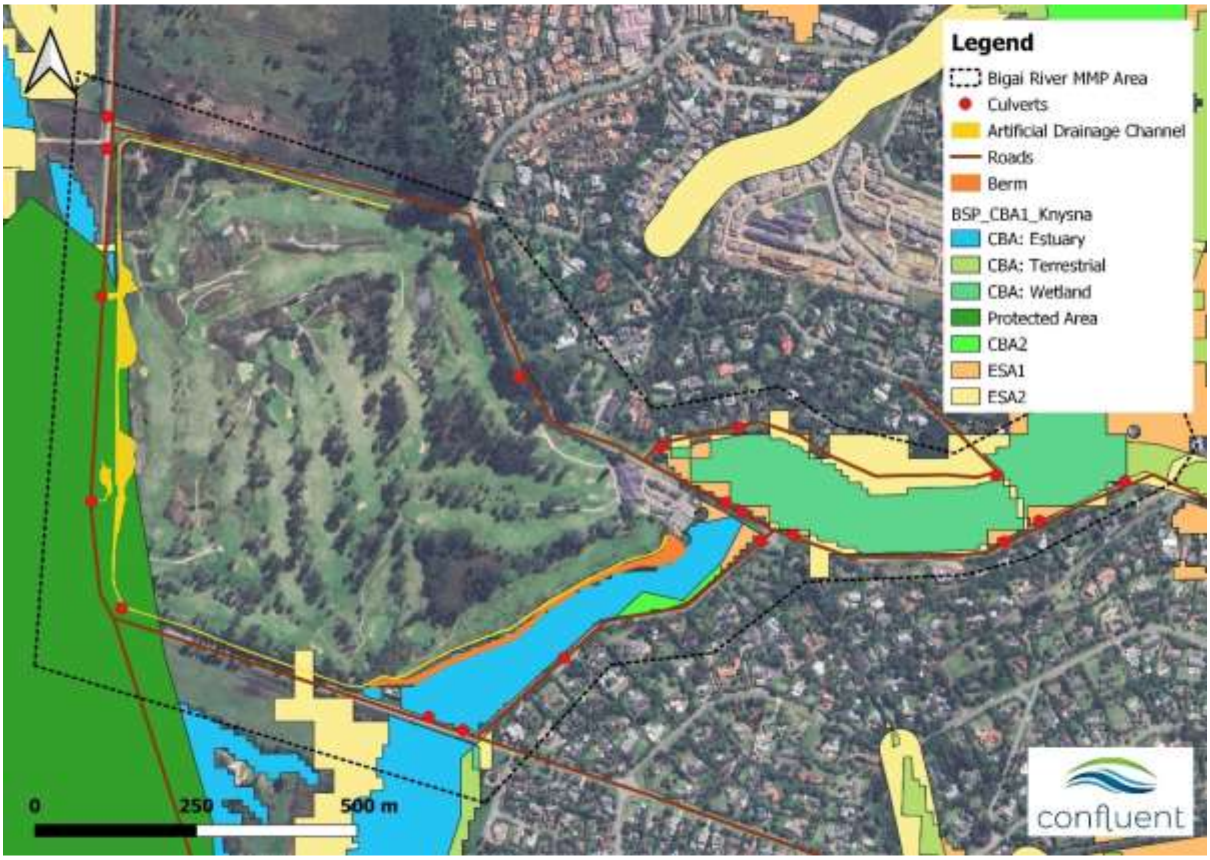

Figure 5. Mapped areas identified in the Western Cape Biodiversity Spatial Plan (WCBSP; 2017).

2.2.3 National Freshwater Ecosystem Priority Areas

The project area is located within a sub-quaternary reach identified in the National Freshwater Ecosystem Priority Areas (NFEPA) as a **FEPA**, which is a Freshwater Ecosystem Priority Area (Nel *et al*., 2011). FEPAs must remain in a good condition to manage and conserve freshwater ecosystems, and to protect water resources for human use. This does not mean these areas should be fenced off from humans, rather that they be supported by good planning, decision-making and management to ensure they are not degraded. The recommended condition for all FEPAs is an ecological category of A or B (Nel *et al.,* 2011).

2.2.4 Strategic Water Source Area

Most of the coastal areas south of the Outeniqua Mountain range, including the project area, area in the Outeniqua Strategic Water Source Area for surface water (SWSA-sw). SWSAs are defined as areas of land that supply a disproportionate (ie. Relatively large) quantity of mean annual runoff in relation to their size and are therefore considered nationally relevant (Le Maitre *et al*., 2018). A key objective in the management of SWSAs is to ensure the quantity and quality of water within and flowing from SWSAs is protected from developments that cause unacceptable and irreparable impacts.

2.3 Sub-catchment Land Use

The lower reaches of the Bigai Wetland primarily receive inflows from three natural tributaries draining the northern and eastern slopes of Noetzie Ridge. The sub-catchment for the Bigai River measures approximately 7.8 km^2. The northern tributaries flow from the densely developed areas of Hornlee and Donkerhoek which have a combination of formal and informal housing. Sewage overflows and blockages are common and discharge into the Bigai River from various sources. The suburb of Hunters Estate consists of formal housing including a retirement estate and a private hospital. Development is high density with resulting high stormwater runoff rates. The southern part of the catchment drains the suburb of Rexford which is a formal residential area built on steeply sloping land. The eastern portion of the catchment has less transformed area and a largely natural stream flows into the Bigai River from this area.

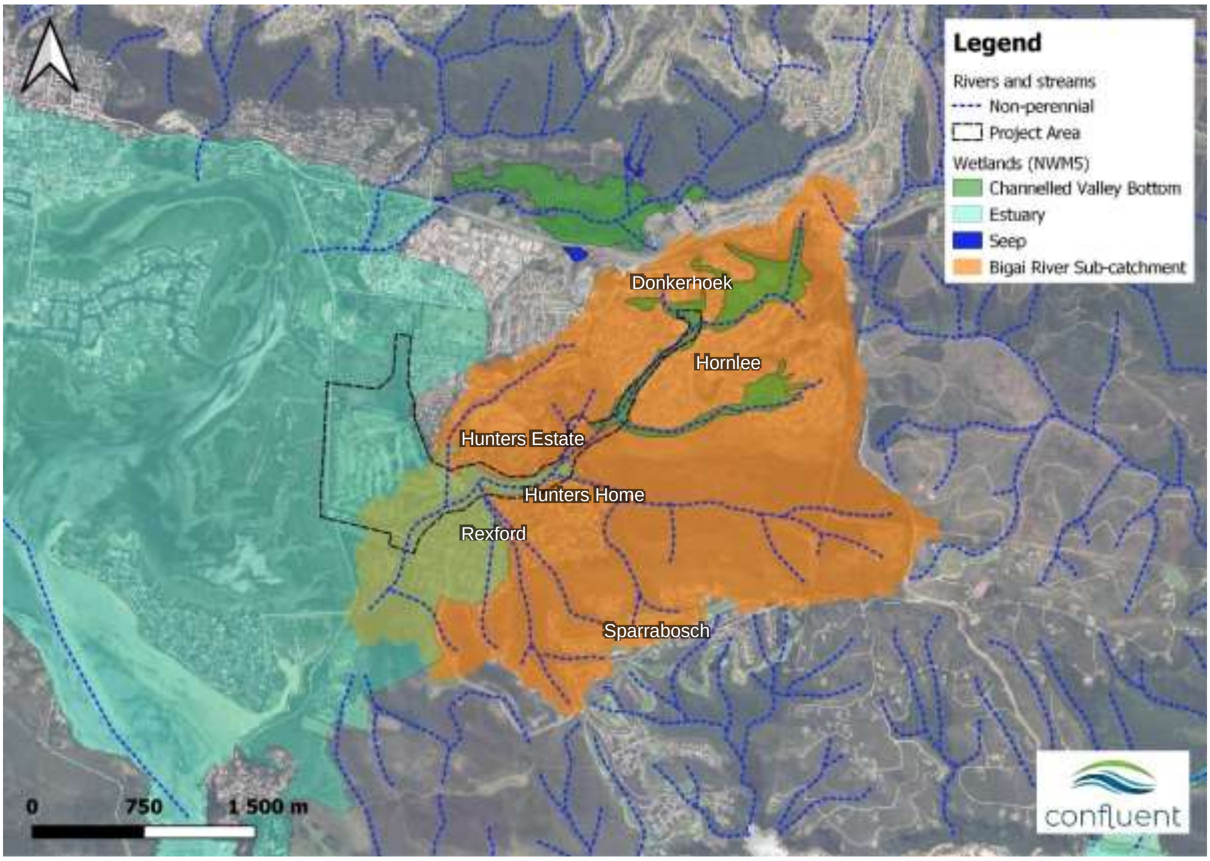

Figure 6. Mapped sub-catchment for the Bigai River showing the project area covered by this MMP indicating suburban areas.

2.4 Historical Assessment

The present location of Knysna Golf Course was set aside in the 1950s and it was described as "*A swampy mosquito-infested area*". One of the golf club committee members invested his own time and resources to dig a drainage ditch using an excavator which runs along the boundary of the 15th hole. This canal carried much water off the course and into the lagoon. However, the golf course has always been prone to flooding, as soon after opening a period of prolonged wet weather resulted in the course closing for nine consecutive Saturdays due to flooding. (Source: Knysna Golf Course History). In the 1970s or 80s a soil berm was built between the golf course and the Bigai River to prevent floodwaters from entering the course. The berm runs adjacent to the drainage ditch which was excavated along the 9th hole.

Figure 7. Historical image of the Knysna Golf Course site during a flood event (Source: Knysna Golf Club History).

Historical aerial photos of the lower Bigai River / Wetland were sourced from the CD:NGI. In 1936 George Rex Drive was present, but the surrounding areas were still largely agricultural and the Bigai Wetland largely followed its original course. The present-day area of the Knysna Golf Course is shown in the 1936 image which indicates that a significant area of the western portion of the wetland was infilled to create the 9th hole of the golf course. A large proportion of the golf course area consisted of estuarine vegetation.

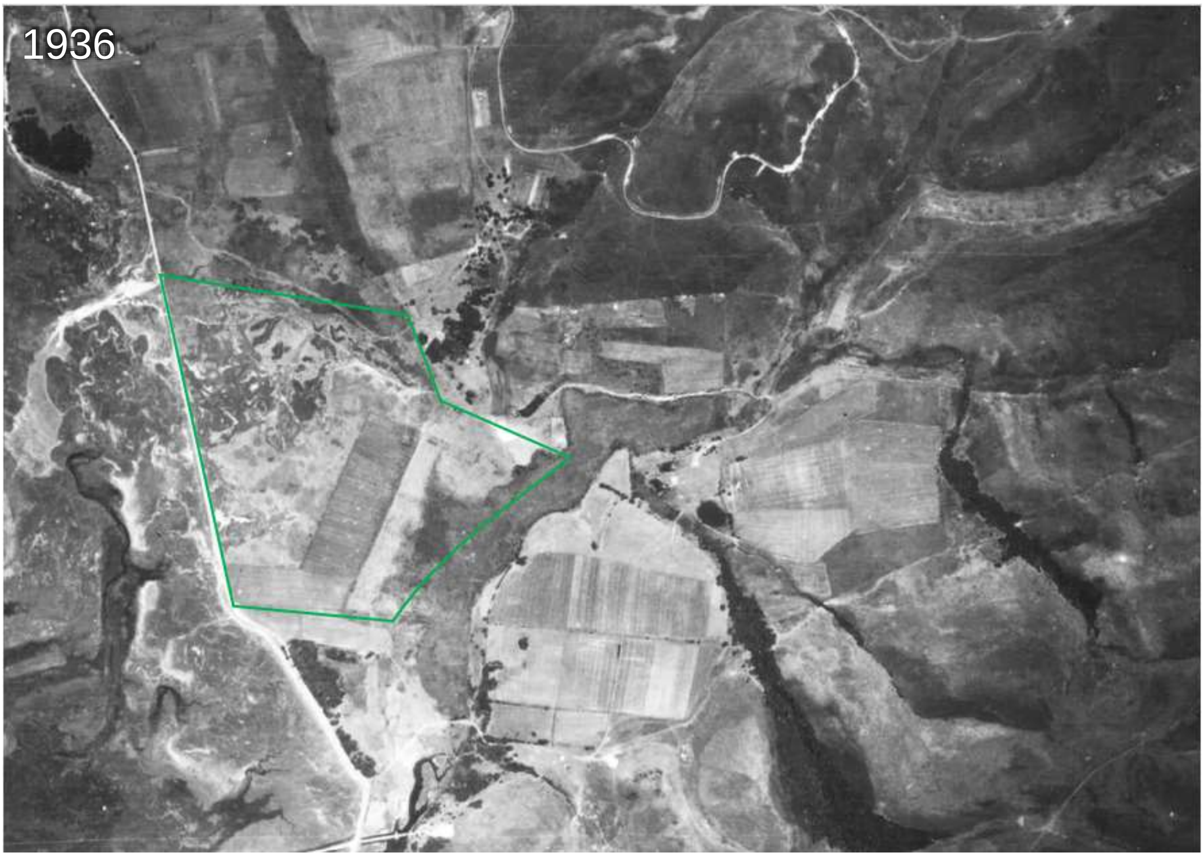

Figure 8. Historical aerial photos of the lower Bigai Wetland area in 1936 and 1974. Location of the golf course with construction of the golf course and streets are highlighted.

2.5 Site Contours

The Department of Environmental Affairs and Development Planning Spatial Information Management Unit has a database of 0,5 m contours for the 500m coastal zone for the Western Cape. These contours were modelled from a lidar survey conducted in 2013. While a decade has passed since then, the contours still provide insights into the accumulation of sediment in the Bigai Wetland which could be leading to reduced flows through the system. The contours do not extend to the Bigai River north of Howard Road.

Islands of sediment around Howard Street range between 3.5 and 4.0 m.a.m.s.l (light yellow in Figure 9). The height gradually decreases downstream to Wilson Street where elevation ranges between 2.0 and 2.5 m.a.m.s.l (medium to darker blue in Figure 9).

While it is likely that a repeat survey of this site would render new levels due to more recent sediment deposits and altered flow paths, observing the contours provide the following insights:

- The Knysna Golf Course is at a lower level than the Bigai River. The Golf Course ranges between 0.5 and 2.0 m.a.m.s.l, which means the Bigai River in the area around Howard Street is approximately 1.5 m to 2.0 m higher than the golf course. Assuming that the golf course and wetland were on more-or-less the same contours in 1936 this means a large quantity of sediment has accumulated in the wetland.

- While height differences are minimal between Howard and Wilson Street, there is still a gradual decrease in levels in a downstream direction indicating that flow downstream would be maintained, albeit at a slow rate.
- There did not appear to be obvious plugs of sediment upstream or downstream of the few culverts which appear in relation to contours in Figure 9 (2013), indicating that sediment may be quite evenly distributed through the wetland. This makes sense because there are no channelled sections of the wetland, with water dispersing fairly uniformly across the site. However, this could only be confirmed with a repeat survey similar to that presented here.

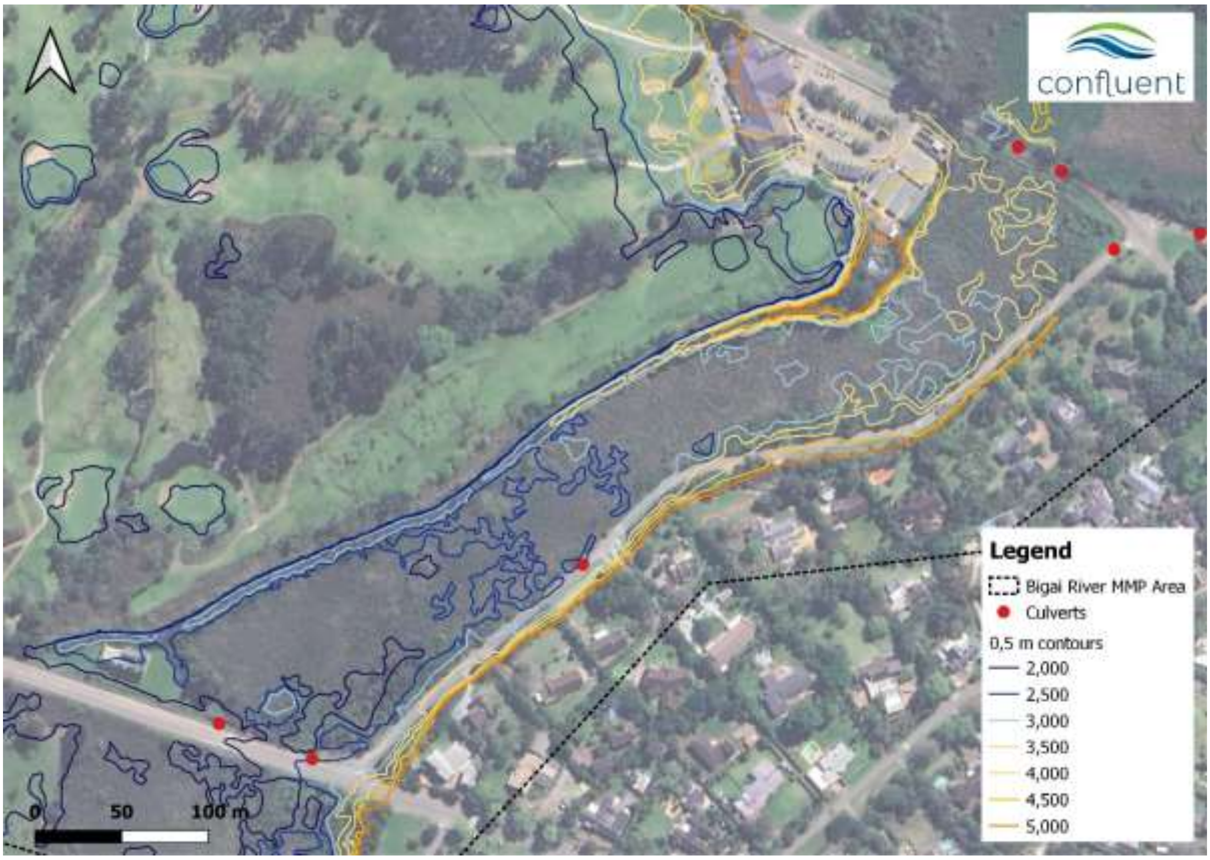

Figure 9. Contours of the Bigai River between Howard Street and Wilson Street in relation to culverts. Based on 2013 Lidar survey of coastal areas (DEA&DP).

3. SITE ASSESSMENT

The Knysna Municipality, Knysna Golf Course and local resident's associations repeatedly highlight the same areas affected by flooding. Each of these problem areas was visited and assessed to determine impacts contributing to poor drainage. Several site visits were undertaken, sometimes weeks after preceding rainfall. However, problem areas on Howard and Thesen Streets remained flooded during each site visit. This issue therefore requires serious and ongoing attention.

3.1 Flood-prone Areas

When high rainfall occurs, sections of Howard Street, Wilson Street and Thesen Street where they intersect with the Bigai Floodplain area become flooded and impassable by vehicles until floodwaters recede somewhat but can remain impassable by pedestrians for at least a week following rainfall. The 9th hole on the Knysna Golf Course becomes unplayable and cannot be maintained for months, negatively affecting revenue and play.

Flooding is being caused by several factors which are summarised as follows:

- Firstly, the lower reach of the Bigai River is naturally flat and poorly drained, being part of the Knysna Estuary. As a result of the low gradient, water tends to 'sit' in the system and drain very slowly (Figure 9).
- Erosion due to poorly managed development in the catchment has resulted in deposition of sediment in the lower Bigai River which has built up the riverbed over time (e.g. Figure 10).
- High nutrient inputs from the catchment due to leaking, blocked, and poorly functioning sewerage infrastructure have stimulated excessive growth of reeds such as *Typha capensis* and *Phragmites australis* which dominate vegetation at the site (Figure 10).
- Gradual silting up and blockage by vegetation of almost all culverts which are meant to drain the lower Bigai River.
- Siltation and vegetation growth in artificial drainage channels on the Knysna Golf Course and Erf 12403.

Figure 10. Photo taken on 31 March 2023 of a bulk sewerline that was opened to remove a blockage due to a walking crutch (arrow). Raw sewage and silt flowed straight downslope into the Bigai Wetland.

Photos of areas which are repeatedly flooded following rainfall events are presented in Table 1 and correspond to areas indicated in Figure 11.

Table 1. Flood-prone areas assessed in this MMP.

Location	Photo	GPS Coordinate
Howard Street near the Golf Course entrance.		34° 3'30.89"S, 23° 4'48.73"E
Howard Street between the Knysna golf course and Erf 12403. Water flows from the site onto the road.		34° 3'13.13"S, 23° 4'17.58"E
Wilson Street. Water flows over the surface of the wetland preferentially towards the electrical sub-station which is not aligned with culverts.		34° 3'42.07"S, 23° 4'31.46"E
Thesen Street		34° 3'27.35"S, 23° 4'47.13"E

Golf Course 9th Hole		34° 3'34.42"S, 23° 4'38.43"E

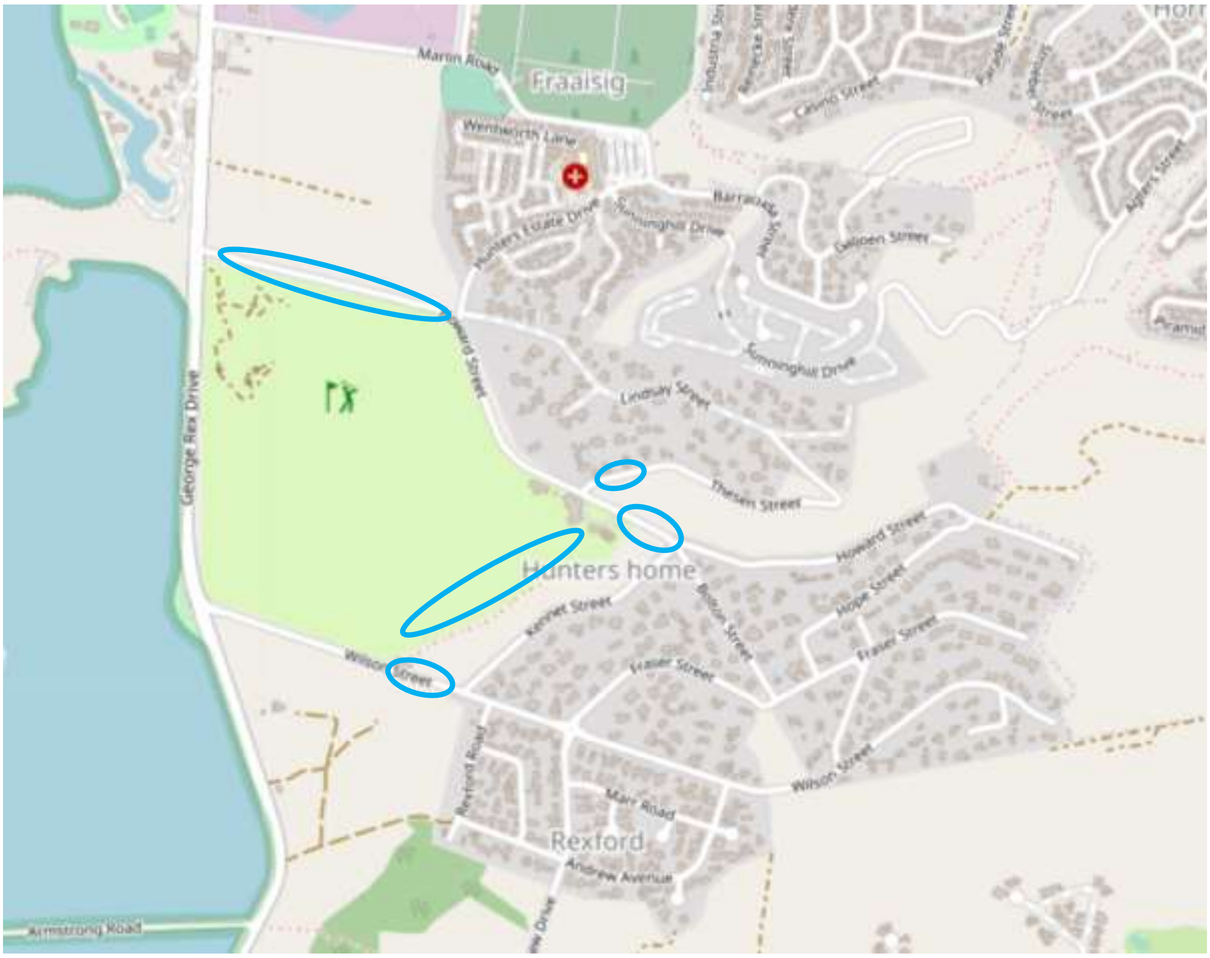

Figure 11. Street map of areas regularly affected by flooding encircled in blue.

3.2 Water Quality Results

One of the valuable ecosystem services provided by wetlands in urban environments is their improvement of water quality. This occurs when water polluted by chemicals, nutrients or suspended sediments is improved by flowing through the wetland, which acts as a biofiltration system. However, this function can become overwhelmed if a wetland is subject to very high inputs of polluted water for a sustained period of time.

While only providing a snapshot of the wetland's function, relevant water quality parameters were measured as part of this study to gain a sense of water quality in the wetland. Samples were collected at sites indicated in Figure 12 on 31 March 2023. A 1 litre sample was collected from each site using bottles pre-rinsed with water from the site, which were immediately kept on ice and subsequently refrigerated. Samples were submitted to Bemlab in Cape Town for analysis. Basic measurements of pH, dissolved oxygen, Electrical Conductivity and temperature were made at each site using a multiparameter Hanna meter.

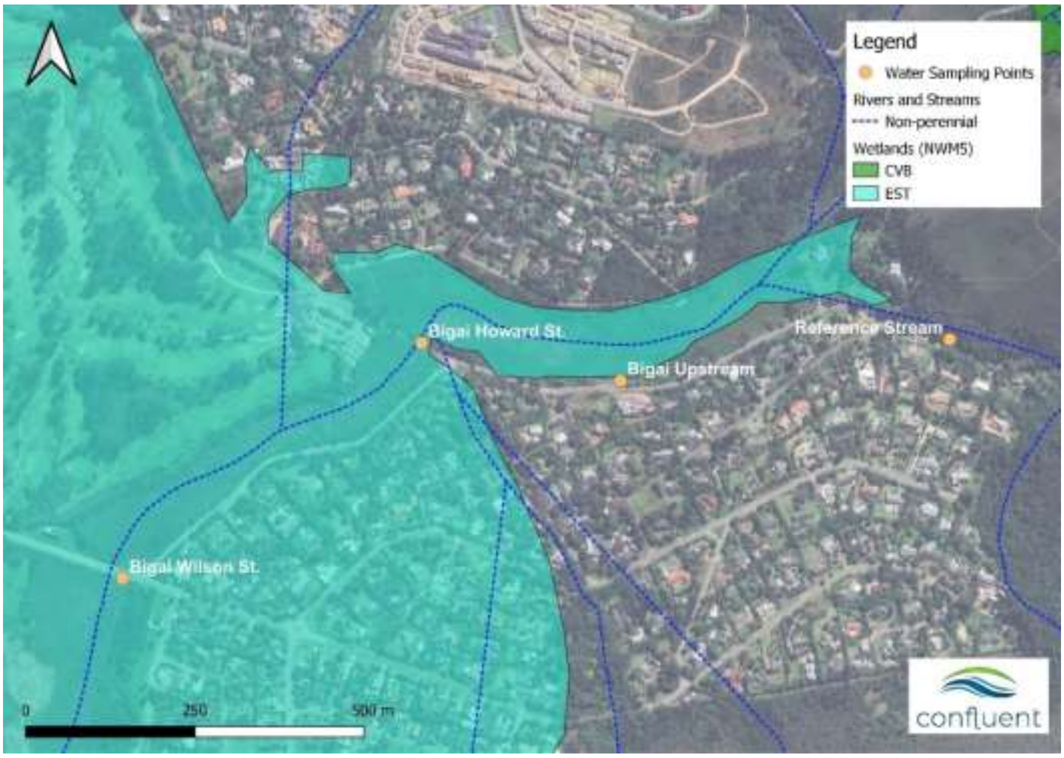

Figure 12. Four water sampling points along the Bigai Wetland and reference stream. Sampled on 31 March 2023.

Table 2. Water quality results from 4 samples collected on 31 March 2023 at locations in Figure 12.

Parameter	Units	Reference Stream	Bigai Upstream	Bigai Howard Street	Bigai Wilson Street
pH	pH units	6.5	7.01	6.55	6.95
Electrical Conductivity	µS/cm	1 302	837	895	786
Dissolved Oxygen	mg/L	8.76	3.09	2.81	4.04
Temperature	°C	16.9	16.5	16.7	16.5
Suspended Solids	mg/L	< 5.0	< 5.0	55.0	20.0
Total Nitrogen	mg/L	< 10.0	23.0	20.0	<10.0
Total Inorganic N	mg/L	< 0.05	18.5	16.3	6.9
Ammonium (NH_4^+)	mg/L	< 0.05	17.8	15.7	6.7
Ammonia	mg/L	< 0.05	0.71	0.62	6.9
Nitrate (NO_3^-)	mg/L	< 0.18	<0.18	< 0.18	3.49
Nitrite (NO_2^-)	mg/L	< 0.01	<0.01	0.01	<0,01
Total Phosphorus*	mg/L	0.25	1.9	5.0	2.3
Orthophosphate	mg/L	< 0.08	0.99	0.56	0.81
E. coli	Cfu/100ml	340	> 2000	420	510
Faecal coliforms	Cfu/100ml	390	> 2000	> 2000	> 2000

*Total Phosphorus Eutrophication Categories: Oligotrophic (< 0.015); Mesotrophic (0.015-0.047); Eutrophic (0.047-0.13); Hypertrophic (> 0.130)

Water quality results presented in Table 2 provide an indication of the level of nutrients, wastewater, and sediment flowing through the system. The reference stream provides a comparison site with relatively fewer impacts anticipated due to minimal development in its catchment. Any impacts to the reference stream would likely originate from a single stream inflowing from the Sparrabosch area (Pezula Golf Estate; Figure 6) and a small part of Hunters Home, as all other streams flow through mostly natural areas. The following conclusions are made from a review of the water quality data:

- Total Phosphorus (TP) values place every sample point in the hypertrophic category on the scales of eutrophication (nutrient enrichment) using this metric (See footnote in Table 2). This is the highest level of enrichment likely to cause nuisance growth of algae or aquatic plants. While values in the Bigai wetland are orders of magnitude higher than those in the reference stream, the fact that TP is so high even in the reference stream indicates that urban development throughout the catchment negatively impacts water quality and is not being managed to preserve aquatic ecosystem health.
- Counts of *E. coli* and faecal coliforms give a good idea of the levels of pollution originating from sewage-wastewater as *E. coli* bacteria occurs in the guts of vertebrate animals (including humans) and can therefore only originate from faecal origin. Bacteria counts were highest in the Bigai wetland, particularly at the upstream site, which may have been related to a sewage spill observed on the same day as sampling (Figure 10). Although it is difficult to determine the degree to which that water would have dispersed through the system at the time of sampling. Again, the presence of *E. coli* in the reference stream indicate small amounts of leaking sewage somewhere in the catchment.
- The pattern of Nitrogen distribution through the wetland indicates high inputs of Total Nitrogen (including Organic N) in the upper reaches of the Bigai Wetland. The decrease in Total N and relative increase in Total Inorganic N either indicates a fresh input of N-enriched water upstream, or nutrient spiralling downstream due to nitrification.
- Suspended solids are an indicator of the amount of suspended (mobile) sediment in the water. None of the values were very high, which is to be expected because water flows very slowly through the system, providing opportunity for all the sediment to settle out in the wetland.

Nutrients and faecal bacterial counts in the Bigai Wetland system are unacceptably high from the perspective of aquatic ecosystem health and human health. Particularly as many workers need to wade bare-legged through the water on flooded roads. *E. coli* is a useful indicator organism of water polluted by sewage, but many other pathogenic (disease-forming) bacteria and viruses occur in water polluted by sewage.

3.3 Present Ecological State (PES)

The extent of the Bigai Wetland assessed in this report is indicated in Figure 2. This section of the wetland is classified as an Unchannelled Valley Bottom Wetland according to Ollis *et al.* (2013). No channels have formed within the wetland despite high volumes of stormwater inflow (Figure 13).

Figure 13. Drone image of the Bigai Wetland looking north-east with the 9th hole of the golf course to the left, and Kennet Street to the right.

3.3.1 PES Methods

The wetland PES was assessed using the Level 1 WET-Health assessment tool developed by Macfarlane *et al*. (2008). The tool aims to assess the integrity of a wetland which is defined as a measure of the deviation of wetland structure and function from the wetland's natural reference condition. The method combines an assessment of hydrological, geomorphological and vegetation health in three modules.

Data collection involved a review of information from the desktop and field assessments considering the extent and intensity of catchment land use impacts, and was undertaken using historical and recent aerial imagery of the site (Chief Directorate: National Geo-spatial Information and satellites). Fieldwork onsite involved the identification and recording of observable impacts to the wetland at the site of relevant activities as well as at reference points upstream and downstream of the activities. The magnitude of observed impacts to the hydrological, geomorphological and vegetation components of the wetland were calculated and combined as per the tool to provide a measure of the overall wetland condition of the wetland. The condition ranges in scale from 1-10 and resultant scores were then used to assign the wetland into one of six PES categories as shown in Table 3.

Table 3. Wetland Present Ecological State categories and impact descriptions.

Ecological Category	Description	Impact Score
A	Unmodified, natural.	0 – 0.9
B	Largely natural with few modifications / in good health. A small change in natural habitats and biota may have taken place but the ecosystem functions are still predominantly unchanged.	1 – 1.9
C	Moderately modified / fair condition. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	2 – 3.9
D	Largely modified / poor condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	4 – 5.9
E	Seriously modified / very poor condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.	6 – 7.9
F	Critically modified / totally transformed. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota.	8 - 10

3.3.2 PES Results

The results of the each of the three modules for WET-Health yielded a score of ‘D’ which ultimately classed the Bigai Wetland in a category **D/E** which is **Largely to Seriously Modified.** The main impacts contributing to the declined state of the wetland are listed below:

- Wetland habitat loss due to construction of the 9th hole at the golf course.
- Loss of hydrological area due to construction of the 9th hole and the flood berm at the golf course.
- Large increase in runoff from the catchment increasing flood peaks and base flows.
- Increase in sedimentation through substantial areas of the wetland.
- Change in dominance of plants to alien species in some areas, and *Phragmites australis* and *Typha capensis* reeds across most of the wetland.

3.4 Ecological Importance and Sensitivity (EIS)

3.4.1 EIS Methods

The revised method for the determination of the EIS of a wetland considers the three following ecological aspects (Rountree *et al*., 2013):

- **Ecological importance and sensitivity**
  - Biodiversity support including rare species and feeding/breeding/migration;
  - Protection status, size and rarity in the landscape context;
  - Sensitivity of the wetland to floods, droughts and water quality fluctuations.
- **Hydro-functional importance**
  - Flood attenuation;
  - Streamflow regulation;
  - Water quality enhance through sediment trapping and nutrient assimilation;
  - Carbon storage

- **Direct human benefits**
    - Water for human use and harvestable resources;
    - Cultivated foods;
    - Cultural heritage;
    - Tourism, recreation, education and research.

Each criterion is scored between 0 and 4, and the average of each subset of scores is used to derive a score for each of the three components listed above. The highest score is used to determine the overall Importance and Sensitivity category of the wetland system (Table 4).

Table 4.Ecological importance and sensitivity categories for wetlands. Interpretation of average scores for biotic and habitat determinants.

Ecological Importance and Sensitivity Category (EIS)	Range of Median	Recommended Ecological Management Class
Very high: Wetlands that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these floodplains is usually very sensitive to flow and habitat modifications. They play a major role in moderating the quantity and quality of water of major rivers.	>3 and <=4	A
High: Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these floodplains may be sensitive to flow and habitat modifications. They play a role in moderating the quantity and quality of water of major rivers.	>2 and <=3	B
Moderate: Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these floodplains is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of water of major rivers.	>1 and <=2	C
Low/marginal: Wetlands that are not ecologically important and sensitive at any scale. The biodiversity of these floodplains is ubiquitous and not sensitive to flow and habitat modifications. They play an insignificant role in moderating the quantity and quality of water of major rivers.	>0 and <=1	D

3.4.2 EIS Results

While no Red Data or unique species were observed during several field trips, it is not impossible that birds such as the Knysna Warbler could occur in the wetland. However, the presence of special species would only marginally alter the EIS which for the Bigai Wetland was classified as **High** (Table 5).

Table 5. Ecological Importance and Sensitivity for the Bigai Wetland.

Ecological importance and sensitivity	Score 0-4	Confidence 1-5	Motivation
Biodiversity support	**1.3**		
Presence of Red Data species	0	2	None recorded and none expected
Populations of unique species	0	2	None recorded or observed
Migration/feeding/breeding sites	4	5	Used extensively by a range of birds and small to medium sized mammals.
Landscape scale	**2.8**		
Protection status of wetland	3	4	Partly included in the Protected Area
Protection status of vegetation type	4	4	Critically Endangered
Regional context of the ecological integrity	2	4	There are similar wetlands in better condition, but not many
Size and rarity of the wetland types present	3	4	Relatively large wetland for a UVB
Diversity of habitat types	2	4	Marginal diversity as eutrophication and sedimentation have homogenised the environment.
Sensitivity of the wetland			
Sensitivity to changes in floods	2	3	Predominantly increased floods.
Sensitivity to changes in low flows	2	4	Vegetation die-back could occur
Sensitivity to changes in water quality	2	4	Change to an altered state of vegetation with different species dominant.
Hydrofunctional Importance	**2.3**		
Direct human benefits	**0.8**		
ECOLOGICAL IMPORTANCE AND SENSITIVITY	**2.8**	**HIGH**	

4. MAINTENANCE ACTION PLAN

During each of the site visits, every culvert meant to drain the area of high flowing water through the Bigai wetland or surrounding areas was inspected to assess the level of blockage and free flow. Most culverts were completely blocked with silt and vegetation.

Photos of infrastructure and points where maintenance is required are presented in Table 9. The coordinates of each site are indicated and correspond with points indicated in Figure 2. Most culverts could be located, but some are well hidden by dense vegetation which will require clearing to access and maintain. Many culverts were completely blocked with reeds and silt and had standing water in them.

4.1 Timing of Maintenance Works

If possible, maintenance actions should take place during cooler winter months (April to August) as this is when most animals are not breeding. This may not be possible given the urgency of the required maintenance and unknown timeframes for approval of the authorisation. Work should not be undertaken when rainfall is predicted, during rainfall, or immediately post-rainfall. At least a day following significant rainfall events should be waited until work commences again.

4.2 Order of Maintenance Works

All maintenance work described in this MMP is to take place in the direction from upstream to downstream. This is to protect the Knysna Estuary, and therefore the culverts along George Rex Drive should be scheduled for clearance last. It is recommended that a silt fence be erected at the outlet of each of the culverts along George Rex Drive and remain in place until at least one significant rainfall has 'flushed' through with improved drainage. Detailed methods for the installation of silt fences are provided in Section 4.5.

4.3 Clearance of Culverts

In all cases where culverts must be cleared, the standard area for clearance should be to expose the full area of concrete (width x height) with an additional 1 m on either side, and 2 m beyond into either wetland or estuarine habitat, maintaining the same depth. Excavations are mostly recommended by hand, but a small excavator working from the road surface may be used for larger culverts where stipulated (Table 9). Immediately following the clearance of all culverts on George Rex Drive, a silt fence must be constructed around the edge of the excavated area to reduce the impact of sedimentation in the estuary. Detailed methods for the construction of silt fences is provided in Section 4.5.

4.4 Excavation of Drainage Channel

The drainage channel on the golf course parallel to the Bigai River is completely overgrown with vegetation which limits the function of this channel in conveyance of flows. Methods are provided in Table 9 for the excavation of accumulated silt and vegetation. Recommendations are made for the disposal of silt on site in the golf course. The golf course uses such silt for landscaping features along fairways, but the silt may not be used in any water features on the golf course.

Vegetation removal should aim to remove all alien plants growing in the channel, and where possible, retain indigenous wetland plants along the banks of the channel. Small wetland plants growing along in the channel itself are beneficial for water quality in terms of sediment trapping and nutrient removal. Where possible, indigenous wetland plants disturbed by excavations should be replanted.

4.5 Vegetation Management

4.5.1 Alien Invasive Plants

A list of commonly encountered alien vegetation throughout the Bigai Wetland area has been provided in Table 1. Adjacent to the drainage channel on the 9th hole the flood protection berm is covered by extensive establishment of alien vegetation (mainly *Acacia mearnsii* and *Acacia* *melanoxylon*), which should be cleared and managed on an ongoing basis through follow up clearing. Manage large alien trees (mainly black wattle) growing along the top of the flood protection berm. These trees are prone to falling over, taking out large pieces of the berm with them. Removal of the trees is not only a legal requirement of the landowner (Knysna Municipality) but will prolong the life of the berm. Trees should be cut and the stumps treated with a registered herbicide (gel type is good as it does not dribble or spread easily). Woody material must not be discarded into the Bigai River or into the artificial drainage channel.

Figure 14. An example of extensive stands of alien vegetation in the drainage channel (*Canna indica*) and above on the flood berm (*Acacia mearnsii*) at the golf course.

Wherever alien plants listed in Table 1 are encountered during maintenance operations in this MMP, these plants must be physically removed or controlled using recognised best practice methods. However, herbicides may be used within wetland areas due to high risk of impacting aquatic life. Ring barking is a good alternative for larger trees in wetland areas.

Table 6. List of declared weeds and invaders recorded in the Bigai Wetland and along the artificial channel and berm at the golf course.

Species Name	Common Name	Growth Form	NEMBA Category
Acacia mearnsii	Black wattle	Tree	2
Acacia melanoxylon	Australian blackwood	Tree	2
Canna indica	Garden canna lily	Shrub	1b
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
Pennisetum purpureum	Elephant Grass	Very tall grass	2
Ricinis communis	Castor Oil Plant	Small tree	2

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 7. NEMBA categories for invasive alien plants.

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.**

4.5.2 Revegetation with Indigenous Plants

Two areas where revegetation may be required would be the flood protection berm at the golf course, and to a lesser degree the drainage channel at the golf course. It is anticipated that most of the wetland plants disturbed during excavation of the drainage channel would rapidly re-establish, but it is worthwhile indicating which are the indigenous species to preserve, an potentially saving these for replanting along the banks of the channel where possible. The aim is to reduce open, disturbed areas of soil which can be rapidly colonised by aliens, and erosion of the soil berm.

Given that *Phragmites australis* (Fluitjiesriet) and *Typha capensis* (Bullrushes) are already abundant at the site, plant rescue efforts should focus on other wetland plant groups such as sedges, rushes and restios, examples are indicated in Figure 15.

Figure 15. Examples of indigenous wetland plants found in the Bigai Wetland that can be rescued and replanted in disturbed areas along the golf course channel.

Revegetation of the berm is likely to be more difficult as the quality of soil is unknown, and the gradient of the slopes is high. As a first step, indigenous grass should be planted, consisting of a mix of *Cynodon dactylon* (kweek) and *Stenotaphrum secondatum* (Buffalo grass) as this will provide a rapid cover and stabilise slopes. It is recommended that no trees be planted on the berm, only large shrubs, as these provide stability without taking half the berm with them if they fall over. A list of recommended plant species which are indigenous to the area, obtainable from nurseries, and that occur in the local fynbos vegetation is presented in Table 8. The plants listed may not always be attainable, and therefore alternative species can be sought from local nurseries or landscapers provided the species occur naturally in the Knysna basin.

Table 8. Indigenous plant species recommended for revegetation of the flood berm at Knysna golf course.

Species Name	Common Name	Growth Form
Aristea capitata	Blousuurkanol	Small tufted Shrub
Aristida junciformis	Ngoningoni three-awn	Large tufted grass
Chlorophytum comosum	Hen and chickens	Small tufted shrub
Euryops virgineus	Rivierharpuisbos	Medium Shrub
Helichrysum cymosum	Strawflower	Small Shrub
Helichrysum petiolare	Licorice plant	Small Shrub
Metalasia densa	Blombos	Medium Shrub
Passerina corymbosa	Gonna	Medium Shrub
Psoralea affinis	Blue bells bush / Fountain bush	Large Shrub
Selago corymbosa	Bitter bush	Shrublet

4.6 Maintenance Action Plan

The action plan for each site where maintenance is required is presented in Table 9. This table must be fully explained to workers and contractors who would undertake the stipulated maintenance actions. The table must be read in conjunction with all preceding information in Section 4.

Table 9. Locations and pictures of infrastructure where maintenance is required. Numbered locations refer to Figure 2.

No.	Location	Photo	GPS Coordinate	Description	Maintenance Actions
1	Kennet Street Street Parcel RE/2090		34° 3'32.50"S, 23° 4'50.66"E	Culvert. Water pushing up (observable flow) through the road surface	• Investigate presence of culvert either side of the road. • If present, the culvert must be cleared by hand of vegetation, sediment & litter. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.
2	Howard Street 2 culverts up and downstream 10m and 4m in length Street Parcel RE/2090		4 m culvert: 34° 3'31.13"S, 23° 4'49.43"E & 10m culvert: 34° 3'30.68"S, 23° 4'48.46"E	Culverts completely covered by vegetation and silt up and downstream of the road crossing.	• Vegetation and sediment must be cleared by hand or using a small excavator positioned on the road. • Area of clearance is along the length of each culvert plus a meter either side (12m and 6m respectively), to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.

3	Howard Street Street Parcel RE/2090		34° 3'32.28"S, 23° 4'52.47"E	2 m culvert blocked by vegetation and silt on both sides of the road.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.
4	Howard Street Street Parcel RE/2090		34° 3'31.59"S, 23° 5'7.39"E	Possible culvert blockage. Water standing on surface and draining onto road. Vegetation growing on road.	• Investigate presence of culvert either side of the road. • If present, the culvert must be cleared by hand of vegetation, sediment & litter. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.
5	Howard Street Street Parcel RE/2090		34° 3'29.99"S, 23° 5'14.82"E	Culvert sides breaking apart. Require repairs. Culvert partially blocked with silt further down.	• Not in a watercourse but needs repair work as the cement sides are breaking apart and siltation has occurred in the pipe. • Silt must be cleared out the pipe.

6	62 Howard Street Street Parcel RE/2090		34° 3'29.60"S, 23° 5'12.58"E	Culvert beneath driveway requires vegetation and silt clearance	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland.
7	Thesen Street Street Parcel RE/2090		34° 3'29.32"S 23° 5'4.79"E	2 m culvert blocked with vegetation and silt which must be removed.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.
8	Thesen Street Street Parcel RE/2090		34° 3'27.01"S, 23° 4'48.45"E	1 m Culvert is silted up and not draining beneath the road and into the wetland opposite. Both culvert sides to be cleared of silt and vegetation.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.

9	Thesen Street Street Parcel RE/2090		34° 3'27.89"S, 23° 4'44.54"E	2 m culvert is silted up and full of vegetation which must be cleared to restore flow conveyance.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.
10	George Rex Drive Street Parcel RE/2090		34° 3'12.94"S, 23° 4'11.06"E	Culvert must be checked for flow conveyance. The invert level may be too high and require lowering. Silt and vegetation must be cleared if necessary.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features. • As soon as the culvert is cleared, a silt fence must be installed on the estuary side of the culvert to prevent excessive siltation from entering the estuary.
11	George Rex Drive Street Parcel RE/2090		34° 3'20.34"S, 23° 4'10.73"E	Culvert recently upgraded and functioning well. May require periodic clearance of silt and vegetation reducing conveyance.	• If flows are blocked in either direction it is necessary to clear vegetation, silt and litter from the culvert by hand. • Area of clearance is aligned with the gabions, plus a metre either side, to the depth of the gabions and 2 m into the wetland / estuary. • Sediment may be used by the golf course for landscaping including water features. • As soon as the culvert is cleared, a silt fence must be installed on the estuary side of the culvert to prevent excessive siltation from entering the estuary.

12	George Rex Drive Street Parcel RE/2090		34° 3'30.62"S, 23° 4'10.14"E	Culvert currently blocked and requires periodic clearance of vegetation and silt.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland/estuary. • Sediment may be used by the golf course for landscaping excluding water features. • As soon as the culvert is cleared, a silt fence must be installed on the estuary side of the culvert to prevent excessive siltation from entering the estuary.
13	George Rex Drive Street Parcel RE/2090		34° 3'11.37"S 23° 4'11.40"E	Culvert pictured when it was last cleared in 2015, it is now blocked and needs to be cleared of silt again. Visible pipes are fibre cables and a water pipe.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland/estuary. • Sediment may be used by the golf course for landscaping excluding water features. • As soon as the culvert is cleared, a silt fence must be installed on the estuary side of the culvert to prevent excessive siltation from entering the estuary.

14	Golf course 9th hole drainage channel (artificial) Erf 2233		900 m length from: 34° 3'33.03"S, 23° 4'44.66"E To 34° 3'35.83"S, 23° 4'11.96"E	Historical artificial channel that drains water off the 9th hole has silted up and requires sediment and vegetation removal.	• Check the weather forecast and plan work for a dry spell lasting at least a week. • Excavate silt and vegetation in the direction from upstream to downstream. • Clearance can be by hand and/or a small excavator positioned on the adjacent fairway. • Clear silt and vegetation from the channel, measuring 2 m wide and 50-80 cm deep. • Ensure the channel is graded in a gentle slope in a downstream direction. • Clear 100m per week over 5 weeks. In this manner disturbance to wildlife will be minimised. • Alien plants should be removed during this process and include Canna lilies (*Canna indica).* • Cleared sediment can be used for landscaping outside of water features by the golf course. • Ensure excavator has no leaks and is in good working order. • All workers must dispose of litter or waste in bins and must not damage or pollute the drainage channel.

14	Golf course flood protection berm between 9th hole and Bigai Wetland Erf 2233		500 m length from 34° 3'33.03"S, 23° 4'44.66"E To 34° 3'39.76"S, 23° 4'27.74"E	Historical soil berm built to reduce flooding on golf course. Has numerous black wattles which must be removed.	• Large black wattles (*Acacia mearnsii*) and Blackwood (*Acacia melanoxylon*) must be cut down and the stumps painted with gel-type herbicide registered for use, not a foliar spray. • Smaller trees can be hand-pulled or removed including roots using a Tree Popper. • Remove all cut biomass from the site and dispose of it at an appropriate green waste site. No material must be discarded in the Bigai Wetland or the drainage channel on either side of the berm. • Aim to achieve a minimum of 80% vegetation cover on the berm.
16	Knysna Golf Course adjacent to George Rex Drive, this channel is adjacent to the above culvert. Erf 2232		34° 3'29.76"S 23° 4'11.43"E	A small embankment of sand and vegetation cuts off the internal from the external channel. A notch (yellow) of approximately 4m³ needs to be excavated to improve flow.	• Dig out a section of 4 m³ of sediment in the embankment to improve through-flow between the drainage channel and the culvert leading to the estuary. • Digging must be done by hand. • Sediment can be used for landscaping in the golf course outside of water features.

confluent

17	Kennet Street Street Parcel RE/2090		34° 3'38.45"S, 23° 4'38.68"E	1 m culvert blocked with silt which must be excavated until the bottom later of concrete has been reached on both sides.	• Vegetation and sediment must be cleared by hand. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, and 2 m into the wetland downstream. • Sediment may be used by the golf course for landscaping excluding water features.
18	Howard Street Street Parcel RE/2090		34° 3'24.40"S, 23° 4'35.94"E	1 m culvert leading to the golf course needs to be cleared of silt and vegetation on both sides of the road.	• Vegetation and sediment can be cleared by hand or using a small excavator working from the road. • Area of clearance is along the length of each culvert plus a metre either side, to the depth of the concrete, clearing can follow the channel as long as necessary to reach the drainage channel on the golf course perimeter. • Cleared sediment may be used by the golf course for landscaping excluding water features.
19	Wilson Street Street Parcel RE/2090		34° 3'42.07"S, 23° 4'32.60"E	12m length Culvert under Wilson Street blocked with sediment and vegetation restricting flow.	• Vegetation and sediment must be cleared by hand or using a small excavator positioned on the road. • Area of clearance is along the length of each culvert plus a meter either side (14m), to the depth of the concrete, and 2 m into the wetland. • Sediment may be used by the golf course for landscaping excluding water features.

20	Wilson Street Street Parcel RE/2090		34° 3'41.41"S, 23° 4'30.51"E	Culvert beneath Wilson street blocked with silt and vegetation restricting water flows.	• Vegetation and sediment must be cleared by hand or using a small excavator positioned on the road. • Area of clearance is along the length of each culvert plus a meter either side (14m), to the depth of the concrete, and 2 m into the wetland. Sediment may be used by the golf course for landscaping excluding water features.

4.7 Construction of Silt Fences

Sediment traps and silt fences are designed to filter flowing water to the degree that pooling occurs upstream of the trap, allowing coarser-grained particles to settle out. Silt fences should be constructed using the following guidelines and referring to the images below:

- Use 80% shade-cloth;
- Support posts should be strong wooden stakes (not metal as this gets stolen) placed 1m apart;
- Top wire must be attached to the shade cloth;
- Posts must be installed on the downstream side of the shade-cloth;
- Shade-cloth must be buried into the downstream channel up to 20cm deep,
- Silt fences must be approximately 50 cm high;
- Wherever possible, single sheets of shade-cloth must be used without joins in material;
- Sediment build-up in the silt fence should be monitored following rainfall, and accumulated silt must be removed from the system.
- Once siltation has reduced following rainfall, the fence must be carefully removed.

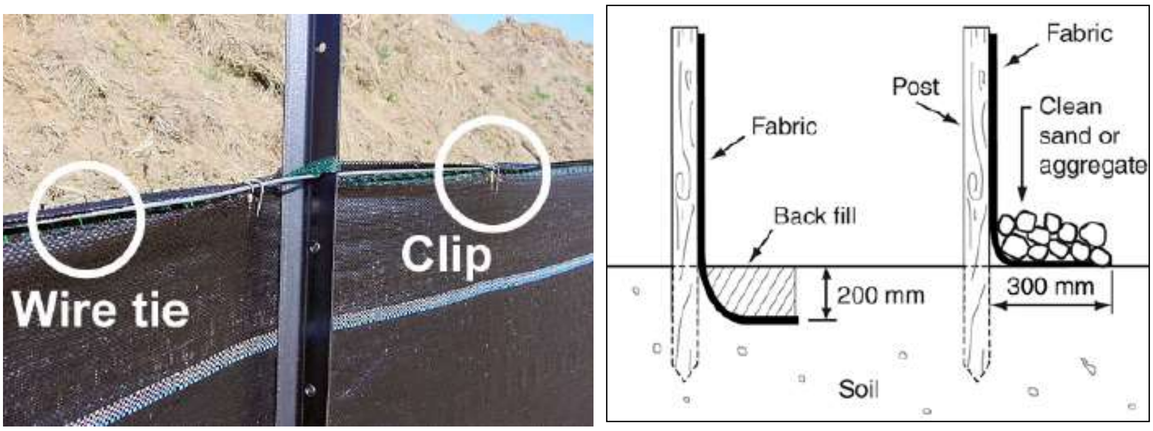

Figure 16. Instructions for installing a silt fence.

5. MONITORING ACTIONS

Short-term and long-term monitoring of the impacts of maintenance, along with indicators of when maintenance should happen again have been recommended.

5.1 Short-term monitoring

- Once maintenance work on George Rex Drive culverts has concluded, sediment controls (silt fences) must be checked after 2-3 days to ensure they are stable, and have not been stolen or vandalised;
- Silt fences must be checked on a regular basis following rainfall events to ensure they are intact. Accumulated silt should be removed from the silt fence. As long as they keep accumulating silt after rainfall they can be kept in place. Once fresh silt is no longer observed in silt fences following rainfall, they should be removed.
- ECO must be appointed to oversee the removal of vegetation/excavation/moving of material from the blocked culverts/stormwater channels and report on the compliance with the MMP to the DFFE on a monthly basis.

5.2 Long-term monitoring

- During and immediately following significant rainfall events, all culverts and channels identified in this MMP should be inspected by the Municipality to determine whether their function has been improved. Photos at each point must be taken as evidence of the level of drainage and function. This photographic record must be actively maintained by the Knysna Municipality Environmental Section.
- The flood protection berm along the 9th hole at the golf course must be monitored every 6 months for the ongoing management of alien vegetation. Once initial clearing has occurred, it is likely that numerous opportunistic alien plants will rapidly establish, making follow up clearance essential.
- Where culverts or channels may require renewed clearance to maintain their function, photos must be taken to show accumulation of silt or vegetation, and maintenance can proceed along the same parameters as described in this MMP.
- Areas where flooding is ongoing despite the actions taken in this MMP need to be documented and flagged, as alternative drainage or maintenance methods will be necessary and would form the subject of a Basic Assessment process in terms of NEMA.

6. RISK MATRIX

Methods used to complete the risk matrix are explained in Appendix 1 of this report. The assessment considers the risks in their mitigated state, and it is therefore imperative that measures to mitigate impacts are fully implemented for the level of risk to apply.

The outcome of the Risk Matrix was a Low Risk to the Bigai Wetland (Table 10). Impacts are mainly associated with risks to water quality and biota through the physical process of excavating sediment and vegetation. This activity is concentrated in a small area associated with each culvert, and where it occurs over a longer distance in the golf course drainage channel, the habitat is artificial and, in many areas, invaded by alien plants. Nonetheless, mitigation / control measures have been made to minimise and avoid impacts as far as possible. Based on the Low Risk outcome, a General Authorisation can be obtained for this MMP.

Table 10. Risk Matrix compiled for Maintenance Management Plan for the Bigai Wetland.

Phases	Activity	Aspect	Impact	Flow Regime	Water Quality	Habitat	Biota	Severity	Spatial scale	Duration	Consequence	Frequency of activity	Frequency of impact	Legal Issues	Detection	Likelihood	Significance	Risk Rating	Confidence level	Control Measures	PES AND EIS OF WATERCOURSE
	Excavation of sediment and vegetation upstreama and downstream of culverts	Siltation Downstream	Reduced water quality and downstream siltation	0	1	1	0	0,5	1	1	2,5	1	1	5	3	10	25	Low	70	- Standardised area of clearance for all culverts is depth to concrete base, width of concrete plus 1m, and 2 m extended into the wetland. This will minimise the area of impact. - Excavations to be undertaken using spades and hand tools unless specified at much larger culverts where a small excavator is more practical. - Clearing of culverts to move from upstream to downstream thus reducing repeated impacts on the same area. - For all culverts on George Rex Drive downstream culverts must be protected by a silt fence until siltation has ceased and they can be removed.	
		People working with tools and light machinery in wetland habitat	Wildlife mortalities, injury and disturbance	0	0	1	2	0,75	1	1	2,75	1	1	5	3	10	27,5	Low	70	-Work to be undetaken during cooler winter months if feasible to avoid the breeding season. - Standardised area of clearance for all culverts is depth to concrete base, width of concrete plus 1m, and 2 m extended into the wetland. This will minimise the area of impact.	

Operational Phase: Maintenance	Excavation of sediment and vegetation from the artificial channel in the golf course	People working with tools, light machinery and a small excavator in artificial wetland habitat	Wildlife mortalities, injury and disturbance	0	0	1	2	0,75	1	1	2,75	1	1	1	4	7	19,3	Low	80	• Excavations mut be by hand or a small excavator where practical. The excavator must be positioned on the golf fairway and not in the channel itself. • Only clear 100m per week for 5 weeks to reduce the impact to wildlife such as birds, frogs and small mammals.	PES: D/E EIS: High
			Siltation and water quality impacts	0	1	1	1	0,75	1	1	2,75	1	2	1	3	7	19,3	Low	70	• Check the weather forecast and plan work for a dry spell lasting at least a week. • Excavation should progress in the direction of upstream to downstream to avoid doubling up on impacts. • Keep to the prescribed dimensions of the channel which is up to 2 m wide and between 50-80 cm deep.	
	Clearance of alien vegetation from the flood berm	Disturbance to vegetation and soil on the berm due to alien vegetationm management	Habitat degradation or water quality impacts to the Bigai Weland	0	0	1	1	0,5	1	2	3,5	1	1	5	2	9	31,5	Low	70	• Cut biomass must be removed from the berm and must not be discarded into the Bigai Wetland or into the drainage channel. • Herbicide cannot be used anywhere along the wetland, but large trees (black wattles) can be cut and their stumps painted with a gel-type herbicide which doesn not disperse easily. • Aim for a minimum of 80% vegetation cover.	

7. CONCLUSIONS

In many ways the work proposed in this MMP is very basic and routine, simply involving the clearance of silt and vegetation from existing culverts and a man-made channel. It is not certain that flooding in the highlighted areas will be completely alleviated as a result of these actions, but it may be reduced. It is also acknowledged that this is the most work that can be achieved under a Maintenance Management Plan. Any additional work proposed to further alleviate flooding would need to be authorised to a further extent in terms of NEMA and the NWA.

This represents a precautionary approach to the environment, with an emphasis on monitoring the effects of simply undertaking routine maintenance of existing structures as a start.

Implementation of this MMP is not likely to result in major impacts to the Bigai Wetland or Knysna Estuary provided all mitigation measures are fully implemented.

Given the Low Risk outcome of the Risk Matrix, a General Authorisation would be applicable in terms of GN509 of the National Water Act.

8. REFERENCES

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9. APPENDIX

9.1 Risk Matrix Methods

The risk assessment matrix (Based on DWS 2016 publication: Section 21 c) and i) water use Risk Assessment Protocol) was implemented to assess risks for each activity associated with the construction and operational phase.

The first stage of the risk assessment is the identification of environmental activities, aspects and impacts. This is supported by the identification of receptors and resources, which allows for an understanding of the impact pathway and an assessment of the sensitivity to change. The definitions used in the impact assessment are as follows:

- An activity is a distinct process or task undertaken by an organisation for which a responsibility can be assigned. Activities also include facilities or infrastructure that is possessed by an organisation.
- An aspect is an 'element of an organizations activities, products and services which can interact with the environment'. The interaction of an aspect with the environment may result in an impact.
- Environmental impacts are the consequences of these aspects on environmental resources or receptors of particular value or sensitivity.
- Resources are components of the biophysical environment and include the flow regime, water quality, habitat and biota of the affected watercourse.

- Severity refers to the degree of change to the status of each of the receptor. An overall severity score is calculated as the average of all scores receptor status in terms of the reversibility of the impact; sensitivity of receptor to stressor; duration of impact (increasing or decreasing with time); controversy potential and precedent setting; threat to environmental and health standards.
- Spatial extent refers to the geographical scale of the impact (Table 12)
- Duration refers to the length of time over which the stressor will cause a change in the resource or receptor (Table 13)
- Frequency of activity refers to how often the proposed activity will take place (Table 14)
- Frequency of impact refers to the frequency with which a stressor (aspect) will impact on the resource (Table 15).

The significance of the impact is then assessed by rating each variable numerically according to the defined criteria (refer to the table below). The purpose of the rating is to develop a clear understanding of influences and processes associated with each impact. The severity, spatial scope and duration of the impact together comprise the consequence of the impact and when summed can obtain a maximum value of 15. The frequency of the activity, impact, legal issues and the detection of the impact together comprise the likelihood of the impact occurring and can obtain a maximum value of 20. The values for likelihood and consequence of the impact are then read off a significance rating matrix and are used to determine whether mitigation is necessary.

In accordance with the method stipulated in the risk assessment key, all impacts for flow regime, water quality, habitat and biota were scored as a 5 (i.e. average Severity score of 5) as all activities occurred within the delineated boundary of the wetland.

Table 11: Scores used to rate the impact of the aspect on resource quality (flow regime, water quality, geomorphology, biota and habitat)

Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful and/or wetland(s) involved	5
Where "or wetland(s) are involved" it means that the activity is located within the delineated boundary of any wetland.	

Table 12: Scores used to rate the spatial scale that the aspect is impacting on.

Area specific (at impact site)	1
Whole site (entire surface right)	2
Regional / neighbouring areas (downstream within quaternary catchment)	3
National (impacting beyond secondary catchment or provinces)	4
Global (impacting beyond SA boundary)	5

Table 13: Scores used to rate the duration of the aspects impact on resource quality

One day to one month, PES, EIS and/or REC not impacted	1
One month to one year, PES, EIS and/or REC impacted but no change in status	2
One year to 10 years, PES, EIS and/or REC impacted to a lower status but can be improved over this period through mitigation	3
Life of the activity, PES, EIS and/or REC permanently lowered	4
More than life of the organisation/facility, PES and EIS scores, a E or F	5

Table 14: Scores used to rate the frequency of the activity

Annually or less	1
Bi-annually	2
Monthly	3
Weekly	4
Daily	5

Table 15: Scores used to rate the frequency of the activity's impact on resource quality

Almost never / almost impossible / >20%	1
Very seldom / highly unlikely / >40%	2
Infrequent / unlikely / seldom / >60%	3
Often / regularly / likely / possible / >80%	4
Daily / highly likely / definitely / >100%	5

Table 16: Scores used to rate the extent to which the activity is governed by legislation

No legislation	1
Fully covered by legislation (wetlands are legally governed)	5

Table 17: Scores used to rate the ability to identify and react to impacts of the activity on resource quality, people and property.

Immediately	1
Without much effort	2
Need some effort	3
Remote and difficult to observe	4
Covered	5

Table 18: Rating classes

RATING	CLASS	MANAGEMENT DESCRIPTION
1 – 55	(L) Low Risk	Acceptable as is or consider requirement for mitigation. Impact to watercourses and resource quality small and easily mitigated.
56 – 169	(M) Moderate Risk	Risk and impact on watercourses are notable and require mitigation measures on a higher level, which costs more and require specialist input. Licence required.
170 – 300	(H) High Risk	Watercourse(s) impacts by the activity are such that they impose a long-term threat on a large scale and lowering of the Reserve. Licence required.

Table 19: Calculations used to determine the risk of the activity to water resource quality

Consequence = Severity + Spatial Scale + Duration
Likelihood = Frequency of Activity + Frequency of Incident + Legal Issues + Detection
Significance\Risk = Consequence x Likelihood