Ecological Health Assessment of the Onrus Estuary

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EXECUTIVE SUMMARY

Background

The Onrus Estuary, located in the Western Cape Province, is included as one of the 290 "functional estuaries" in the country, and is one of 28 such systems in the cool temperate biogeographic region, and one of eight estuaries in this region to be classified as a small temporarily closed system. The Onrus is a very small estuarine lagoon with a relatively small floodplain and covers in total approximately 15 ha. The Mean Annual Runoff (MAR) reaching Onrus Lagoon has been significantly reduced by water use in the catchment, mainly for agricultural activity, and the construction of the De Bos Dam in 1976. This dam constitutes the primary freshwater resource supplying potable water to the Overstrand region.

The most recent National Biodiversity Assessment (NBA) (2019) rated the condition or Present Ecological State (PES) of the Onrus Estuary as a "D" or "Heavily Modified". This was based on findings of an Ecological Health Assessment that was completed for the Onrus Estuary as part of the process of determining the freshwater reserve for all significant water resources in the Breede-Gouritz Water Management Area in 2017.

The Onrus Estuary has recently been severely negatively affected by a 1:100 year flood that occurred in the Onrus catchment in September 2023. This flood resulted in an enormous quantity of sediment being deposited in the estuary which has fundamentally altered hydrodynamic and ecological functioning of the system. This flood event prompted this re-evaluation of ecological health of the Onrus Estuary, completed in 2024, following protocols laid down by Turpie et al. (2012) in the Estuary Health Index Manual. The assessment was undertaken under the auspices of the Onrus Catchment to Coast (C2C) Rehabilitation and Restoration programme. The C2C programme was originally launched by the Overstrand Municipality, together with other landowners, water resource users, government organizations and Environmental NGO's in 2024 and forms part of the Overstrand Municipality's 2022-2027 Integrated Development Plan (IDP). The objective of the plan is to adopt a holistic approach to watershed management. By rehabilitating the entire catchment corridor, the aim is to safeguard water resources, prevent land degradation, preserve biodiversity, and mitigate the effects of climate change to ensure the long-term resilience and sustainability of its people and nature.

Abiotic health

Hydrology

Simulated freshwater flow sequences for the Onrus Estuary were generated for natural and present-day conditions (land use, water use etc.) using the Water Resources Simulation Model 2000 (WRSM 2000) (Pitman) rainfall-runoff model during classification of significant water resources in the Breede-Gouritz Water Management Area in 2017 (DWS 2017). These data were also used in this health assessment as we do not believe there have been any significant or material changes in the hydrology since the previous assessment was undertaken.

Analysis of these data suggest that there has been a significant change in mean annual runoff (MAR) between Reference (9.17 Mm^3/a) and Present (4.75 Mm^3/a) (51.8% reduction in MAR) mostly linked with agricultural use of water in the catchment and water use from the municipal De Bos Dam, which was built in 1976 approximately 9 km upstream of the estuary mouth. This dam constitutes the primary freshwater resource supplying potable water to the Overstrand region and has a storage capacity of 6 Mm^3 with an annual supply capacity of approximately 3.3 Mm^3. The Municipality has been allocated 2.8 Mm^3 with an additional 0.47 Mm^3 reserved for compensation of downstream water users. To maintain normal river flow downstream of the dam, it was calculated that 0.23 Mm^3 per month would have to be released between October and April each year, totalling 1.6 Mm^3. (DWS 2017) note that while 0.47 Mm^3 was released annually for downstream users, the 1.6 Mm^3 annual compensation release to ensure normal river flow has not been implemented.

According to the DWAF (1996) estimates, the portion of the Onrus River catchment below the De Bos Dam contributes some 42% of the natural MAR. The Antjies River tributary and a number of small streams flow into the Onrus River below the dam, while groundwater from the sandy (primary) aquifer is also believed to help sustain water levels in the estuary.

Overall, DWS (2017) estimated that reduction in MAR for the Onrus Estuary translates to around 48.2%, while reduction is the size of the 1:10, 1:20 and 1:50 year floods was estimated at 40, 41 and 35%, respectively. Hydrological health for Present Day was assessed on the basis of overall change in MAR and in flood frequency at 48% (D category). Confidence in this assessment was low due to limited flow gauging in the catchment.

Hydrodynamics

The Onrus Estuary is classified as a small temporarily closed system (Van Niekerk et al. 2019). In DWS (2017), it was reported that data from the DWS water level gauge (G4T011) and personal observations of the authors indicated that the mouth was closed at times with a large sandbar. CSIR (1991) estimated that the average crest height of the berm was estimated at +2.8 m mean seal level (MSL) and that due to its small size the estuary is most often in a semi-closed state as it can fill and overtop at relatively low inflow rates by means of a narrow channel that forms on the western edge of the sandbar. It was also noted in DWS (2017), that this narrow channel serves as an overflow, rather than a tidal inlet, and seawater only penetrates during high storm spring tides as evident from kelp in the lower reaches of the estuary. With the arrival of sufficiently large floods, however, the overflow channel scours deep enough to allow for a brief period of tidal fluctuations, i.e. Open State. The sandbar starts rebuilding on the seaward side as sand is deposited back on the beach by wave action and usually closes within ten days, reverting back to an overflow channel. The Onrus Estuary was therefore described in DWS (2017) as being in a "perched" semi-closed state for the majority of the time, with the estuary outlet higher than the tidal range. The main body of the estuary was at a level less than 1 m above MSL across much of its length and dropped down as low as 1.3 m below MSL in places.

A series of topographic surveys conducted between 1994 and 2024 indicated little change in the profile of the estuary up to 2022, and also suggest that the mouth region of the estuary has changed little since the 1990s, that the berm is still at around +2.8 m MSL and that there is still a narrow channel on the west side of the mouth that serves as an overflow for the estuary. The bed level in the main body of the estuary changed dramatically in 2023 following a major flood in September of that year when the Overstrand experienced 135 mm of rain in 48 hours. This flood resulted in an enormous quantity of sediment being deposited in the estuary which has fundamentally altered hydrodynamic and ecological functioning of the system. Much of the sediment that was deposited in the estuary originated from a major wetland system (the Onrus Wetland) some 4 km upstream of the estuary.

Deposition of sediment in the estuary caused the bed level to rise to between 0.5 m and 3.0 m above MSL across its entire length. The volume of sediment deposited in the estuary (based on the change in the bathymetry profiles between the 2021 and 2023 surveys) is estimated at around 180 000 m^3. Since the flood, there has been some redistribution of sediment in the estuary and bed levels are now more than 1 m above MSL aside from a few small patches near the mouth. Effectively this places the estuary bed level above the height of all but the most extreme tides with the result that seawater is barely able to penetrate into the mouth of the estuary and tidal exchange has been all but eliminated. The greatly elevated bed levels in the estuary also represent a major flood risk now as there is no deep basin to capture sediment brought down from the catchment in future or to slow down the flood flows.

This has had a dramatic impact on the hydrodynamic functioning of the estuary. Van Niekerk (2017 in DWAF 2017) identified three distinct abiotic states (Closed, Semi-Closed and Open) for the Onrus Estuary based on personal observations, photographs and the DWS water level, with an occurrence level of 7, 64 and 29%, respectively. This can be contrasted with a frequency of occurrence under reference conditions of 1.5, 55.4 and 43.1%, respectively. Corresponding salinity levels for the abiotic states were identified as being <5, 5-10 and 25-30. Following the floods the frequency of occurrence of these states has now changed to 89, 10 and 1%, respectively. This has resulted in the hydrodynamic health score for the estuary dropping from an estimated 86% in 2017 (B category) to 13% at present (F category).

Water quality

There is limited historical data for water quality for the Onrus Estuary but it has always been identified as a freshwater-dominated system, where instantaneous salinity varied from around 0-4 PSU during the closed state to around 31.7 PSU when the estuary was open to the sea. DWS (2017) suggested that under the Reference condition, the open water areas of the estuary were mostly clear (suspended solids <5 mg/ℓ), well-oxygenated (dissolved oxygen ~8 mg/ℓ) and oligotrophic (DIN <50 mg/ℓ and DIP < 10 mg/ℓ). DWS (2017) also provided some estimates of what they considered "characteristic" water quality conditions under each of the abiotic states (closed, semi-closed, open) for the Reference and for their Present Day (2017) condition. Based on these estimates, DWS (2017) rated water quality in the estuary as Moderately modified (D category) and allocated a score of 56% to water quality health.

A rapid ecological assessment was undertaken of the estuary as part of this study, which included collection of data on water quality (temperature, salinity, dissolved oxygen, pH, Total Suspended Solids, ammonia, nitrate, nitrite and dissolved inorganic phosphorus). These data suggest that projections by DWS (2017) were largely correct but that conditions have deteriorated even further since this time as a result of the massive deposition of sediment in the estuary (salinity levels in the estuary are expected to be markedly lower now than in 2017, even under open mouth conditions, due to a much reduced tidal prism) along with further increases in nutrient levels and suspended sediment levels.

Water quality health scores for the Present Day (2024) were derived in a similar way to those for 2017 (DWS 2017), in accordance with methods set out in the EHI manual, and were based on average water quality conditions under each abiotic state and the anticipated frequency of occurrence of the various states. Based on this, we estimate that the water quality health of the Onrus Estuary has declined from around 56% (D category) in 2017 to 36% (E category) in late 2024.

Physical habitat

In their assessment of the state of the Onrus Estuary Heinecken & Damstra (1983) concluded that it was likely that marine sediments (coarse sand) could enter the lower part of the estuary during extreme storm events but generally do not penetrate further than 100 m upstream of the estuary mouth. They found that beyond 100 m, marine sediment is replaced by finer, catchment-derived sediment with a higher percentage of organic mud. Average deposition of catchment-derived sediment for the period 1940 to 1990 was estimated at approximately 1 200 m^3 per year (CSIR 1991). The De

Bos Dam acts as a sediment trap and therefore most of the sediment deposits originate from the lower catchment below the dam. DWS (2017) surmised that over the subsequent two decades, agricultural development had remained relatively stable and sedimentation rates were not expected to have increased substantially over this period. This is borne out in the bathymetric surveys, which indicate little sediment build up in the estuary over this period. Based on this information and some limited observations of the habitats in the estuary, DWS (2017) surmised that supratidal and intertidal sediment structure were expected to be relatively similar to that under the Reference Condition, but there has been a significant increase in the organic sediment fraction in the subtidal areas of the estuary as a result of contamination by raw sewage.

The situation changed dramatically in 2023, following a major flood in September of that year when the Overstrand experienced 135 mm of rain in 48 hours. This flood resulted in an enormous quantity of sediment being deposited in the estuary which has fundamentally altered hydrodynamic and ecological functioning of the system as outlined above. Intertidal sand and mud flats that were present in the estuary are now entirely absent, and are rapidly being invaded by *Phragmites australis* that was historically restricted to the shallow waters along the banks of the estuary. The characteristics of the sediment in the estuary also changed dramatically as a result of the flood, with the result that most of the estuary is now filled with coarse river sand with patches or even thick layers of peat scattered here and there. Muddy sediments that were present in the middle and upper reaches of the system in 2017 are now entirely gone.

Based on the forgoing, the physical habitat health of the Onrus Estuary was rated at a D category (50%) in 2017 but has now declined to an F category now (2024, 15%).

Biotic health

Microalgae

Microalgae are an important source of food for fish and microfauna and occur as phytoplankton in the water column, as benthic microalgae on sediment surfaces and attached to macrophytes as epiphytes. Flagellates, which are usually numerically dominant in the water column use their flagella to maintain their position in the water column. Flagellates can be either autotrophic or heterotrophic (consumers rather than photosynthetically active). The green microalgae are a diverse group that can be present in high abundance.

There is very limited data on microalgae in the Onrus Estuary, but factors affecting microalgae health are well understood. Microalgae communities were regarded as "largely" or "heavily" modified by DWS (2017) as a result of reduced river flow (estimated to be around 60% of natural), increases in nutrient levels in the estuary (up to 10 times that expected under reference conditions), reduced tidal exchange and reduced salinity levels (average levels have dropped from around 21 to 14). Nutrient levels in the estuary have increased further since 2017 (30-100% higher), tidal exchange in and out of the estuary has been all but eliminated along with much of the open water and deep subtidal habitats, and salinity in the estuary has dropped to an average of 1 PSU. These changes would all have impacted on microalgae communities in the Onrus Estuary in a dramatic way. Current health of the microalgae community is rated as "highly" or "severely" degraded (EHI score = 20%).

Macrophytes

DWS (2017) published a map of the different macrophyte habitats and their distribution within the 5 m contour around the estuary based on a field survey and 2014 aerial photographs. Dense monospecific stands of common reed *Phragmites australis* were present on the banks of the estuary. In some areas *Phragmites* was replaced by the bulrush *Typha capensis*. Reeds fringing the banks of the mouth were short and sparse compared to the dense stands occurring in the middle and upper reaches of the estuary. Some clumps of *Schoenoplectus scirpoides* were present amongst the reeds. A narrow strip of coastal forest dominated by milkwoods *Sideroxylon inerme*, bush tick berry *Osteospermum monilifera* (previously *Chrysanthemoides monilifera*) and invasive rooikrans *Acacia cylops* occurred along the western bank of the estuary. A small percentage of this habitat has been removed due to residential houses and gardens which back onto the estuary. A sedge similar in appearance to young Phragmites, possibly *Ficinia nodosa* (previously *Scirpus nodosus*), fringed the open water in front of the coastal forest.

Heinecken & Damstra (1983) identified pondweed *Potamogeton pectinatus* and the algae *Chara* growing together in the bottom sediments of the shallower upper northern part of the lagoon but this had disappeared by the time DWS (2017) completed their assessment.

Some marked changes to macrophytes communities in the Estuarine Functional Zone (EFZ) of the Onrus Estuary have taken place since the assessment by DWS (2017). Much of the terrestrial environment surrounding the estuary is now dominated by alien plant species. This includes Red-eye wattle *Acacia cyclops*, Plume albizia *Paraserianthes lophantha*, and Mousehole tree *Myoporum tenuifolium*. According to a recent satellite imagery analysis, the extent of this alien infestation has increased dramatically since 2021. Furthermore, following the flood in September 2023, which has led to a dramatic reduction in water depth across the entire estuary and a significant reduction in salinities levels in the estuary (reduced from an average of around 21 in 2017 to around 1 now), *Phragmites* are encroaching into the estuary channel at a dramatically increased rate. The increase in nutrient levels, reduction in salinity and elimination of tidal variations in the Onrus Estuary have created almost "perfect storm" conditions for encroachment of *Phragmites* into the estuary channel.

The health of the macrophytes was assessed in the same way in 2017 and 2024, in terms of species richness, abundance and community composition. Change in species richness was measured as the loss in the average species richness expected during a sampling event, excluding species thought to not have occurred under Reference conditions. Abundance was measured as the change in area cover of macrophyte habitats (% similarity = 100*present area cover / reference area cover). Change in community composition was assessed using a similarity index which is based on estimates of the area cover of each macrophyte habitat in the reference and present state. Much of the floodplain of the Onrus Estuary (3.26 ha) has been removed by disturbance and development. Reed encroachment (156% increase in 2017 and a further 7.7% in 2024) has significantly reduced open water habitat. Under natural conditions invasive plant species would not have occurred in the system. These impacts have resulted in a community composition score of 49% for 2017 (DWS 2017) and 30% for 2024.

Invertebrates

Estuarine invertebrates can be divided into a number of sub-groups based on where they reside in the estuary. Zooplankton live mostly in the water column, benthic organisms live in the sediments on the bottom and sides of the estuary channel, and hyperbenthic organisms live just above the sediment surface. Benthic organisms are frequently further subdivided into intertidal (those living between the high and low water marks on the banks of the estuary) and sub-tidal groups (those living below the low water mark).

There is no available information on the Zooplankton inhabiting the Onrus Estuary and very limited information on benthic and hyperbenthic invertebrates. The invertebrate information is restricted to the 1983 CSIR report on the Estuaries of the Cape (Heinecken & Damstra 1983) and forms the baseline description of the Onrus Estuary. The 1979-1980 survey identified 23 benthic and hyperbenthic invertebrate species from six taxonomic classes (Heinecken & Damstra 1983). The seaward end of Onrus Estuary was predominantly inhabited by the sandprawn *Callichirus kraussi* in shallow areas, while Crown crabs, *Hymenosoma orbiculare* occurred in slightly deeper water. Amphipods, polychaetes, tanaids and chironomid larvae were also present in this area.

The upper parts of the estuary were reportedly characterised by muddy substrate which was inhabited by Amphipods, polychaetes and chironomid larvae but in relatively low numbers. Mussels (*Brachidontes virgiliae)* attach to waterlogged branches and submerged rocks. In the upper reaches the amphipod, *Americorrophium triaeonyx* and tanaid, *Tanais stanfordi* were abundant, with polychaetes, amphipods, isopods *Corixidae* sp. and Chironomid larvae being present. The anoxic blind arm supported populations of the polychaete, *Ceratonereis keiskama*; amphipod, *Americorrophium triaeonyx*; along with Chironomid larvae. The submerged algae *Chara* and macrophyte *Potamageton pectinatus,* provided habitat for several species of invertebrates (Heinecken & Damstra 1983), although there were no noted submerged macrophytes in July 2016, which indicated the loss of this habitat type. Additionally, the island of *Scirpus littoralis* provided habitat for amphipods, isopods and numerous insect larvae while the *Phragmites* spp. reed beds hosted a similar suite of invertebrates as well as two species of Arachnida.

As part of this study, we sampled invertebrates at six stations up the length of the estuary in October 2024. Sampling was conducted with a hand corer which samples an area of 0.025 m^2 and volume of 0.76 m^3. Three replicate cores were collected at each site. Numbers of invertebrate taxa and their abundance in the estuary was extremely low. A total of only nine taxa and 31 individuals were recorded with more than half of the samples (11 out of 18) being completely empty. Most of the taxa recorded were freshwater species which is consistent with very low salinity levels recorded in the estuary. The absence of sandprawns *Callichirus kraussi* is noteworthy. This represents a very dramatic reduction in health status of the invertebrate community in the estuary relative to that recorded by Heinecken & Damstra (1983). The recent flood and resultant deposition of sediment in the system has all but eliminated benthic invertebrate fauna from the estuary. Species that remain are mostly of freshwater origin.

DWS (2017) scored the health of the invertebrate community at 55% (D category) but this has clearly got very much worse since that time. We suggest that invertebrate abundance has been most significantly affected (20%), followed by species richness (30%) and community composition (35%). This brings the overall health score for 2024 to 20% (minimum of these three metrics). Confidence in this assessment was rated as "Medium".

Fish

Three historic reports are available on the ichthyofauna of the Onrus Estuary; these include data collected during the 1980 ECRU survey (Heinecken & Damstra 1983), a survey undertaken by Harrison (1999) in 1994 and another by (Turpie & Clark 2007) in 2006. A total of 10 species were identified as being present in the estuary in these studies (Table 4-15). These include three estuarine resident species, Estuarine round herring *Gilchristella aestuaria*, Knysna sand goby *Psammagobius knysnaensis* and Silverside *Atherina breviceps,* all of which breed in estuaries (the latter two also have marine breeding populations). Juvenile flathead mullet *Mugil cephalus* are dependent on estuaries as nursery areas, whilst juvenile southern mullet *Chelon richardsonii (*formerly *Liza richardsonii)* and white stumpnose *Rhabdosargus globiceps* occur in estuaries but are generally more common at sea. The freshwater mullet *Myxus capensis* breeds at sea, but uses estuaries as nursery areas and spends much of its adult life in rivers (catadromy). Both Cape galaxias *Galaxias zebratus* and Mozambique tilapia *Oreochromis mossambicus* are euryhaline freshwater fish, although the latter has expanded its range, being native to the more tropical waters of Kwa-Zulu Natal and Eastern Cape (Whitfield 1994, Lamberth et al. 2008). The freshwater fish Cape kurper *Sandelia capensis* was only recorded in 1980.

Another survey of the fish fauna of the Onrus Estuary was undertaken as part of this study in October 2024. Sampling was conducted using a beach seine net with samples taken at six sites up the length of the estuary. A total of only four species of fish were recorded with the most abundant being the mullet (*Chelon richardsonii* and *Mugil cephalus)* and estuarine round herring *Gilcristella aestuaria*. Knysna sandgoby *Psammagobius knysnaensis* were caught in small numbers at one site right near the mouth only. No fish were recorded above Site 3 in the estuary. Both the numbers of fish species and total abundance of fish present in the estuary have dropped quite dramatically since the earlier surveys in 1980, 1994 and 2006. Number of species ranged from 6-8 across these three surveys and total abundance ranged from around 70-1100 fish/haul. This must be contrasted with only 4 species recorded in 2024 and an average of 55 fish per haul.

Under reference conditions, the estuary was probably tidal just under half the time (43% open mouth phase), whilst marine connectivity was maintained during the semi-closed phase for much of the remaining time. Sandy marine derived sediments were probably more common in the lower estuary; the water was oligotrophic and clear, and open water habitat was much greater than at present. These conditions would have provided suitable foraging and nursery areas for adults and juveniles of a wide range of marine migrant species, both estuary-associated marine species as well as marine 'vagrants' – e.g. white steenbras *Lithognathus lithognathus*, leervis *Lichia amia*, white stumpnose *Rhabdosargus globiceps* and elf *Pomatomus saltatrix*. These species, together with sand (as opposed to mud) associated estuarine resident species such as the Cape sole *Heteromycteris capensis* and Knysna sand goby *Psammogobius knysnaensis* were most likely present, or much more abundant in the estuary under reference conditions. As was the case more recently, mullet species (mostly *Chelon richardsonii, Myxus capensis,* and *Mugil cephalus,* probably also *L. dumerilii*) would have been very important in the system. The silverside *Atherina breviceps* would probably have been more abundant in the clear, marine influenced water, whilst *Gilchristella aestuaria* (currently the most abundant species) would have probably been less dominant. Cape kurper and Cape galaxias would probably only rarely entered the estuary during floods when freshwater conditions dominated. Mozambique tilapia would not have been found and eels *Anguilla mossambica* and *A. marmorata* elvers and adults would probably have migrated through the estuary on a regular basis (their existence in the system under present conditions is unknown but considered very unlikely).

Under present conditions, the mouth of the Onrus is predominantly closed or semi-closed (~95 % occurrence), but may break open for short periods after heavy rainfall several times during the year. The narrow channel that mostly functions as an overflow from the estuary may scour deeper, resulting in brief periods of tidal influence before it closes again. During closed or semi-closed mouth conditions seawater only enters the estuary via the overflow at spring tides if at all. The fish composition described above demonstrates that even with limited interaction between the sea and the estuary, as was the case until last year, the Onrus Estuary still played a role in recruitment of larval and juvenile marine fish. It is possible that the removal of large areas of the common reed *Phragmites australis* in 1993/1994 temporarily improved the fish nursery function of the Onrus Estuary, but ongoing sedimentation and regrowth of reeds has negated much of the improvement in habitat associated with the dredging. This also changed dramatically following the flood in September 2023.

Health of the fish community in the Onrus Estuary is considered to be highly impoverished at present relative to conditions in 2017, but especially relative to Reference conditions. Abundance has been most severely affected (down from 50% in 2017 to 25% now), followed by species richness (down from 65 to 30%) and community composition (down from 65 to 35%). Overall health score at present was judged to be an "E" category (25%). This can be contrasted with an overall rating of D (50%) in 2017.

Birds

Historical accounts by Damstra (1980) record a total of 28 bird species were recorded including the relatively uncommon Pied Avocet, Swift Tern and Water Thick-knee, as well as Pied Kingfisher and Malachite Kingfisher. A count of all waterbirds on the estuary was also carried out by Underhill & Cooper (1983). During this count a total of 10 waterbirds from four species were counted including five Red-knobbed Coots, one Water Thick-knee, three Hartlaub's Gulls and one Cape Wagtail.

More recent surveys at the Onrus River estuary have recorded a total of 171 bird species over the last two decades, including rare vagrants and summer migrants. While the reed beds support higher numbers of passerine species, the encroachment of *Phragmites* in the lower reaches of the estuary has led to a decrease in overall avian diversity by reducing the area of open water habitat available. Of the 171 species recorded, 53 of them have not been seen since around 2015; the vast majority of which are species that rely on open water habitat for feeding and foraging (Odendal 2019).

In addition to the encroachment of *Phragmites* reeds, the avian diversity at Onrus River estuary has been heavily impacted by the September 2023 flood event. Prior to the flooding event, an average of ~150 individuals representing ~27 species were recorded during Coordinated Waterbird Counts (CWAC) (Table 4.18). This dropped substantially after the flood event to only 8 individuals representing 3 species during the November 2023 counts. While the number of birds recorded had risen in the February 2025 counts (110 individuals), the species diversity is still low, with only 12 species being observed, and has not yet recovered to pre-flood levels (Odendal 2019). The high number of individuals is largely attributed to an influx of African Sacred Ibises in response to a sewage spill (pers. comms. Anton Odendal). The African Scared Ibis is an opportunistic feeder that preys on a variety of insects, crustaceans, worms, frogs, fish and carrion. The are often found around sewage works.

A third survey of the estuary was conducted as part of this study in 2024. Waterbirds present on the estuary were counted in five discrete areas encompassing the full extent of the estuary functional zone. A total of 39 water birds from nine species were recorded. This is very similar to the numbers of birds recorded by Underhill & Cooper (1983) but is very much more depauperate than the bird fauna recorded by Damstra (1980) or by the pre-flood CWAC counts. This suggests that bird number and species composition has changed quite dramatically since the 1970s and after the flood event. Alternatively, the survey by Underhill & Cooper (1983) may have been conducted under suboptimal conditions. Low numbers of waders and absence of wading birds on the estuary is consistent with the poor (or absence of any) tidal exchange and low invertebrate and fish biomass in the estuary.

Under reference conditions, it is expected that the estuary would have had higher freshwater flows and scouring, resulting in greater connection with the marine environment. The reference condition would not have had the increased erosion and nutrient enrichment from catchment activities that has encouraged reed bed growth, and as a result more flood plain habitats that would have been favoured by invertebrate feeders and other waterfowl, would have been present. A higher incidence of breaching would have contributed to a more favourable environment for marine invertebrates and the scouring of the estuarine habitats would have prevented the build-up of anoxic muds. As a result, it is expected that under reference condition invertebrate feeding birds such as terns, gulls and waders would have been more abundant than they are under present conditions. It is possible that increased marine connectivity which provided a more suitable foraging and nursery areas for adult and juvenile fish species compared to present day, contributed to a more abundant and diverse piscivore community. Under reference conditions, there would also be an absence of the high levels of human disturbance seen during the holiday periods, which could have had a significant impact on bird fauna. However, the waterbird community at this estuary would not have ever been particularly abundant or diverse.

Based on this, the overall health of the avifauna of the Onrus Estuary is considered to be poor at present (40% of Reference) mainly due to changes in the community composition of the birds on the estuary (virtual absence of waders and wading birds, 40%) but also due to low abundance (50%) and species richness (55%). This must be contrasted with a slightly better score of 65% allocated to the avifauna in the 2017 assessment (DWS 2017).

Present Ecological Status (PES)

In 2017, using minimum scores for each component, the overall present ecological status for the Onrus Estuary was found to be 56%, with abiotic scores being slightly higher (60%) than biotic scores (52%). Re-evaluation of the system in 2024 after the major flood in September 2023 based on surveys undertaken for this study in October 2024 suggests that overall health of the estuary has declined dramatically (now 27% overall = "E" category). Declines in physical health (hydrodynamics and mouth condition, physical habitat alteration and water quality) played a major role here, but the drop in all biotic health parameters was also significant. This is unacceptable in terms of the National Water Act (NWA) and must be addressed as a matter of urgency.

Recommended Ecological Category (REC)

Recommended Ecological Category (REC) is decided on the basis of conservation importance, using a set of rules. Conservation importance, in turn, comprises biodiversity importance, a score which is taken from an existing dataset, and functional importance. The Recommended Ecological Category and Conservation importance of the Onrus Estuary was evaluated in the estuary flow assessment workshop undertaken by DWS (2017). At the time, a biodiversity importance score of 60 was assigned to the estuary. The functional importance was estimated to be 20, given its small size and lack of connection to the sea. Using these scores in conjunction with national scores on size, zonal type rarity, and habitat diversity, the overall importance score for the Onrus was determined as 46 (DWS 2017). This puts it in the category of "low to average importance". We do not believe that there is any reason to change these scores at this stage.

Since the estuary is not on the list of existing or desired protected areas (Turpie et al. 2012), the rule for REC is to maintain the PES. However, the minimum PES for any estuary in South Africa is set at a D category (40%), therefore the REC for the Onrus Estuary is a D. As such, there is an urgent need to improve the health of this estuary from its current status of E (27%).

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LIST OF ABBREVIATIONS

Anchor	Anchor Environmental Consultants
C2C	Catchment to Coast
CWAC	Coordinated Waterbird Counts
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved oxygen
DWAF	Department of Water Affairs and Forestry
DWS	Department of water and Sanitation
ECRU	Estuarine and Coastal Research Unit
EDC	Estuarine Dependence Category (Whitfield 1999).
EFZ	Estuarine Functional Zone
EHI	Estuarine Health Index
IDP	Integrated Development Plan
MAR	Mean Annual Runoff
Mm^3	Million metres cubed
MSL	Mean Sea Level
NBA	National Biodiversity Assessment
NGO	Non-Governmental Organization
NH4-N	Ammonia
NO2-N	Nitrites
NO3-N	Nitrates
PES	Present Ecological State
PO4-P	Phosphate
PSU	Practical Salinity Units
REC	Recommended Ecological Category
TSS	Total Suspended Solids

1 INTRODUCTION

Estuaries in South Africa are broadly divided into "functional estuaries" and "microsystems" (Van Niekerk et al. 2020). In total, there are 290 functional estuaries and 202 micro-systems. These systems incorporate much of the only sheltered marine habitat along the South African coastline and are thus extremely important for biodiversity conservation and socio-economic development. The enormous value of estuaries is also reflected in the range and value of the ecosystem services they provide including water supply and regulation, nutrient supply and cycling, refugia and migration corridors, raw materials and resources for subsistence and commercial use, outlets for recreational and tourism, and transport services. Ecosystem services provided by estuaries in South Africa are, however, coming under increasing pressure, both as a result of increasing demand for coastal resources to support ever increasing coastal populations as well as due to large-scale environmental change.

The Onrus Estuary, located in the Western Cape Province (Figure 1-1), is included as one of the 290 "functional estuaries" in the country and is one of 28 such systems in the cool temperate biogeographic region, and one of eight estuaries in this region to be classified as a small temporarily closed system (Van Niekerk et al. 2020). The Onrus is a very small estuarine lagoon with a relatively small floodplain and covers in total approximately 15 ha. The Mean Annual Runoff (MAR) reaching Onrus Lagoon has been significantly reduced by water use in the catchment, mainly for agricultural activity, and the construction of the De Bos Dam in 1976. This dam constitutes the primary freshwater resource supplying potable water to the Overstrand region.

Figure 1-1. Location of the Onrus Estuary along the southwest coast of south Africa (left) and the extent of the Estuarine Functional Zone (EFZ).

The Onrus Estuary ranks 94th of all South African estuaries in terms of its overall conservation importance and, as such, is not considered to be particularly important for estuarine biodiversity on a national scale (Turpie & Clark 2007). The Onrus Estuary is, however, an important recreational area along the Cape south coast, and the small resident population of Onrus is bolstered considerably during holiday periods by tourists.

The most recent National Biodiversity Assessment (NBA) (2019) rated the condition or Present Ecological State (PES) of the Onrus Estuary as a "D" or "Heavily Modified". This was based on findings of an Ecological Health Assessment that was completed for the Onrus Estuary as part of the process of determining the freshwater reserve for all significant water resources in the Breede-Gouritz Water Management Area in 2017 (DWS 2017). This assessment revealed that the estuary was in a "D" category (Largely modified), which is the lowest permissible state for any water resource in the country according to the National Water Act (1998). This rating indicates a large shift in natural processes and ecosystem functions with loss of habitat and biota having occurred. The system is described as experiencing a "High" cumulative pressure level and is influenced by "Very High" pollution pressure and "High" pressure as a result of flow modifications, habitat loss and alien fish (Van Niekerk et al. 2019).

The Onrus Estuary has recently been severely negatively affected by a 1:100 year flood that occurred in the Onrus catchment in September 2023. This flood resulted in an enormous quantity of sediment being deposited in the estuary which has fundamentally altered hydrodynamic and ecological functioning of the system. Much of the sediment that was deposited in the estuary originated from a major wetland system (the Onrus Wetland) some 4 km upstream of the estuary. This wetland system is in a poor state of health having been subject to a long history of abuse. It has been drained for agricultural purposes for the past 70 years, and has experienced significant sediment losses and geomorphological changes as a result of natural and accelerated erosion (Grundling et al. 2019). The peat which underlies the wetland has become desiccated, and alien invasive plant species have started to colonise degraded parts of the wetlands. An uncontrolled veld fire ignited the desiccated peat in the wetland in 2019 which further destabilised the system, laying the ground for the massive loss of sediment, peat and vegetation from the wetland in 2023 (Figure 1-2).

Figure 1-2. Fire in the Onrus wetland (2019) and the wetland after the flood in September 2023.

This flood event prompted this re-evaluation of ecological health of the Onrus Estuary, completed in 2024, following protocols laid down by Turpie et al. (2012) in the Estuary Health Index Manual (see §2 for more details on this). The Estuary Health Index (Turpie et al. 2012) was developed as a standardised and tested method for assessing the Present Ecological Status (PES) or health of an estuary as a baseline and against which to set future objectives and measure progress according to management targets. It was designed for use in the determination of the freshwater Reserve for estuaries, as well as for use in management of estuaries generally, is the formally accepted approach for assessing estuary health as set out in the methods for the determination of the ecological reserve for estuaries (DWA 2012).

Re-evaluation of the health the Onrus Estuary was undertaken as part of the Onrus Catchment to Coast (C2C) Rehabilitation and Restoration programme. The C2C programme was originally launched by the Overstrand Municipality, together with other landowners, water resource users, government organizations and Environmental NGO's in 2024 and forms part of the Overstrand Municipality's 2022-2027 Integrated Development Plan (IDP). The objective of the plan is to adopt a holistic approach to watershed management. By rehabilitating the entire catchment corridor, the aim is to safeguard water resources, prevent land degradation, preserve biodiversity, and mitigate the effects of climate change to ensure the long-term resilience and sustainability of its people and nature. Motivation for the project originates in the fact that the Onrus catchment is a very important water resource in the region (domestic, agricultural and industrial uses) and a perception that environmental flow requirements of key aquatic ecosystems (wetlands, riverine and estuarine) in the catchment are not being met at the moment. The project is overseen by a Steering Committee who is to provide strategic leadership in addition to ensuring synergy, alignment, and optimal resource mobilisation between key implementing partners to secure the Onrus River Catchment through coordinated and collective action. Confidence in the data available for the assessment was assessed to be "Medium" and the level of the assessment as "Intermediate".

2 DETERMINATION OF ESTUARY HEALTH THROUGH THE ESTUARINE HEALTH INDEX (EHI)

The Estuary Health Index (Turpie et al. 2012) was developed as a standardised and tested method for assessing the Present Ecological Status (PES) or health of an estuary as a baseline and against which to set future objectives and measure progress according to management targets. It was designed for use in the determination of the freshwater Reserve for estuaries, as well as for use in management of estuaries generally, is the formally accepted approach for assessing estuary health as set out in the methods for the determination of the ecological reserve for estuaries (DWA 2012).

The EHI methodology entails scoring each of the abiotic and biotic components of an estuary, to produce an overall measure of the health of the estuary as a percentage resemblance to the reference or natural condition. The components studied are as follows:

- Abiotic (or driving components):
    - Physical dynamics (measured in terms of seasonal river inflow patterns, floods, mouth dynamics, water level variations, water movement patterns, changes in sediments and deposition and erosion areas)
    - Water quality (measured in terms of system variables, nutrients and toxic substances); microbiological contaminants - linked to human health - are excluded as it does not pertain to the ecological component;
- Biotic (response) components:
    - Estuarine flora (microalgae and macrophytes)
    - Estuarine fauna (invertebrates, fish and birds.

The EHI is calculated as the average of a suite of Abiotic and the Biotic scores; the Abiotic score being the average of the hydrology (HL), hydrodynamics (HD), physical habitat (PH) and water quality (WQ) scores, and the biotic score being the average of the microalgae (MI), macrophyte (MA), invertebrate (I), fish (F) and bird (B) scores (Figure 2-1):

$$EHI = \frac{(\frac{\mathrm{HL, HD, PH, WQ}}{4} + \frac{\mathrm{MI + MA + I + F + B}}{5})}{2}$$

All of these components are scored as percentage resemblance to the reference or natural condition, following specific guidelines. The biotic components consider average species richness, community composition and overall abundance.

Determining the EHI score therefore involves (a) estimating what the estuary was like in its natural condition (the Reference condition) in terms of physical and biological characteristics and processes, (b) scoring the present condition of each component relative to this estimated Reference as a score out of 100, and (c) aggregating the overall score and converting the score to its Present Ecological Status category using a simple scale of A to F (Table 2-1). This method standardises health assessment across estuaries of varying size, type and climatic region. It is important to note that the A to F scale represents a continuum, with conceptual rather than precise boundaries. This introduces a level of uncertainty as to which category some estuaries may fall into, potentially having components that have membership in two categories. Taking this into account the 2018 NBA assessment introduced straddling categories, denoted by A/B, B/C, C/D etc, to represent scores ±3 from the category boundary scoring range (Van Niekerk et al. 2013, 2019).

It was also emphasised that smaller, sensitive estuaries tend to degrade to the lower health Categories (C to F) more rapidly, while the larger, permanently open estuaries have a greater level of resilience and can generally maintain a boundary category if pressures are not increased (Van Niekerk et al. 2019).

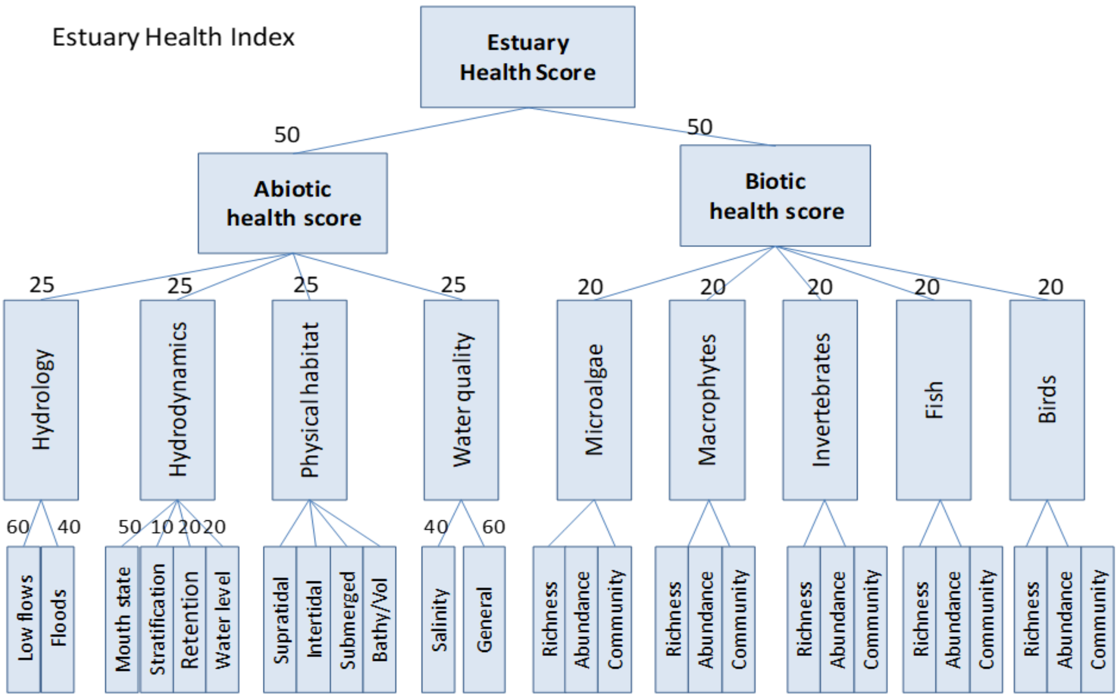

Figure 2-1. Contribution of abiotic and biotic parameters to the Estuary Health Index. Numbers indicate weighting. (Source: Turpie et al. 2012).

Computation of the EHI, and indeed the ecological reserve, can be undertaken at a number of different level depending on the amount of information that is available on the system in question, the times and budget available for collection of additional information, the degree of confidence with which the specialist can make decisions, interpretations and judge the likely impacts of developments within the Estuarine Functional Zone. Confidence is inherently a subjective measure, as some specialists may be inherently more confident than others. Therefore, DWA (2012) provides guidelines for assessing confidence as shown in Table 2-2.

Conventionally, four different levels of assessment for the EHI and Reserve Determination are recognised (DWA 2012, Turpie et al. 2012):

- Desktop estimate (to obtain a low confidence value for the reserve of a water resource for use in the Water situation assessment model)
- Rapid determination
- Intermediate determination
- Comprehensive determination.

Table 2.1. Estuarine health categories (NBA 2018, Van Niekerk et al. 2019).

Condition (% of pristine)	≥91%	90-75	75 - 61	60 - 41	40-21	≤20
Continuum	A	A/B B	B/C C	C/D D	D/E E	E/F F
Ecological Management Category (DWS)	A Natural	B Largely natural / few changes	C Moderately modified	D Largely modified	E Highly degraded	F Extremely degraded
NBA Ecological modification	Natural/Near natural		Moderate	Heavily	Severe/Critical	
Functionality	Retain Process & Pattern (Representation)		Some loss of Process & Pattern	Significant loss of Process & Pattern	Little Process & Pattern	
Restoration cost	None/ Low		Low/ Medium	High	Very high, potentially irreversible structural changes	

Category	Description
A	**Unmodified, approximates natural condition.** The natural abiotic processes should not be modified. The characteristics of the resource should be determined by unmodifed natural disturbance regimes. There should be no human induced risks to the abiotic and biotic processes and function.
B	**Near natural with few modifications.** A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged.
C	**Moderately modified**. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	**Heavily modified**. A large shift natural processes and ecosystem functions and/or loss of habitat, biota have occurred.
E	**Severely modified**. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	**Critically modified**. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural abiotic processes and associated biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Table 2.2. Guidelines for describing levels of confidence (Source: DWA 2012).

Limit	Degree of confidence
Very Low	If no data were available for the estuary or similar estuaries (i.e. < 40% certain)
Low	Limited data were available, and estimates could be out by 60% (40%-60 certain of estimate)
Medium	If reasonable data were available for the estuary and estimates could be out by 20-60% (i.e. 60% – 80% certain of estimate)
High	If good data were available for the estuary and estimates are probably not more than 20% out (i.e. > 80% certain of estimate)

Although there are no official requirements with regards to which level of assessment be undertaken for a given development, guidelines from DWA (2012), *Methods for the Determination of the Ecological Reserve for Estuaries,* suggest that desktop assessments are intended for use in National Water Resources Strategy as part of planning processes only; rapid level assessments are intended for individual licensing for small impacts in unstressed catchments of low importance and sensitivity; intermediate level assessments are intended for individual licensing in relatively unstressed catchments, while comprehensive determination is intended for all compulsory licensing, involving small or large impacts in very important and/or sensitive catchments.

This assessment of the EHI for the Onrus Estuary included a survey of all abiotic (hydrological, hydrodynamics, water quality, physical habitats) and most of the biotic (macrophytes, invertebrates, fish, birds) aspects of the estuary and was based on reasonably good body of historic data that was available on the estuary. Confidence in the data was assessed to be "Medium" and the level of the assessment as "Intermediate".

3 ABIOTIC HEALTH

3.1 Hydrology

3.1.1 Present and Reference State

Simulated freshwater flow sequences for the Onrus Estuary were generated for natural and present-day conditions (land use, water use etc.) using the Water Resources Simulation Model 2000 (WRSM 2000) (Pitman) rainfall-runoff model during classification of significant water resources in the Breede-Gouritz Water Management Area in 2017 (DWS 2017). The description of the hydrology of the Onrus River and flow data for the Onrus River presented here is taken largely from the account included in that report.

Monthly flow sequences are presented in the appendix (Section 7) for the period 1920-2009, while summary flow data for the same period are presented in Table 3-1. (Reference conditions) and Table 3-2 (Present day conditions). Analysis of these data suggest that there has been a significant change in mean annual runoff (MAR) between Reference (9.17 Mm^3/a) and Present (4.75 Mm^3/a) (51.8% reduction in MAR) mostly linked with agricultural use of water in the catchment and water use from the municipal De Bos Dam, which was built in 1976 approximately 9 km upstream of the estuary mouth. This dam constitutes the primary freshwater resource supplying potable water to the Overstrand region and has a storage capacity of 6 Mm^3 with an annual supply capacity of approximately 3.3 Mm^3 (Du Plessis 1995). The Municipality has been allocated 2.8 Mm^3 (Shand 1973, 1987, Cilliers & Withers 2014) with an additional 0.47 Mm^3 reserved for compensation of downstream water users. To maintain normal river flow downstream of the dam, it was calculated that 0.23 Mm^3 per month would have to be released between October and April each year, totalling 1.6 Mm^3 (Shand 1987). DWS (2017) note that while 0.47 Mm^3 was released annually for downstream users, the 1.6 Mm^3 annual compensation release to ensure normal river flow has not been implemented.

Table 3.1. Simulated monthly flows (in Mm^3) under **Reference Conditions**.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	3.761	4.541	1.773	1.205	2.352	1.304	4.369	4.350	5.540	6.337	7.354	5.676
90%ile	1.830	1.261	0.375	0.331	0.364	0.265	1.045	2.337	3.132	3.617	4.711	3.251
80%ile	1.076	0.650	0.166	0.104	0.104	0.160	0.366	1.027	1.963	2.475	3.574	1.823
70%ile	0.749	0.335	0.131	0.090	0.090	0.101	0.245	0.717	1.011	1.835	2.408	1.404
60%ile	0.525	0.227	0.124	0.090	0.076	0.076	0.166	0.403	0.698	1.253	1.767	1.002
50%ile	0.318	0.190	0.110	0.083	0.076	0.076	0.124	0.238	0.563	0.894	1.446	0.869
40%ile	0.273	0.166	0.107	0.076	0.069	0.069	0.097	0.179	0.427	0.629	1.102	0.641
30%ile	0.246	0.159	0.097	0.076	0.069	0.062	0.076	0.131	0.329	0.444	0.684	0.474
20%ile	0.234	0.145	0.090	0.069	0.055	0.055	0.068	0.109	0.208	0.377	0.475	0.330
10%ile	0.200	0.131	0.089	0.061	0.055	0.054	0.055	0.076	0.123	0.255	0.274	0.255
1%ile	0.145	0.090	0.054	0.040	0.034	0.034	0.034	0.046	0.076	0.122	0.175	0.162

Table 3.2. Simulated monthly flows (in Mm^3) under **Present Conditions**.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99%ile	2.016	2.716	0.923	0.561	1.124	0.643	2.230	2.214	2.969	3.313	4.336	3.555
90%ile	1.172	0.647	0.169	0.139	0.160	0.112	0.473	1.135	1.583	1.809	2.522	1.492
80%ile	0.539	0.328	0.090	0.069	0.062	0.083	0.166	0.472	0.938	1.155	1.674	1.075
70%ile	0.380	0.170	0.076	0.062	0.055	0.062	0.112	0.328	0.492	0.904	1.165	0.647
60%ile	0.265	0.131	0.072	0.055	0.048	0.048	0.083	0.189	0.320	0.593	0.873	0.515
50%ile	0.190	0.110	0.069	0.048	0.048	0.041	0.062	0.110	0.269	0.418	0.614	0.418
40%ile	0.172	0.097	0.062	0.048	0.041	0.041	0.055	0.090	0.200	0.294	0.528	0.328
30%ile	0.145	0.090	0.062	0.041	0.039	0.034	0.041	0.069	0.152	0.219	0.325	0.239
20%ile	0.131	0.083	0.055	0.041	0.034	0.034	0.041	0.062	0.102	0.185	0.235	0.185
10%ile	0.109	0.076	0.048	0.034	0.033	0.028	0.033	0.047	0.062	0.137	0.159	0.144
1%ile	0.076	0.054	0.034	0.027	0.027	0.021	0.021	0.027	0.047	0.068	0.095	0.081

Taking into account the anticipated demand for water from the growing population in the Greater Hermanus Area, it was anticipated that the Municipality's annual allocation of 2.8 Mm^3 from the De Bos Dam would be reached by about 1997 (Shand 1991). The Overstrand Municipality submitted an application for a higher water allocation to the then Department of Water Affairs and Forestry (DWAF, now Department of Water and Sanitation DWS). Permission to increase the municipal allocation was denied by DWAF, which instead assisted the municipality in initiating the Greater Hermanus Water Conservation Programme in November 1996. This included a water demand management component that relied on a block tariff system for water consumption, and the removal of alien vegetation carried out by the Working for Water programme.

Despite the implementation of the Water Conservation Programme, the Municipality was drawing 4 Mm^3 of water from the dam by 2006 (Overstrand Municipality 2010). From mid-2007 however, the surface water supply was supplemented by groundwater from the Gateway Wellfield. Subsequently, the Camphill and Volmoed Wellfields were established in the Hemel en Aarde Valley to augment the water supply from the De Bos Dam and the Gateway Wellfield in Hermanus. Consequently, the Municipality has not exceeded the permitted allocation of 2.8 Mm^3 since 2011 (P. Robinson, Pers Comm.).

There is no gauge measuring outflow through the outlet pipe (Figure 3-1), which can be opened or closed with a valve. In April 2013 the flow rate was crudely estimated (using a 20 ℓ bucket and stopwatch) at 8 ℓ/s, which translates to an annual release of approximately 0.25 Mm^3. It is therefore unlikely that enough water is released for the environmental reserve downstream of the dam.

According to the (DWAF 1996) estimates, the portion of the Onrus River catchment below the De Bos Dam contributes some 42% of the natural MAR. The Antjies River tributary and a number of small streams flow into the Onrus River below the dam, while groundwater from the sandy (primary) aquifer is also believed to help sustain water levels in the estuary.

Using the Mean Annual Runoff figures from the initial De Bos Dam Yield Study (Shand 1987), the CSIR (1991) estimated that the flood flow rates in the Onrus River for a 1:5, 1:20 and 1:50 year flood event were 75, 121 and 157 m^3/sec. If the extreme scenario was assumed, with the dam retaining all flow, the estimated flood flow rates from the remainder of the catchment would be 44, 71 and 94 m^3/sec. The authors concluded that the flow rates have been reduced by less than 40%.

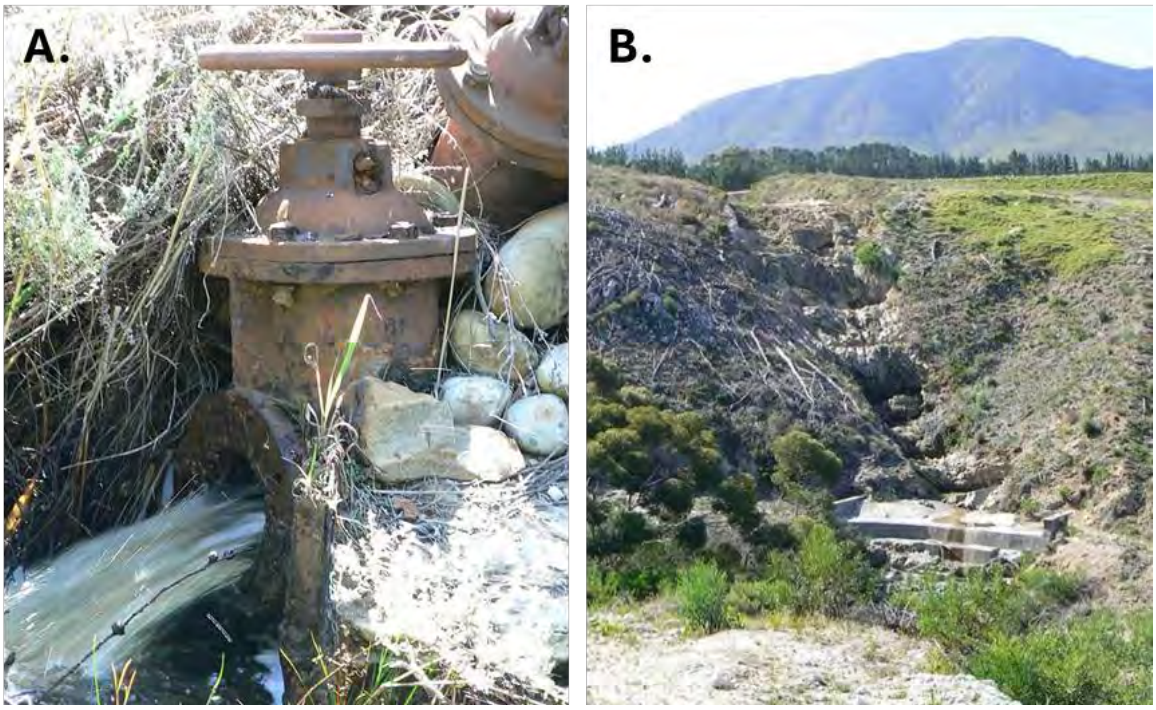

Figure 3-1. (A) The outflow from the De Bos Dam into the Onrus River in March 2013, and (B) the spillway down which water flows when the dam overflows.

3.1.2 HYDROLOGY HEALTH SCORE FOR PRESENT DAY (2024) AND 2017 (DWS 2017)

Reduction in MAR for the Onrus Estuary at the time when classification of all significant water resources in the Breede-Gouritz Water Management Area was completed in 2017 (DWS 2017) was estimated at 48.2%, while reduction in the size of the 1:10, 1:20 and 1:50 year floods was estimated at 40, 41 and 35%, respectively. There is no reason to suspect that this has changed materially in the time since then, thus similar estimates of change in MAR and flood frequency for the Present Day (2024) have been included here.

Hydrological health for Present Day was assessed on the basis of the overall change in MAR and in flood frequency. Results are presented in Table 3-3. Confidence in this assessment was rated as low as simulated flows have not been properly calibrated against gauged data.

Table 3.3. Hydrology health scores for 2017 and Present Day (2024) relative to the Reference Condition.

Variable	DWS (2017)	Present (2024)	Confidence
a. % similarity in MAR	48	48	L
b. Change in flood frequency	61	61	L
Score (min a, b)	**48**	**48**	**L**
Health category	**D**	**D**	**L**

3.2 HYDRODYNAMICS

The Onrus Estuary is classified as a small temporarily closed system (Van Niekerk et al. 2019). In DWS (2017), it was reported that data from the DWS water level gauge (G4T011) and personal observations of the authors indicated that the mouth was closed at times with a large sandbar.

CSIR (1991) estimated that the average crest height of the berm was estimated +2.8 m MSL and that due to its small size the estuary is most often in a semi-closed state as it can fill and overtop at relatively low inflow rates by means of a narrow channel that forms on the western edge of the sandbar. It was also noted in DWS (2017), that this narrow channel serves as an overflow, rather than a tidal inlet, and seawater only penetrates during high storm spring tides as evident from kelp in the lower reaches of the estuary. With the arrival of sufficiently large floods, however, the overflow channel scours deep enough to allow for a brief period of tidal fluctuations, i.e. Open State. The sandbar starts rebuilding on the seaward side as sand is deposited back on the beach by wave action and usually closes within ten days, reverting back to an overflow channel. The Onrus Estuary was therefore described in DWS (2017) as being in a "perched" semi-closed state for the majority of the time, with the estuary outlet higher than the tidal range. The main body of the estuary was at a level less than 1 m above MSL across much of its length and dropped down as low as 1.3 m below MSL in places (Figure 3-6).

There is some historic data on water level variation in the Onrus Estuary for the period 1994 - 2011 (Figure 3-2). The estuary drained at least a dozen times over this period which suggests that the sandbar at the estuary mouth was still regularly breached when floods were large enough. These open mouth periods tended to last for a few weeks to months based on data from the flow gauging station located within the estuary (Figure 3-2 and Figure 3-3).

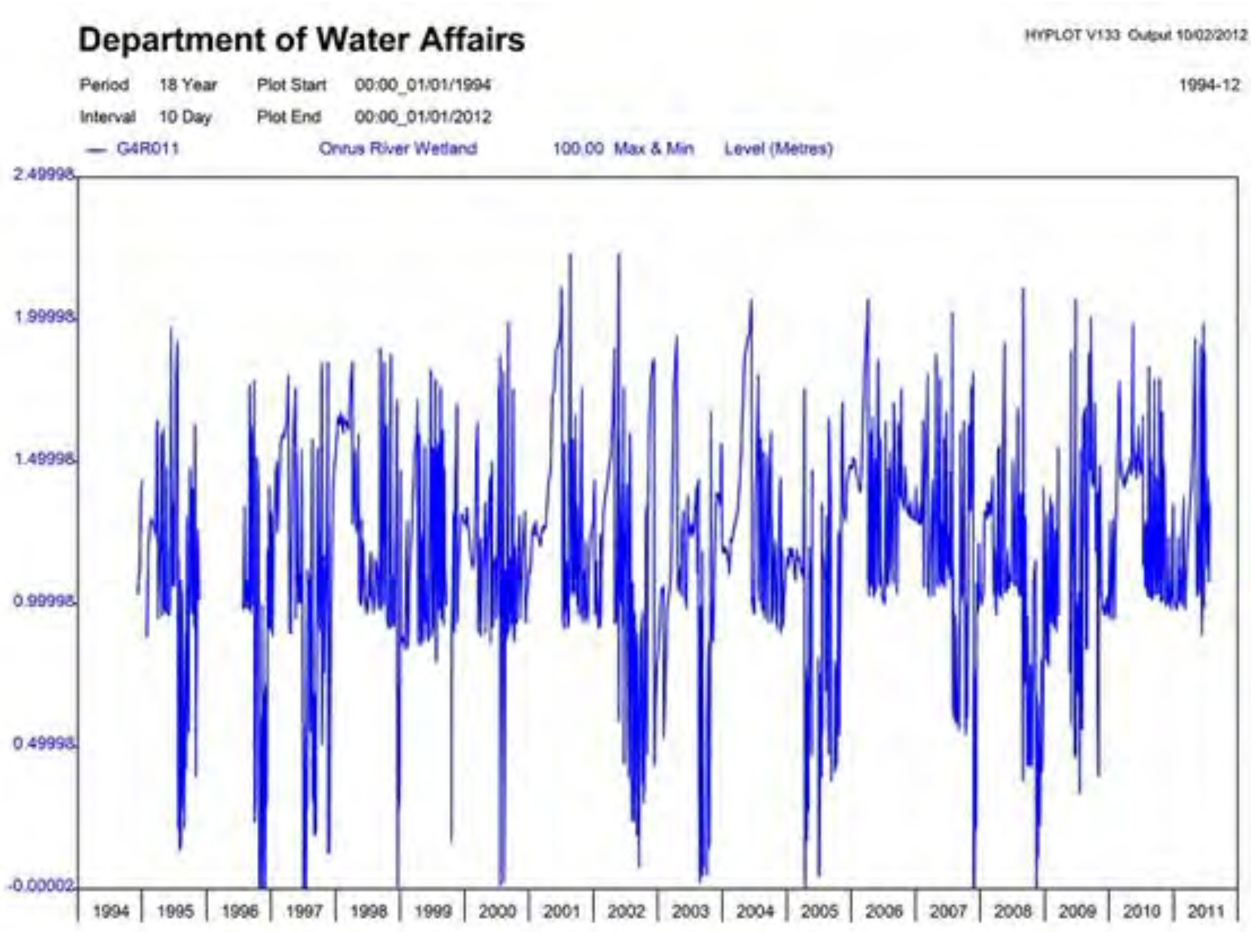

Figure 3-2. Water level in the Onrus Lagoon for the period 1994-2011, indicating occasions when the estuary drained after breaching of the sandbar (Source: Onrus Lagoon water level gauge G4T011, Department of Water and Sanitation). Location of the gauge is indicated on Figure 3-3.

Figure 3-3. Location of the water level gauge (G4R011) in the Onrus Estuary.

It is likely though that De Bos Dam has attenuated flood flows to some extent and also the frequency at which the sandbar (berm) is breached. Lower flows are also likely to have resulted in the mouth closing sooner after breaching than prior to the commissioning of the dam (Van Niekerk & Turpie 2012). This is evident when considering the natural mouth breach that occurred on 19 October 2012 following heavy rainfalls. First the water level increased, then the lagoon drained, after which tidal fluctuations were evident for a short period (three weeks) before the mouth closed once more (Figure 3-4and Figure 3-5).

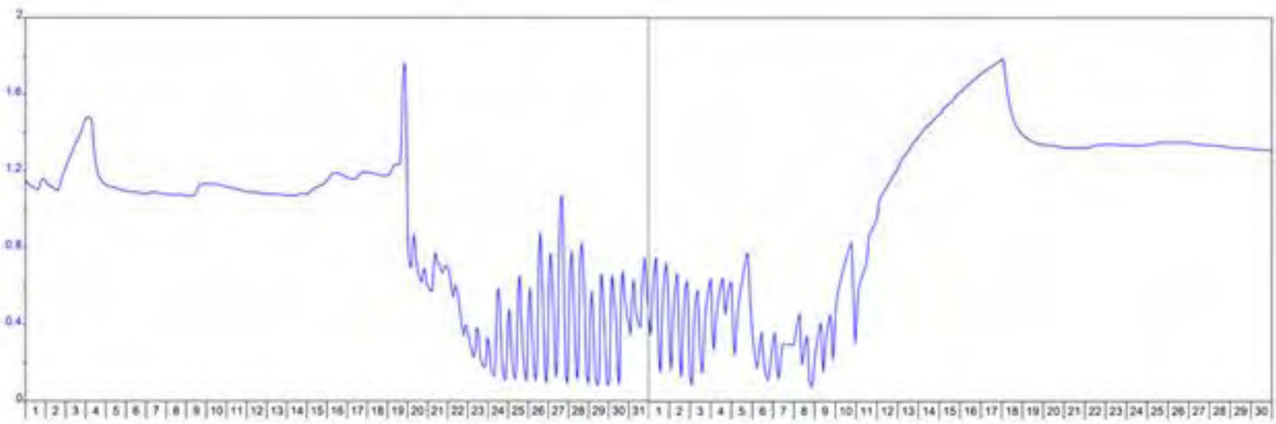

Figure 3-4. Data from the Onrus Lagoon water level gauge plotted for one-hour intervals for the period 1 October to 30 November 2012. The lagoon breached naturally on 19 October 2012 following heavy rainfalls. (Source: DWS).

Figure 3-5. The estuary mouth on 23 October 2012, following the natural breaching on 19 October.

Marine sediments (coarse sand) may enter the lower part of the lagoon during extreme storm events but generally do not penetrate further than 100 m upstream of the estuary mouth (Heinecken & Damstra 1983). Beyond 100 m marine sediment is replaced by finer, catchment-derived sediment with a higher percentage of organic mud (CSIR 1991). Anecdotal information suggested that a flood following a fire in the late 1940s or early 1950s had resulted in the sudden silting-up of Onrus Lagoon, but more intensive farming activity in the catchment since that time would also have increased the sedimentation rate. Average deposition of catchment-derived sediment for the period 1940 to 1990 was approximately 1 200 m^3 per year (CSIR 1991). The De Bos Dam acts as a sediment trap and therefore most of the sediment deposits originate from the lower catchment below the dam. Over the past 20 years, agricultural development has remained relatively stable and sedimentation rates are not expected to have increased substantially in this period.

The shape of the estuary, together with the relatively low inflow and the reduction of winter spates by the De Bos Dam should result in very little scouring or flushing of accumulated sediment (Heinecken & Damstra 1983). However, simulation of scenarios for flow rates under natural conditions as well as for impoundment of all inflow by the De Bos Dam indicated that flow rates for 1:5, 1:20 and 1:50 year flood events was reduced by less than 40% (CSIR 1991). It was concluded that this would have not significantly impacted on siltation or scouring of the estuary. These findings would need to be re-evaluated in light of the revised estimates of natural and present-day MAR, though.

In 1991, most of the lagoon was above mean sea level (MSL) and only about 1 m deep, but there was a basin of approximately 1.5 m depth opposite 'the peninsula'. It was proposed that the estuary be dredged to restore open water in the Onrus Estuary, which had been severely invaded by the common reed *Phragmites australis*. The aim was to remove 45 000 m^3 of sediment to create channels 40-60 cm wide and 1.5 m deep to increase flow velocities during floods and hence reduce sedimentation rates (CSIR 1991). It was also anticipated that some deeper holes excavated to -2 m MSL would aid in trapping sediment (CSIR 1993).

The dredging was conducted in 1993 and succeeded in removing about 30 000 m^3 of sediment. A bathymetric survey conducted immediately after the dredging was completed indicated that the targeted 1 m below MSL level was reached in only a few areas. Subsequent surveys in 1994 following a major flood (by Department of Water and Sanitation) and in October 2002 (by Pieter Badenhorst) both revealed that very little infilling had taken place since 1993 (Figure 3-6). Most of the deposition had occurred in the northern channel (Badenhorst 2002).

Subsequent topographic surveys (2014, 2021, 2023 and 2024, Figure 3-7 - Figure 3-8.) suggest that the mouth region of the estuary has changed little since the 1990s, that the berm is still at around 2.8 m above MSL and that there is still a narrow channel on the west side of the mouth that serves as an overflow for the estuary. The bed level in the main body of the estuary also changed little between 1994 and 2021, but changed dramatically in 2023 following a major flood in September of that year when the Overstrand experienced 135 mm of rain in 48 hours. This flood resulted in an enormous quantity of sediment being deposited in the estuary which has fundamentally altered hydrodynamic and ecological functioning of the system. Much of the sediment that was deposited in the estuary originated from a major wetland system (the Onrus Wetland) some 4 km upstream of the estuary. This wetland system is in a poor state of health having been subject to a long history of abuse. It has been drained for agricultural purposes for the past 70 years and has experienced significant sediment losses and geomorphological changes as a result of natural and accelerated erosion (Grundling et al. 2019). The peat which underlies the wetland has become desiccated, and alien invasive plant species have started to colonise degraded parts of the wetlands. An uncontrolled veld fire ignited the desiccated peat in the wetland in 2019 which further destabilised the system, laying the ground for the massive loss of sediment, peat and vegetation from the wetland in 2023.

Deposition of sediment in the estuary caused the bed level to rise to between 0.5 m and 3.0 m above MSL across its entire length. The volume of sediment deposited in the estuary (based on the change in the bathymetry profiles between the 2021 and 2023 surveys) is estimated at around 180 000 m^3. Since the flood, there has been some redistribution of sediment in the estuary and bed levels are now more than 1 m above MSL aside from a few small patches near the mouth. Effectively, this places the estuary bed level above the height of all but the most extreme tides with the result that seawater is barely able to penetrate into the mouth of the estuary and tidal exchange has been all but eliminated. The greatly elevated bed levels in the estuary also represent a major flood risk now as there is no deep basin to capture sediment brought down from the catchment in future or to slow down the flood flows.

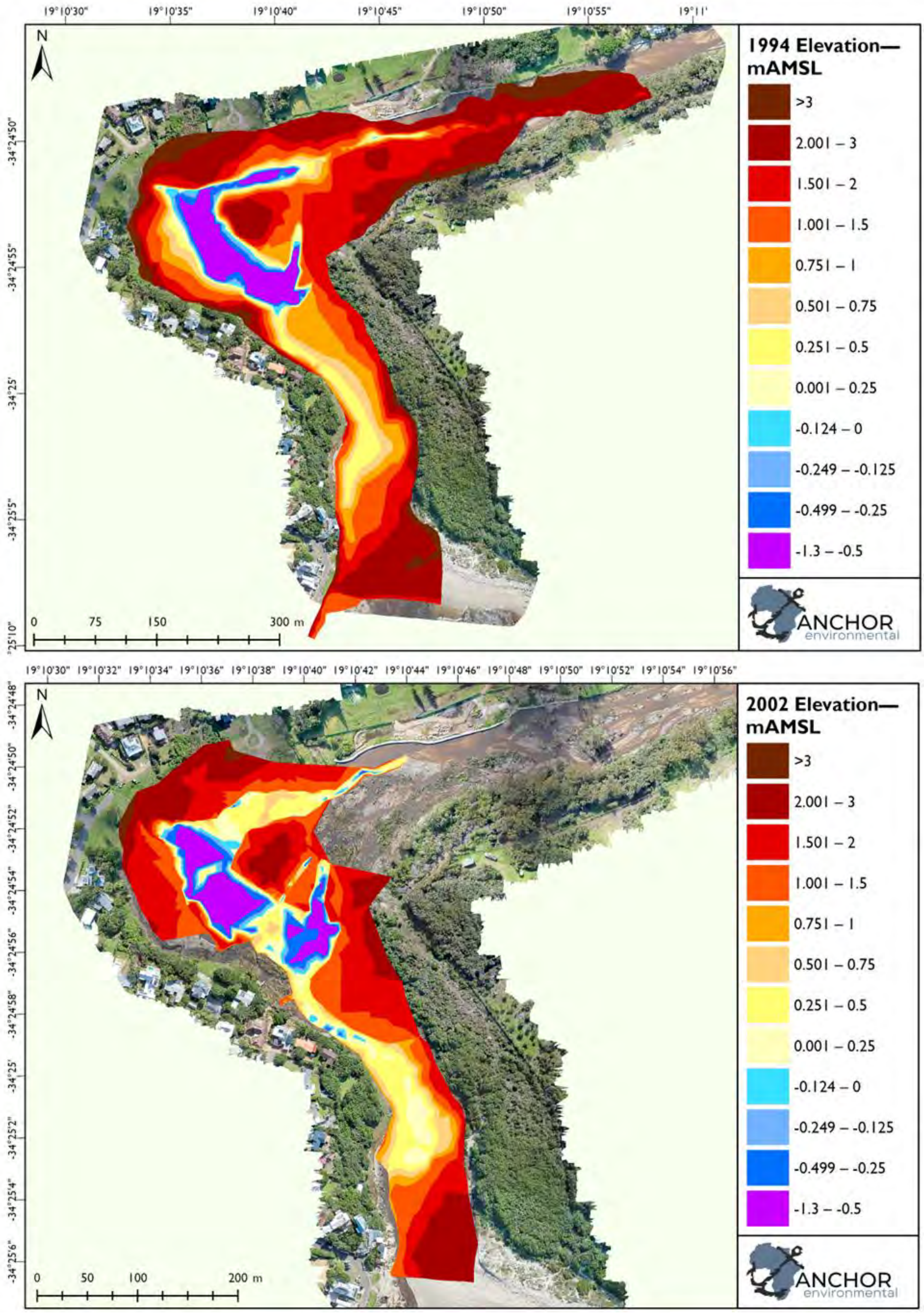

Figure 3-6. Bathymetric profiles of the Onrus Estuary compiled from surveys undertaken in 1994 (top) and 2002 (bottom).

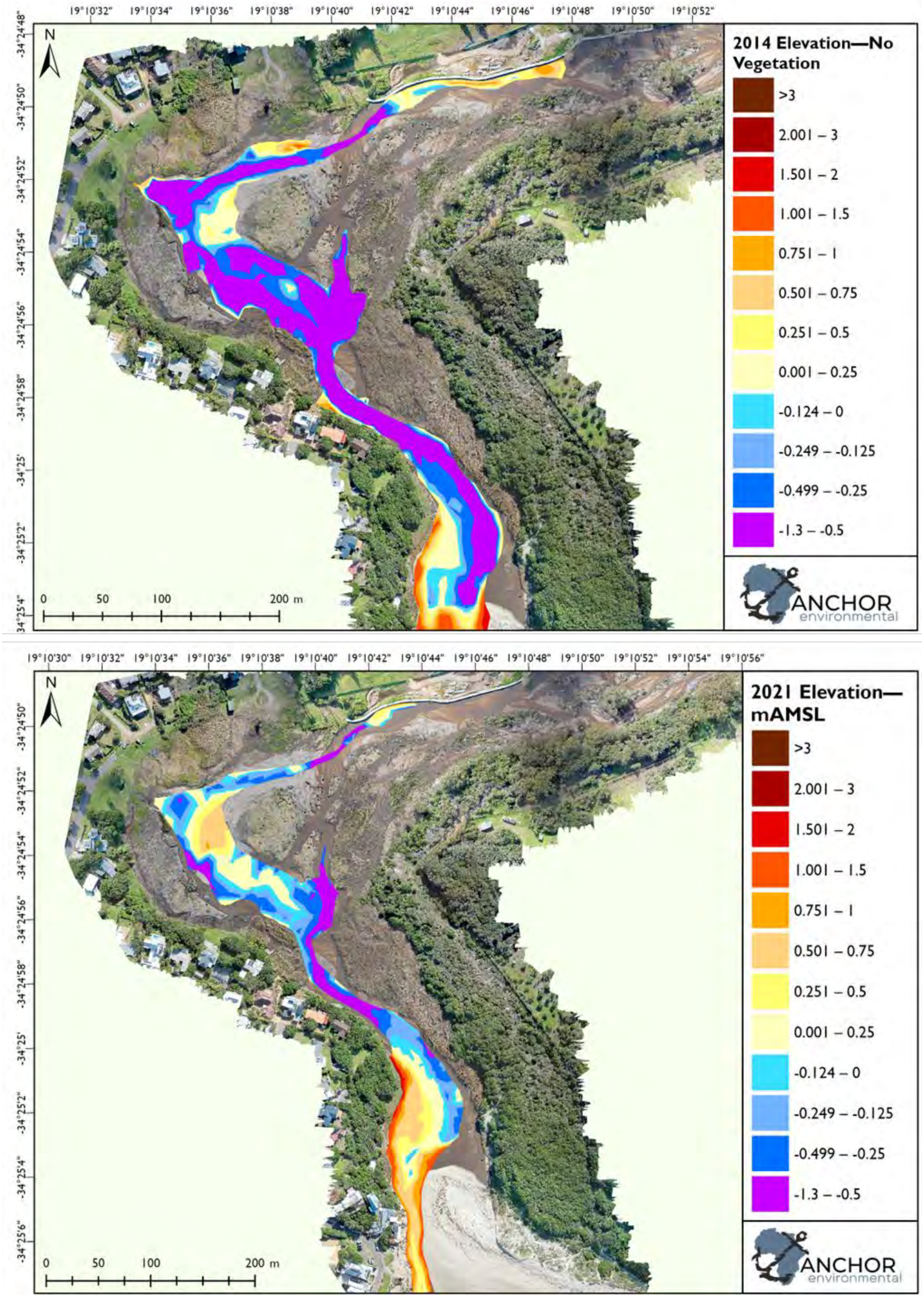

Figure 3-7. Bathymetric profiles of the Onrus Estuary compiled from surveys undertaken in 2014 (top) and 2021 (bottom).

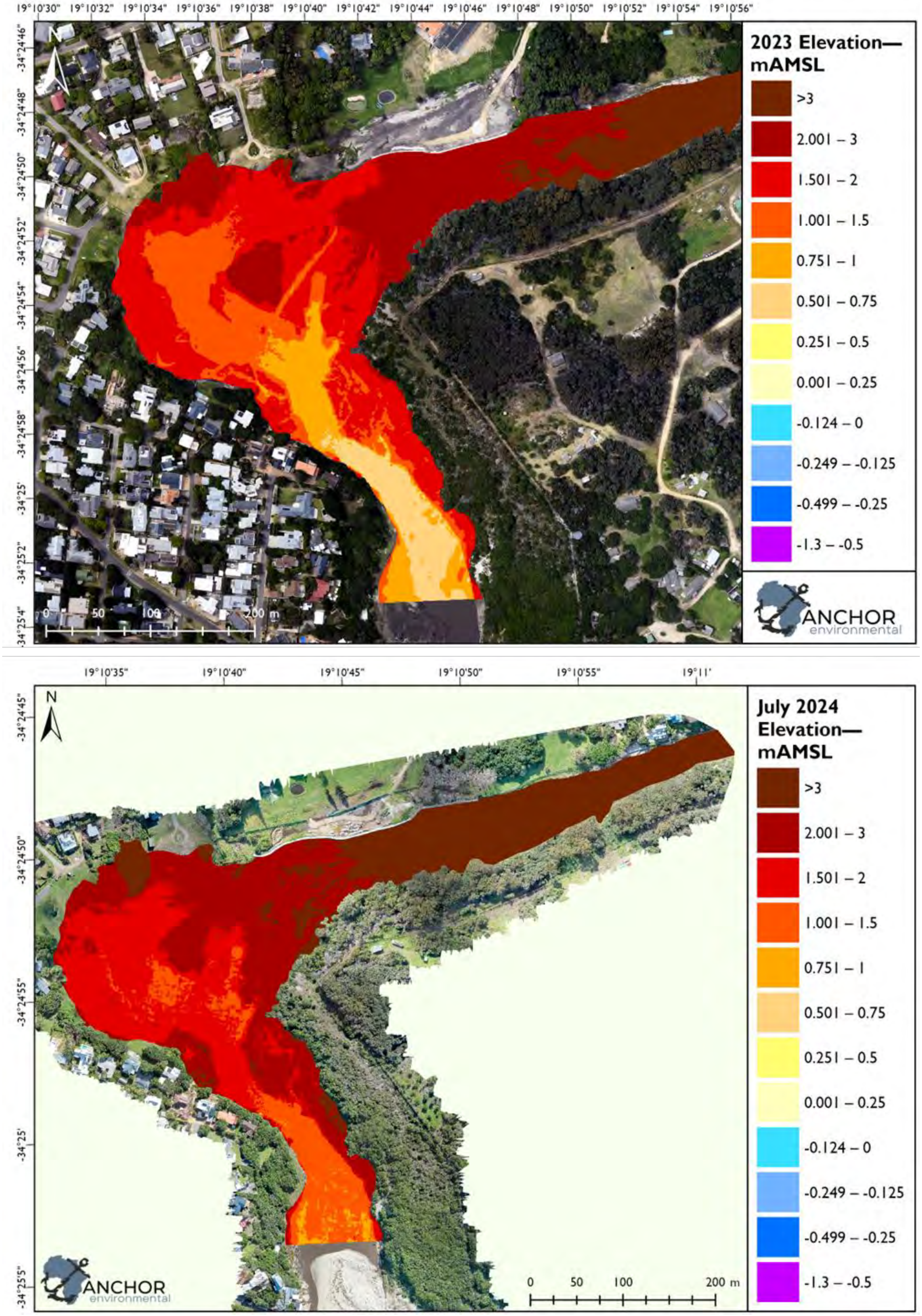

Figure 3-8. Bathymetric profiles of the Onrus Estuary compiled from surveys undertaken in 2023 (top) and 2024 (bottom).

Van Niekerk (2017 in DWAF 2017) identified three distinct abiotic states (Closed, Semi-Closed and Open) for the Onrus Estuary based on personal observations, photographs and the DWS water level gauge data (Table 3-4). It was not possible to estimate the occurrence/duration of these abiotic states with a high degree of certainty as a result of high variability in the water level associated with the closed to semi-closed state and the difficulty in identifying the presence of the small/shallow outflow channel on old aerial photographs and satellite imagery. However, a best estimate based on available time and data resources from this assessment is presented in Table 3-5.

Table 3.4. Characteristic abiotic states in the Onrus Estuary.

Abiotic State	Water level (m) associated with abiotic state	State duration	Estimated occurrence from water level data	Salinity
Closed (no connectivity)	> 1.6	Weeks to months	7%	<5
Semi-closed (with an outflow to the sea)	0.7 - 1.6	Months	64%	5-10
Open (with tidal exchange)	< 0.7m	Days to weeks	29%	25-30

The occurrence of the various abiotic states in 2017 was superimposed on the simulated runoff time series data for the Present State (1920-2009, appendix (Section 7)) to determine flow ranges associated with each state. These flow ranges were then used to estimate the frequency of occurrence of the various Abiotic States under the Reference Condition. From this analysis, Van Niekerk (2017 in DWAF 2017), estimated that there has been a 13% increase in the occurrence of mouth closure from Reference to Present, with a concomitant 13% decrease in the Open State (Table 3-5). Overall, it was reported that the estuary has experienced a significant loss of connectivity to the sea from Reference to Present.

Table 3.5. The occurrence of the Abiotic States in 2017, under the Reference Condition and Present Day (2024).

Abiotic State	Flow range (m^3/s)	% Occurrence		
		Reference	Present 2017	Present 2024
Closed	<0.0015	1.5	14.6	89.0
Semi-closed	0.01-0.0015	55.4	55.9	10.0
Open	> 0.01	43.1	29.4	1.0

In the absence of any water level data for the estuary post-2011, it was not possible to perform a similar analysis in 2024 for this assessment. However, given that the bed level of the estuary is now at 1.0-3.0 m above MSL across the entire estuary and seawater penetration into the estuary is almost negligible even at spring high tide, the occurrence of the semi-closed and open phases can safely be assumed to be negligible or at least of very short duration (e.g. following a major flood) (Table 3-5). While river outflow may be able to keep the mouth of the estuary open for much of the year, the extensive sedimentation within the system, and substantially raised bed level (Figure 3-9) mean that penetration of seawater into the system will remain negligible throughout the year.

Hydrodynamic EHI scores for the Onrus Estuary corresponding with this assessment are provided in Table 3-6, with the score dropping dramatically from 86% of natural in 2017, to only 13% in 2024.

Table 3.6. Hydrodynamic health scores for 2017 and Present Day (2024) relative to the Reference Condition.

Variable	2017	Present (2024)	Confidence
a. Mouth condition & abiotic states	86	13	M
Hydrodynamics and mouth conditions score	**86**	**13**	**M**
Health category	**B**	**F**	**M**

Figure 3-9. Extensive sedimentation in the Onrus Estuary following the floods in September 2023 have all but eliminated open water and deeper channel habitat in the estuary to the extent that it is no longer even possible to navigate with a small inflatable boat on the estuary.

3.3 Water quality

For the purposes of this study, and for the evaluation undertaken by DWS (2017), the open water area of the Onrus Estuary was defined as a single zone. Three abiotic states were considered namely:

- Closed
- Semi-closed
- Open

No measured data on water quality for the Reference condition (i.e. prior to anthropogenic influences) could be obtained for this estuary. However, historical information suggests that the Onrus Estuary has always been a freshwater-dominated system, where instantaneous salinity varied from 0-4 PSU during the closed state, to 31.7 PSU when the estuary was open to the sea (e.g. in 1994, Heinecken & Damstra 1983, S. Lamberth, pers. comm., Sue Matthews Overstrand Municipality 2013).

The only available water quality data for the system were collected in November 1979 (Heinecken & Damstra 1983) (Table 3-7) and for this study in 2024 (Table 3-8 and Figure 3-10). In 1979, salinity levels were low (0-1), dissolved oxygen was high (9.7-13.2 mg/l) and nutrient levels (NH4-N, NOx-N, DIN and PO4-P) were all fairly low (11-103 µg/ℓ) (Table 3-7). Measurements collected in 2024 suggest conditions were similar, with salinity levels also low (0.17-1.59), dissolved oxygen levels a bit lower (5.8-9.3 mg/l), and nutrient levels, especially DIN (173-683 µg/ℓ), somewhat higher (Table 3-8). DWS (2017) had assumed that water quality had deteriorated markedly as a result of increased anthropogenic influence (increased urban development and overflow from sewage pump stations), particularly during the closed state (mostly impacted by sewage pump station overflow) in the period between 1983 and 2017 which is certainly borne out by measurements taken in 2024.

Table 3.7. Available data on water quality in Onrus Estuary (November 1979). Source: Heinecken & Damstra 1983. Locations of sampling stations are indicated on Figure 3-10.

Location	A2: channel	B5: channel	E1: channel	F3: channel	G3: blind arm	Onrus River
Salinity (PSU)	1	0	0	0	0	0
DO (mg/ℓ)	10.2	12.1	10.3	10.8	9.7	13.2
DIN (µg/ℓ)	68		30	50	99	20
NO_x-N (µg/ℓ)	43		19	39	80	10
NH_4-N (µg/ℓ)	25		11	11	19	11
PO_4-P (µg/ℓ)	59		56	56	103	7

Table 3.8. Water quality data for the Onrus Estuary collected in 2024. Locations of sampling stations are indicated on Figure 3-10. Note that measurements at Sites 1-6 were collected on 9 Oct 2024 and those at site 3A were taken on 11 June 2024.

	Site 1	Site 2	Site 3	Site 3A	Site 4	Site 5	Site 6
Temperature (°C)	18.1	17.6	18.4	15.0	17.8	17.7	17.8
Salinity	1.59	0.19	0.21	0.21	0.17	0.17	0.17
Dissolved oxygen (mg/L)	5.8	8.7	7.4	9.3	9.1	9.0	9.1
Dissolved oxygen (% Saturation)	61.1	91.4	79.2	96.5	95.4	94.7	94.1
pH	7.03	7.62	7.16	6.35	7.74	7.43	7.25
DIN (µg/ℓ)	173	180	693	-	183	303	193
NH_4-N (µg/ℓ)	110	110	140	-	120	120	130
NO_3-N (µg/ℓ)	<180	<180	550	-	<180	180	<180
NO_2-N (µg/ℓ)	<10	10	<10	-	<10	<10	<10
PO_4-P (µg/ℓ)	<80	<80	<80	<80	<80	<80	<80
Total Suspended Solids (TSS, mg/ℓ)	75.6	21.6	34.2	126.0	180.0	171.6	75.6

Considering the catchment of the system, DWS (2017) suggested that under the Reference condition, the open water areas of the estuary were mostly clear (total suspended solids (TSS) <5 mg/ℓ), well-oxygenated (dissolved oxygen ~8 mg/ℓ) and oligotrophic (DIN <50 mg/ℓ and DIP < 10 mg/ℓ) (e.g. De Villiers & Thiart 2007) (Table 3-9). Based on very limited data and information, and expert opinion, DWS (2017) provided some estimates of what they considered "characteristic" water quality conditions under each of the abiotic states (closed, semi-closed, open) for the Reference and for their Present Day condition (2017). These estimates are included in Table 3-9 along with estimated "characteristic" water quality conditions for 2024.

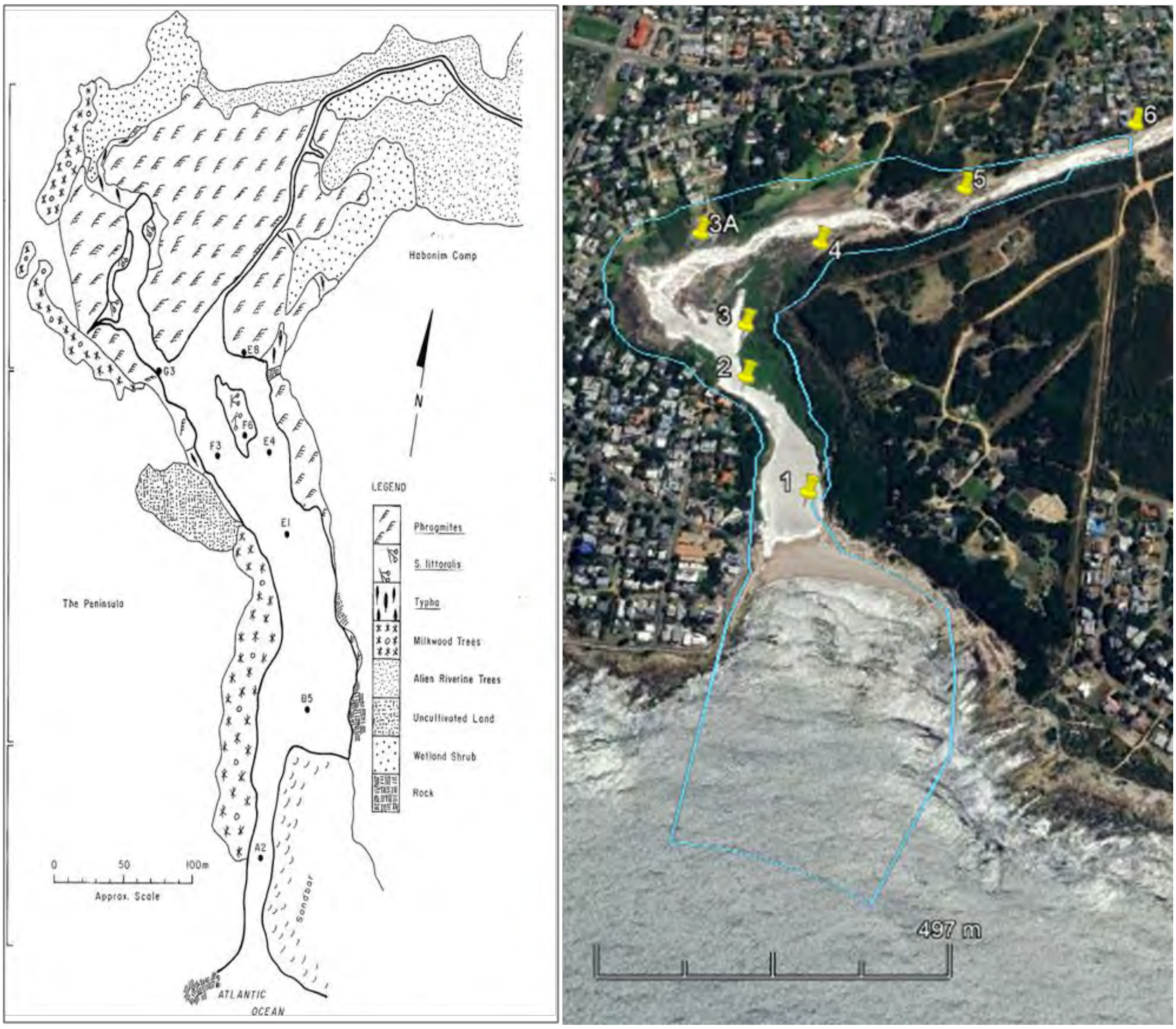

Figure 3-10. Location of sample stations used by Heinecken & Damstra (1983, left) and in this study (2024, right).

DWS (2017) projected that the most extreme modifications in water quality from reference conditions could be expected under State 1 (closed) when low river inflow and long residence time would result in the highest nutrient build-up and lowest dissolved oxygen (during algal blooms large diurnal variation can be expected, ranging from supersaturation during the day to hypoxia/anoxia at night) linked to sewage pump station overflow and urban runoff (Table 3-9). Highest total suspended solid (TSS) concentrations were also expected during the closed state associated with algal blooms (phytoplankton). A verage salinity in the estuary was assessed as being somewhat lower in 2017 than under reference conditions due to the increase in closed mouth conditions and the associated decrease in marine connectivity (overall 13% reduction in the open state).

Available data for 2024 suggest that projections by DWS (2017) were correct but that conditions have deteriorated even further since this time as a result of the massive deposition of sediment in the estuary (salinity levels in the estuary are expected to be markedly lower now than in 2017 even under open mouth conditions due to a much reduced tidal prism) along with further increases in nutrient levels and suspended sediment levels (Table 3-10).

Water quality health scores for the Present Day (2024) were derived in a similar way to those for 2017 (DWS 2017), in accordance with methods set out by DWA (2012) and Turpie (2012), and were based on average water quality conditions under each abiotic state (Table 3-11) and the anticipated frequency of occurrence of the various states (Table 3-5). The water quality health score for the Onrus Estuary has decreased from 56% of natural in 2017, to 36% of natural in 2024 (Table 3-11).

Table 3.9. Characteristic water quality conditions for each of the abiotic states (closed, semi-closed, open) estimated for the Reference, Present and the alternative scenarios, based on limited data and expert opinion.

Salinity (PSU)	Reference	DWS (2017)	Present Day (2024)
State 1: Closed	5	5	0
State 2: Semi-closed	15	10	1
State 3: Open	30	25	5
DIN (µg/ℓ)			
State 1: Closed	50	500	1000
State 2: Semi-closed	50	300	500
State 3: Open	50	100	150
DIP (µg/ℓ)			
State 1: Closed	10	80	80
State 2: Semi-closed	10	50	50
State 3: Open	10	20	20
DO (mg/ℓ)			
State 1: Closed	8	3	3
State 2: Semi-closed	8	6	6
State 3: Open	8	8	8
TSS (mg/ℓ)			
State 1: Closed	5	30	200
State 2: Semi-closed	5	10	80
State 3: Open	5	10	30

Table 3.10. Estimated average water quality conditions under the Reference state, in 2017 and Present day (2024).

Scenario	Salinity	DIN (µg/ℓ)	DIP (µg/ℓ)	DO (mg/ℓ)	TSS (mg/ℓ)
Reference	21	50	10	8	5
2017	14	270	46	6	13
Present Day (2024)	1	350	80	6	80

Table 3.11. Water quality scores for 2017 and Present Day relative to the Reference Condition

Variable		2017	Present Day	Confidence
1	**Salinity**	86	40	M
2	**General water quality**			
	a) Nutrient (DIN/DIP) concentrations	34	30	L
	b) Dissolved oxygen	87	87	L
	c) Total suspended solids	56	35	L
	d) Toxic substances	70	60	L
Water quality score*		**56**	**36**	
Health category		**D**	**E**	

**Score = (0.6 x S + 0.4 x min (a to d))*

3.4 PHYSICAL HABITAT

In their assessment of the state of the Onrus Estuary Heinecken & Damstra (1983) concluded that it was likely that marine sediments (coarse sand) could enter the lower part of the estuary during extreme storm events but generally would not penetrate further than 100 m upstream of the estuary mouth. They found that beyond 100 m, marine sediment is replaced by finer, catchment-derived sediment with a higher percentage of organic mud (CSIR 1991). Anecdotal information suggested that a flood following a fire in the late 1940s or early 1950s had resulted in the sudden silting-up of Onrus Lagoon, but more intensive farming activity in the catchment since that time would also have increased the sedimentation rate. Average deposition of catchment-derived sediment for the period 1940 to 1990 was estimated at approximately 1 200 m^3 per year (CSIR 1991). The De Bos Dam acts as a sediment trap and therefore most of the sediment deposits originate from the lower catchment below the dam. DWS (2017) surmised that over the subsequent two decades, agricultural development had remained relatively stable and sedimentation rates were not expected to have increased substantially over this period. This is borne out in the bathymetric surveys, which indicate little sediment build up in the estuary over this period (Figure 3-6).

Heineken & Damstra (1983) also surmised that given the shape of the estuary, together with the relatively low inflow and the reduction of winter spates by the De Bos Dam, that there would be very little scouring or flushing of accumulated sediment. However, simulation of scenarios for flow rates under natural conditions as well as for impoundment of all inflow by the De Bos Dam indicated that flow rates for 1:5, 1:20 and 1:50 year flood events was reduced by less than 40% (CSIR 1991). As outlined earlier in this report (Section 3.2), in 1991 most of the estuary was above mean sea level (MSL) and only about 1 m deep, but there was a basin of approximately 1.5 m depth opposite 'the peninsula'. Dredging conducted in 1993 resulted in the removal of around 30 000 m^3 of sediment and creation of channels 40-60 m wide and 1.5 m deep. A bathymetric survey conducted immediately after dredging was completed indicated that the -1 m MSL level was reached in only a few areas. Subsequent surveys in 1994, 2014 and 2021 indicated that the dredging efforts had been successful, and that little infilling had taken place since that time. DWS (2017) noted that the Onrus Estuary was showing signs of significant infilling and shallowing throughout the system, resulting from loss of floods (and associated scouring) and poor land-use practises which had caused an increase in sediments from the catchment and the ingress of reeds which in turn was increasing the sediment trapping efficiency of the system.

Based on this information and some limited observations of the habitats in the estuary, DWS (2017) surmised that supratidal and intertidal sediment structure were expected to be relatively similar to that under the Reference Condition, but there has been a significant increase in the organic sediment fraction in the subtidal areas of the estuary as a result of contamination by raw sewage. The organic material was described as being evident as a thick layer of consolidated sludge that coated the bottom of the system. The extent of this sludge layer was not determined but was thought to be extensive as evidenced by its presence in fish sampling gear at a few sites.

The situation changed dramatically in 2023 following a major flood in September of that year when the Overstrand experienced 135 mm of rain in 48 hours. This flood resulted in an enormous quantity of sediment being deposited in the estuary which has fundamentally altered hydrodynamic and ecological functioning of the system. Deposition of sediment in the estuary as a result of this flood caused the bed level to rise to between 0.5 m and 3.0 m above MSL across its entire length. The total volume of sediment deposited in the estuary (based on the change in the bathymetry profiles between the 2021 and 2023 surveys) is estimated at around 180 000 m^3. Since the flood, there has been some redistribution of sediment in the estuary and bed levels are now more than 1 m above MSL aside from a few small patches near the mouth. Effectively this places the estuary bed level above the height of all but the most extreme tides with the result that seawater is barely able to penetrate into the mouth of the estuary and tidal exchange has been all but eliminated. Intertidal sand and mud flats that were present in the estuary are now entirely absent, and are rapidly being invaded by *Phragmites australis* that was historically restricted to the shallow waters along the banks of the estuary. The characteristics of the sediment in the estuary also changed dramatically as a result of the flood, with the result that most of the estuary is now filled with coarse river sand (Figure 3-11). Analysis of sediment samples from five sampling sites arranged up the length of the estuary (Figure 3-10) indicates that sediments in the system comprise of a mixture of sand (Site 1 and 2), slightly gravelly sand (Sites 3, 4, 6) and gravely sand (Site 5) with patches or even thick layers of peat scattered here and there. Median particle size for these samples ranged from 350-832 µm (Table 3-12). Muddy sediments that were present in the middle and upper reaches of the system in 2017 are now entirely gone. Organic content of the samples was low for all sites (0.57-2.46%).

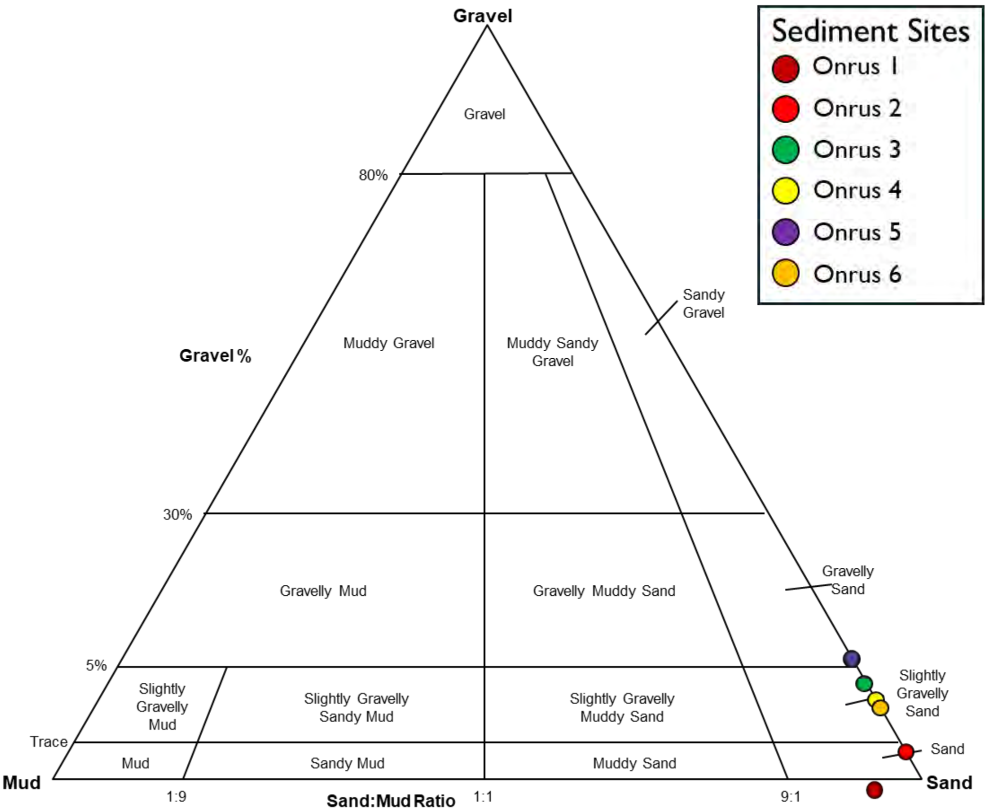

Figure 3-11. Ternary diagram indicating the make-up of sediment collected from sampling sites in the Onrus Estuary.

Table 3.12. Characteristics of sediment from six sampling sites on the Onrus Estuary collected in October 2024. MdØ = median particle size in µm, TOC = Total Organic Content.

Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Description	Sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Gravelly Sand	Slightly Gravelly Sand
MdØ (µm)	350.2	462.2	701.8	727.6	831.8	698.9
TOC(%)	2.46	0.57	0.91	0.64	1.09	0.83

All sites had trace metal concentrations far below any of the thresholds presented within South Africa's: "National Action List for the Screening of Dredged Material Proposed for Marine Disposal" (GN 867 of 2011), which is currently South Africa's only gazetted set of sediment quality guidelines (Table 3.13). These sediment data combined indicate that the Onrus sediments are non-contaminated and consist predominantly of clean sand and are therefore suitable for many forms of reuse.

Table 3.13. Levels of trace metals (in mg/kg) in sediments from the Onrus estuary. Warning, Level 1 and Level 2 thresholds from South Africa's National Action List (GN 867 of 2011) are also included.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	SA National Action List (mg/kg)		
							Warning Level	Level 1	Level 2
Aluminium (Al)	274.1	248.0	272.3	350.5	360.4	306.9			
Arsenic (As)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**42**	**57**	**93**
Cadmium (Cd)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**1.2**	**5.1**	**9.6**
Cobalt (Co)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			
Chromium (Cr)	4.68	12.22	10.53	15.37	9.41	9.18	**135**	**260**	**370**
Copper (Cu)	0.50	1.68	1.02	4.16	0.50	1.73	**110**	**230**	**390**
Iron (Fe)	1867	5932	5354	7956	6049	5317			
Nickel (Ni)	1.56	3.87	3.81	5.23	3.61	3.42	**62**	**140**	**370**
Lead (Pb)	1.42	1.20	1.02	1.32	1.61	0.97	**110**	**218**	**530**
Vanadium (V)	1.37	1.33	1.00	0.50	1.46	0.50			
Zinc (Zn)	1.59	2.04	1.53	2.37	1.52	1.85	**270**	**410**	**960**
Mercury (Hg)	<0.01	<0.01	<0.01	0.01109	0.0141	<0.01	**0.43**	**0.84**	**1.5**

Based on the forgoing, the physical habitat health of the Onrus Estuary in 2017 and 2024 was scored in accordance with Table 3-14, with the score for this component of estuary health dropping from 50% in 2017 to only 15% if natural in 2024.

Table 3.14. Physical habitat scores for 2017 and Present Day (2024) relative to the Reference Condition.

Variable	2017	Present (2024)	Confidence
a. Supratidal area and sediments	60	20	M
b. Intertidal areas and sediments	60	20	M
c. Subtidal area and sediments	50	40	M
d. Estuary bathymetry/water volume	50	15	M
Score min (a to d)	**50**	**15**	**M**
Health category	**D**	**F**	

4 BIOTIC HEALTH

4.1 MICROALGAE

4.1.1 MICROALGAL GROUPS

Microalgae are an important source of food for fish and microfauna and occur as phytoplankton in the water column, as benthic microalgae on sediment surfaces and attached to macrophytes as epiphytes. Flagellates, which are usually numerically dominant in the water column use their flagellae to maintain their position in the water column. Flagellates can be either autotrophic or heterotrophic (consumers rather than photosynthetically active). The green microalgae are a diverse group that can be present in high abundance.

There is very limited data on microalgae in the Onrus Estuary. Harrison (1962) reported a lack of filamentous and free-living green algae in the estuary. An analysis of dense detritus from an algal bloom in June 2012 indicated a mixed assemblage of diatoms and four species of blue-green algae (Massie & Clark 2016). Cyanophytes (blue green algae) are non- flagellated photosynthetic bacteria that are often abundant under freshwater nutrient rich conditions. Some cyanophytes are nitrogen fixers, which is beneficial in oligotrophic estuaries. Some species produce toxins which can be harmful if present in high concentration. Although not necessarily numerically dominant, diatoms have relatively large cells and mostly occur on the sediment surface until disturbance or high flow suspends them in the water column. Some diatoms migrate within the water column diurnally.

4.1.2 DESCRIPTION OF FACTORS INFLUENCING MICROALGAE

The factors influencing different microalgal groups are summarised in Table 4-1. Based on these considerations, the expected influence of the different abiotic drivers and states on microalgae can be inferred.

Table 4.1. Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings.

Variable	Microalgal response
Open water area	Proportional reduction of phytoplankton with loss of open water area.
Salinity	Different microalgal species occur across the salinity gradient and thus are useful indicators of prevailing conditions.
Mouth condition	The intertidal zone is often rich in microphytobenthos. Under closed mouth more stable sediment conditions MPBs are also abundant when the water is clear and depth is less than 1 m.
Water flow rate	Under water high flow benthic microalgae are suspended in the water column. Many diatoms that are commonly benthic (epipelic) are common. This is especially the case where the fine sediment fraction is suspended due to turbulence.
Water retention time	Biomass elevated in high retention states.
Floods	Temporary reduction in microalgal biomass as a result of flooding.
Turbidity	High turbidity can limit benthic microalgal biomass but usually not phytoplankton biomass as the cells move into the photic zone in shallow estuaries due to wind mixing and vertical migration.
Water quality	Low nutrient conditions are characterised by maximum species diversity. Diversity decreases at high nutrient concentrations but biomass increases.
Toxins	Literature indicates that there is an unspecified adverse effect with certain toxins
Macrophyte community structure	Microalgae particularly diatoms attached to submerged and emergent macrophytes.
Oxygen levels	Decay of phytoplankton blooms can lower oxygen concentrations.

Although there is little information on the microalgae of the Onrus Estuary it is understood that prolonged periods of mouth closure can result in high nutrient levels that would encourage the proliferation of macroalgae and blooms of microalgae (Massie & Clark 2016). Poor water quality is due to inputs from the sewage lines, stormwater inputs and agricultural return flows. Blooms of the filamentous green macroalgae *Cladophora* spp. have been observed in the estuary.

4.1.3 REFERENCE CONDITION

Relative change from Reference to Present State are summarised in Table 4-2.

Table 4.2. Summary of relative changes from reference to present condition.

Reference condition Key drivers	**Change**
↓ river flow , ↑ mouth closure, ↓ tidal prism	↑ Phytoplankton and benthic microalgal biomass due to greater water retention time.
↓ intertidal habitat due to development & disturbance and reduced tidal prism	↓ Habitat for intertidal benthic microalgae.
↑ nutrient enrichment	↑ Phytoplankton and benthic microalgal biomass as well as epiphytes on expanding reeds. Possibility of nuisance toxic species (HABs – harmful algal blooms) that will outcompete other species.
Total Change	↑ Microalgal biomass, ↓ species richness

4.1.4 MICROALGAE HEALTH

Health scores allocated for the Onrus Estuary in DWS (2017) and for present day (2024) are summarised in Table 4-3. Microalgae communities were regarded as "largely" or "heavily" modified by DWS (2017) as a result of reduced river flow (estimated to be around 60% of natural), increases in nutrient levels in the estuary (up to 10 times that expected under reference conditions), reduced tidal exchange and reduced salinity levels (average levels dropped from around 21 to 14 in 2017). In 2024, nutrient levels in the estuary have increased further since 2017 (30-100% higher), tidal exchange in and out of the estuary has been all but eliminated along with much of the open water and deep subtidal habitats, and salinity in the estuary has dropped to an average of 1 PSU. These changes would all have impacted on microalgae communities in the Onrus Estuary in a dramatic way. Current health of the microalgae community is rated as "highly" or severely" degraded (EHI score = 20).

Table 4.3. Microalgae component health score.

Variable	**Summary of change**	**Score 2017**	**Score 2024**	**Confidence**
1. Species richness	Shift from oligotrophic to nutrient enriched ecosystem, species richness decreases. Increase in mouth closure and shift to more freshwater species. Possible occurrence of nuisance toxic species.	60	40	L
2. Abundance	Reduced freshwater inflow, increases residence time resulting in an increase in biomass of both phytoplankton and benthic microalgae compared to natural conditions. Nutrient rich closed-mouth conditions would favour microalgal blooms.	50	40	L
3. Community composition	Potential shift from diatoms and Chlorophytes to Cyanophytes (blue-green algae) which occur in standing water and outcompete other microalgal groups under nutrient rich, freshwater conditions.	40	20	L
Biotic component health score		**40**	**20**	**L**
Health category		**D**	**E**	

4.2 Macrophytes

4.2.1 Macrophyte groups

The main habitats and macrophytes groups present in the Onrus Estuary are listed in (Table 4-4). The estuary has been encroached by reeds (6.6 ha in 2014) since the 1940/50s (Table 4-4). Reed encroachment and sedimentation was first documented in the estuary in a study conducted as part of the Estuaries of the Cape Series published by the CSIR in the early 1980's (Heinecken & Damstra 1983). It was found that large open water areas were replaced with extensive reed growth between 1921 and 1976. Aerial photographs from 1938, 1961, 1973 and 1989 confirm this trend (Figure 4-1). In 1938, reeds were confined to isolated patches on the northern shore. By 1961 the reedbed had spread along this shoreline, and by 1973, three years before the De Bos Dam was built, the main waterbody was largely covered by reeds. By 1989 the channels were being choked, and open water had been reduced to only 25% of the total estuary area, compared to 61% in 1938. It was concluded that in the absence of a good management policy, sedimentation would continue and that the reedbeds would extend towards the mouth.

Little other macrophyte habitat is present. Records indicate the presence of the submerged macrophyte pondweed *Potamogeton pectinatus*. Some coastal forest with milkwood *Siderxylon inerme* remains at the mouth.

Table 4.4. Macrophyte habitats and functional groups recorded in the estuary (spp. examples in italics). Source: DWS (2017).

Habitat type	Defining features, typical/dominant species	Area (ha)
Open surface water area	Serves as habitat for phytoplankton.	2.59
Sand and mudflats	Sand/mud banks provide a possible area for microphytobenthos to inhabit.	1.86
Reeds and sedges	Common reed *Phragmites australis* and bulrush *Typha capensis* are dominant.	6.57

4.2.2 Baseline description

DWS (2017) published a map of the different macrophyte habitats and their distribution within the 5 m contour around the estuary based on a field survey and 2014 aerial photography (Figure 4-2). Dense monospecific stands of common reed *Phragmites australis* were present on the banks of the estuary (Figure 4-2). In some areas *Phragmites* was replaced by the bulrush *Typha capensis*. Reeds fringing the banks of the mouth were short and sparse compared to the dense stands occurring in the middle and upper reaches of the estuary. Some clumps of *Schoenoplectus scirpoides* were present amongst the reeds.

Heineken & Damstra (1983) identified pondweed *Potamogeton pectinatus* and the algae *Chara* growing together in the bottom sediments of the shallower upper northern part of the lagoon. According to Massie & Clark (2016) red water fern *Azolla filliculoides* has been occasionally recorded in the estuary. The indigenous blue water lily, *Nymphaea nouchali*, was noted in the estuary in the summer of 2011. In July 2016 the estuary was accessed by foot and no submerged macrophytes were noted (Figure 4-3).

A narrow strip of coastal forest dominated by milkwoods *Sideroxylon inerme*, bush tick berry *Osteospermum monilifera* (previously *Chrysanthemoides monilifera*) and invasive rooikrans *Acacia cylops* occurred along the western bank of the estuary. A small percentage of this habitat has been removed due to residential houses and gardens which back onto the estuary. A sedge similar in appearance to young Phragmites, possibly *Ficinia nodosa* (previously *Scirpus nodosus*), fringed the open water in front of the coastal forest (Figure 4-3).

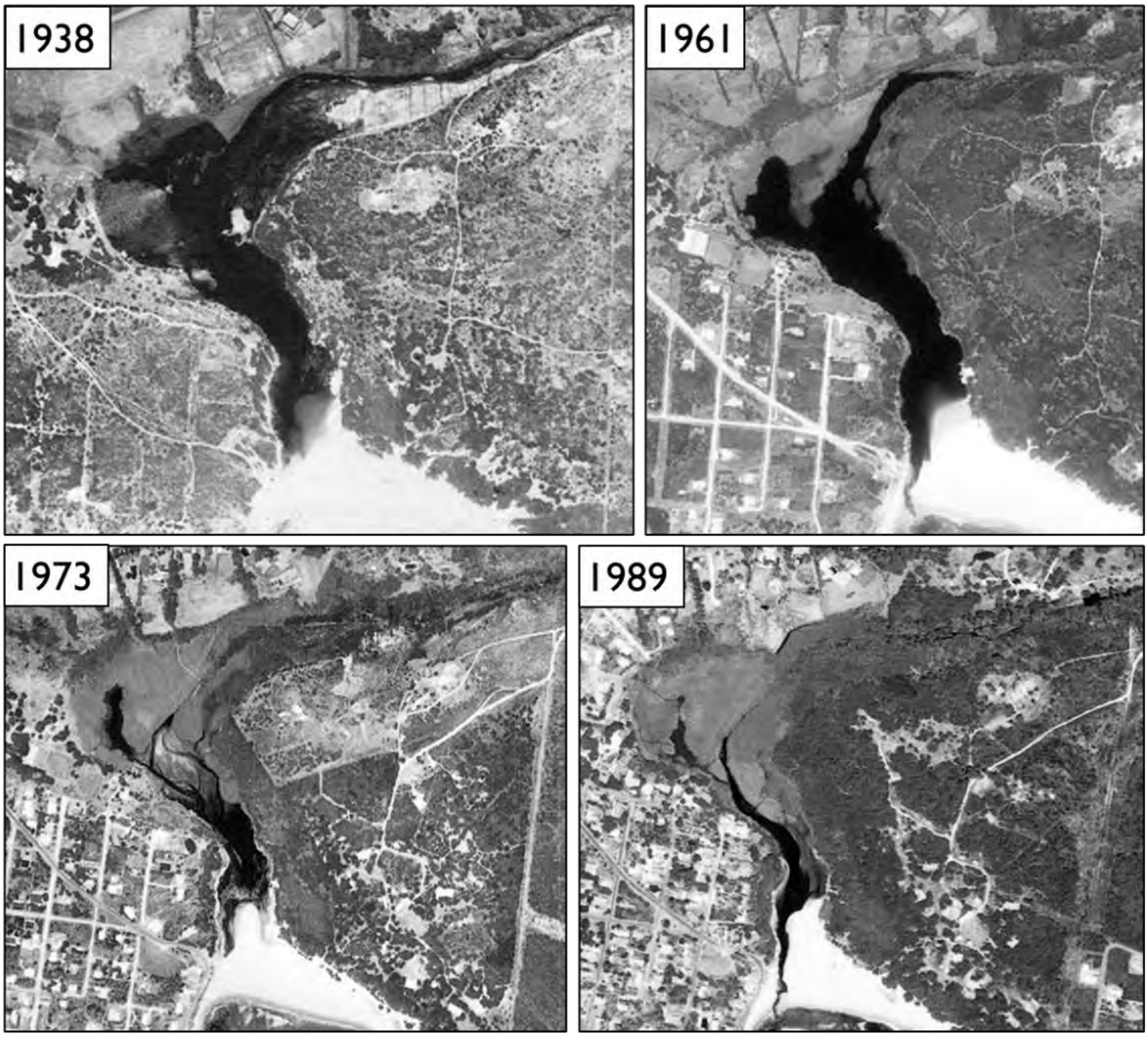

Figure 4-1. Historical aerial photography of the Onrus Estuary in 1938, 1961, 1973, and 1989.

Typical coastal dune vegetation occurred at the mouth of the estuary and behind the reeds on the eastern bank. Dune forest represented by *Carpobrotus acinaciformis, Euclea racemosa, Metalasiamuricata* and Searsia *gluaca* occurred behind the coastal dune vegetation, bordering on the reserve. Wetland species and invasive Kikuyu grass *Pennisetum clandestinum*, was noticeable in the undergrowth of this vegetation. A number of weedy, garden escapees and invasive plants were prevalent in the disturbed habitat near the Habonim camp.

In 2024, some marked changes to macrophytes communities in the EFZ of the Onrus Estuary have taken place since the assessment by DWS (2017). Much of the terrestrial environment surrounding the estuary is now dominated by alien plant species (Figure 4-4). Given that the invaded areas are mostly heavily forested, it is anticipated that the majority of the infestation is from the following invasive tree species: Red-eye wattle *Acacia cyclops*, Plume albizia *Paraserianthes lophantha*, Mousehole tree *Myoporum tenuifolium*. Indeed, it is known that the area to the west of the estuary—including both the Habonim Property and the Municipal land further north—is heavily infested with alien acacia species.

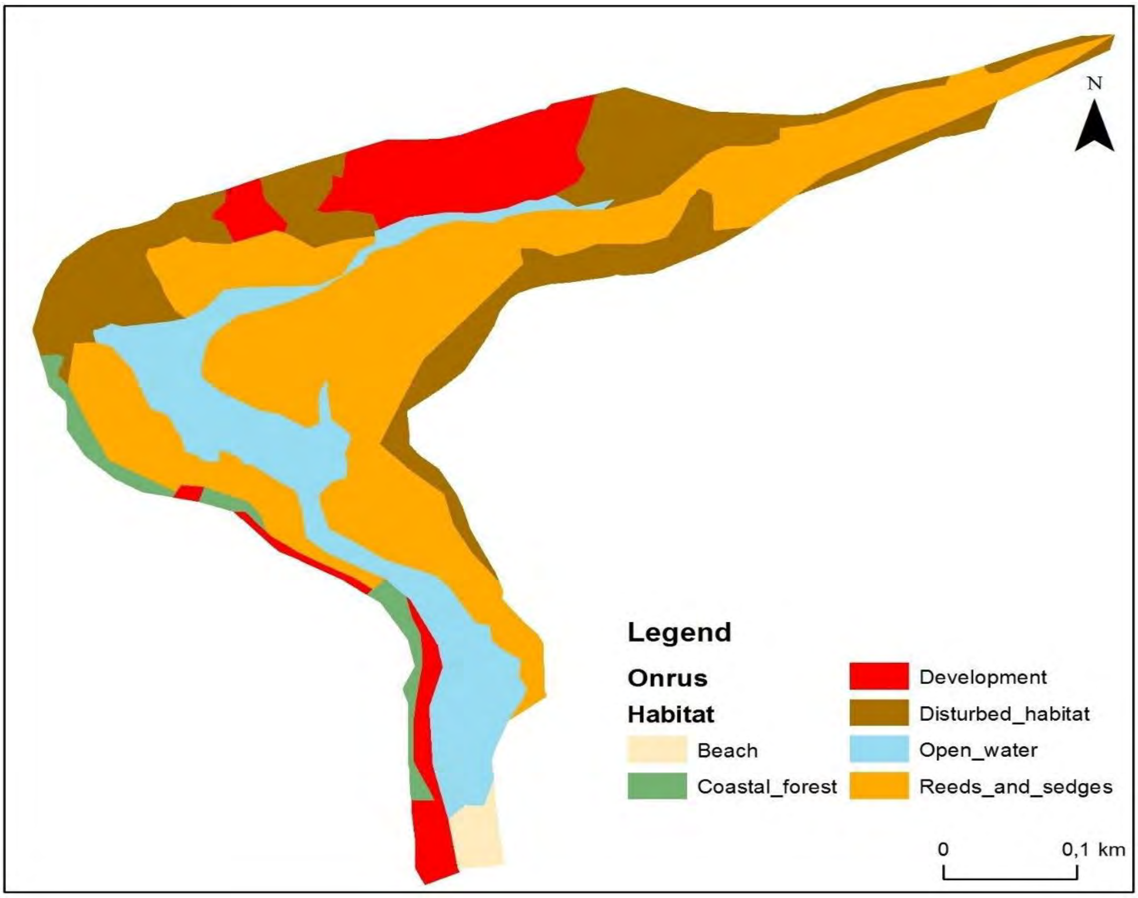

Figure 4-2. Distribution of macrophyte habitats at Onrus Estuary in 2016 based on a field survey and 2014 aerial photography.

Figure 4-3. Photographs of the Onrus Estuary (July 2016). (Source: DWS (2017).

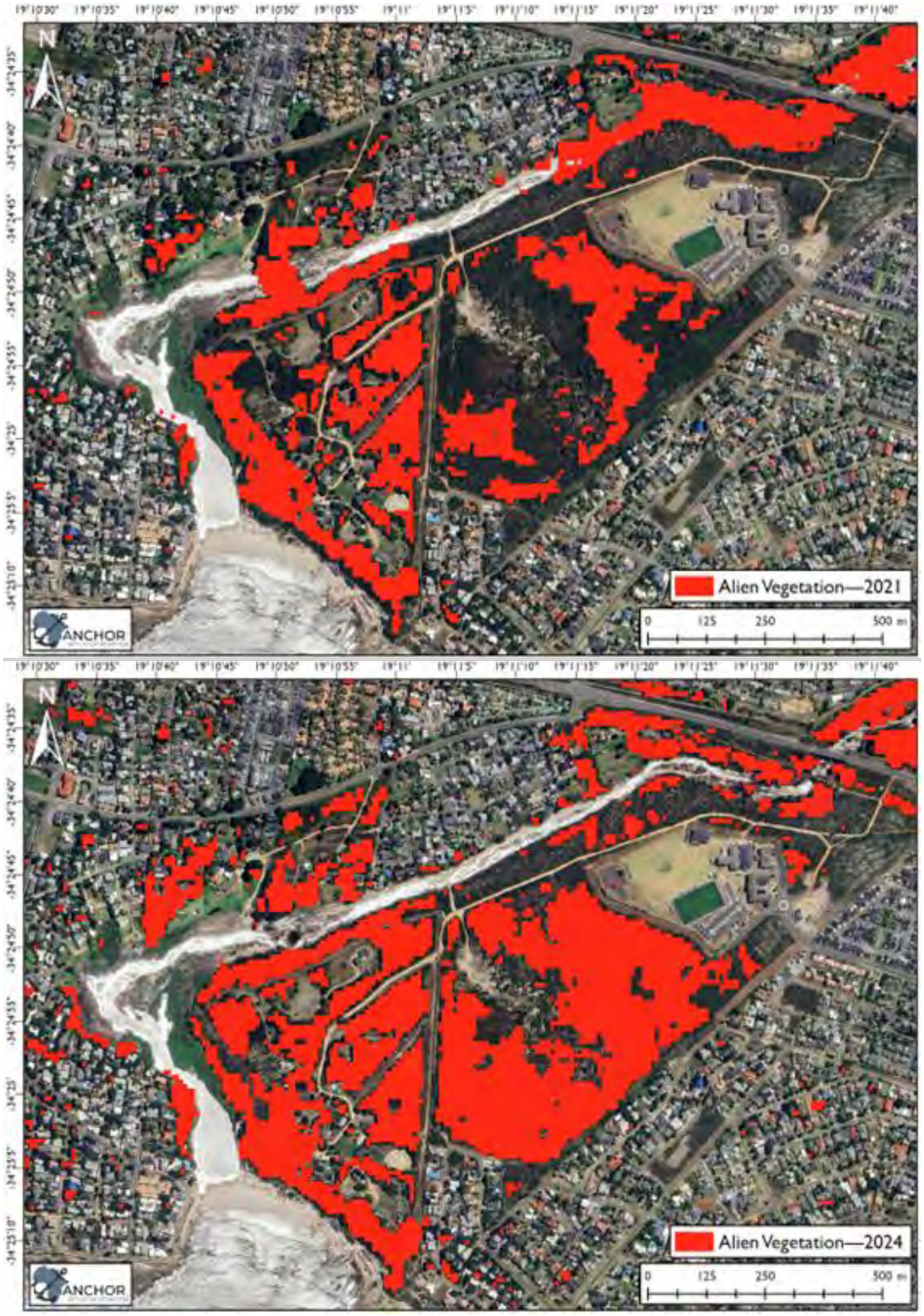

Figure 4-4. Change in the extent of alien invasive vegetation since 2021—as delineated by satellite analysis.

Concerningly, Figure 4-4, which shows the delineated areas of vegetations classified as "alien invasive" according to a recent satellite imagery analysis, has shown that the extent of this alien infestation has increased dramatically since 2021. Whilst it was not possible to fully ascertain the extent of indigenous vegetation remaining in-and-around these alien stands, it is presumed that since much of these invasions are from acacia species, which are known to alter the surrounding soil chemistry and rendering it unsuitable for indigenous plants, little indigenous vegetation likely persists in these areas. Indigenous and alien species identified by the 2018 NBA, and likely to constitute the majority of the present invasions, are listed in Table 4-5.

Furthermore, following the flood in September 2023, which has led to a dramatic reduction in water depth across the entire estuary and a significant reduction in salinity levels in the estuary (reduced from an average of around 21 in 2017 to around 1 now), *Phragmites* are encroaching into the estuary channel at a dramatically increased rate (Figure 4-5). Note that *Phragmites* thrives when nutrient levels are elevated, does not survive well in areas where soil water salinity at the rooting depth is greater than 15 (Lissner & Schierup 1997, Yu et al. 2012), seed germination in *Phragmites australis* is nearly inhibited completely at salinity >3 and thrives under stable, as opposed to fluctuating water levels (Cross & Fleming 1989). The increase in nutrient levels, reduction in salinity and elimination of tidal variations in the Onrus Estuary have created "perfect storm" conditions for encroachment of *Phragmites* into the estuary channel.

Table 4.5. Estuarine vegetation recorded in the Onrus Estuary as of the 2018 NBA.

Macrophyte Species			
Scientific Name	Common Name	Scientific Name	Common Name
Triglochin elongata Buchenau	Upper tidal arrowgrass	*Typha capensis*	Common bulrush
Juncus acutus	Sharp Rush	*Pelargonium capitatum*	Rose geranium
Juncus kraussii	Salt Marsh Rush	*Tetragonia decumbens*	Dune spinach
Stenotaphrum secundatum	St. Augustine grass	*Tetragonia fruticosa*	Kinkelbossie
Stuckenia pectinata	Sago pondweed	*Carpobrotus acinaciformis*	Dune sour fig
Phragmites australis	Common reed	*Ficinia pygmaea Boeck*	Star grass
Schoenoplectus corymbosus	Common Sedge Basket Grass	*Phragmites australis*	Common reed
Alien Invasive Species			
Cortaderia selloana	Pampas grass	*Datura stramonium*	Jimsonweed
Pennisetum clandestinum	Kikuyu grass	*Myoporum tenuifolium*	Mousehole Tree
Schoenoplectus triqueter	triangular club-rush	*Paraserianthes lophantha*	Plume albizia
Datura stramonium	Jimsonweed	*Acacia cyclops*	Red-eye wattle
Canna indica	African arrowroot		

Figure 4-5. Extensive infilling of the Onrus estuary channel and other open water areas means that it is now ripe for invasion by *Phragmites australis*.

The response of macrophytes to physico-chemical/abiotic characteristics and processes, and to the varying abiotic states common within the Onrus Estuary is shown in Table 4-6 and Table 4-7.

Table 4.6. Effect of abiotic characteristics and processes, as well as other biotic components on macrophyte habitats.

Process	Macrophytes
Mouth condition (provide temporal implications where applicable)	The estuary is perched and therefore the frequency and duration of mouth breaching would influence removal of sediment and reed habitat. Salt marsh does not occur due to lack of intertidal habitat and saline conditions.
Retention times of water masses	Low flow and long water retention times encourages the establishment of submerged macrophytes and macroalgae in the Onrus Estuary.
Flow velocities (e.g. tidal velocities or river inflow velocities)	Low river and no tidal flows enables the establishment of submerged macrophytes and macroalgae. High flow velocity during floods would remove reeds.
Total volume and/or estimated volume of different salinity ranges	The estuary is fresh, except for short periods during open mouth conditions following flooding events. This limits the establishment of salt marsh habitat. The lack of a salinity gradient restricts species richness.
Floods	Large floods are important for breaching of the sandbar at the mouth and enables mixing of water to reduce nutrient concentrations. During floods some of the accumulated sediment and reeds are removed from the estuary.
Salinity	Because the estuary has little tidal influence macrophyte diversity is low. Historically it has always been freshwater dominated system but is now even more fresh than ever.
Turbidity	Submerged macrophytes have been recorded in calm areas amongst the reeds.
Dissolved oxygen	The estuary is well oxygenated. Input of organic matter from decaying reeds during closed mouth conditions could result in localized low oxygen concentrations.
Nutrients	Low salinity together with high nutrient inputs would increase macrophyte growth particularly reeds and sedges that have increased in abundance since reference conditions. This can be related to sedimentation and nutrient input from sewage spills and urban run-off. These fringing reeds and sedges play an important role in nutrient uptake.
Sediment characteristics (including sedimentation)	Sedimentation and shallowing of the estuary particularly in the middle and upper reaches would encourage the growth and expansion of reeds and sedges into the main water channel.
Other biotic components	Cattle grazing on the reeds has been recorded in the past. Invasive plants were common.

Table 4.7. Summary of macrophyte responses to different abiotic states.

State	Response
Closed	Elevated nutrient level, low salinity and stable water levels that are associated with closed mouth conditions will all facilitate expansion of reeds in the estuary
Semi-closed	Macrophytes will change in response to water level fluctuations with reeds expanding when water level is low.
Open	Submerged macrophytes and macroalgae will be lost due to scouring and tidal flow. Some reed habitat may be removed due to scouring.

4.2.3 Reference condition

Reed encroachment has been problematic in the estuary since the 1940/50s following sedimentation due to erosion from catchment activities and reduced freshwater inflow which prevents the breaching of the mouth and scouring of the estuary. The dense rhizomes of the *Phragmites* roots further encourage siltation. Nutrient enrichment from catchment activities and sewage spills further encourages reed growth. Although dredged in 1993/4 to remove accumulated sediment and reeds, reeds are still abundant. Table 4-8 summarises management and changes in reed habitat over time in the estuary. Disturbance and development have led to a decrease in natural vegetation surrounding the estuary and resulted in invasion by garden escapees and invasive plant species. Table 4-9 summarises the main changes in macrophytes at the Onrus Estuary over time.

It is likely that the entire estuary channel will soon be invaded by *Phragmites* beds leaving little other habitat in the estuary.

Table 4.8. History of management of reed encroachment at Onrus Estuary (source Massie & Clark 2016).

Year	Action
1938	61% of the estuary area was open water. Reeds confined to isolated patches on the northern shore.
1961	Reeds has spread along the northern shorelines
1973	Water body largely covered by reeds
1989	Open water reduced to only 25% of the total estuary area
1993	Reed beds comprised 3.8 ha. Dredging of the estuary to remove accumulated sediment and 1.5 ha of reeds.
2002	Rehabilitation report showed no significant sedimentation since dredging except for some sedimentation that occurred during a flood shortly after the dredging.
2012	Residents cleared the *Phragmites* stand present on the eastern side of the estuary and planted arum lilies on the reed rhizomes. Some of this habitat was taken over by *Typha* and the remaining cleared areas by *Commelina* sp. suppressing reed growth

Table 4.9. Summary of relative changes in macrophytes from Reference Condition to Present state.

Drivers	Changes
↓ river flow	↑ sedimentation and reed growth
↑ nutrients	↑ growth of all macrophytes
↑ mouth closure	↑ residence time of water, reed and macroalgal growth
↑ development, disturbance and invasive plants	↓ floodplain habitats

4.2.4 Macrophyte health

The health of the macrophytes was assessed in terms of species richness, abundance and community composition. Change in species richness was measured as the loss in the average species richness expected during a sampling event, excluding species thought to not have occurred under Reference conditions (Table 4-10). Richness has only changed slightly dropping from 80% of natural in 2017 to 70% of natural in 2024 (Table 4-11) Abundance was measured as the change in area cover of macrophyte habitats (% similarity = 100*present area cover / reference area cover). Much of the floodplain of the Onrus Estuary (3.26 ha) has been removed by disturbance and development. Reed encroachment (156% increase in 2017 and a further 7% in 2024) has significantly reduced open water habitat (Table 4-10). Under natural conditions invasive plant species would not have occurred in the system, however satellite imagery shows that the distribution of these species has increased significantly in the EFZ in the last few years. Change in community composition was assessed using a similarity index which is based on estimates of the area cover of each macrophyte habitat in the reference and present state. (Czekanowski's similarity index: ∑ (min (ref,pres) / (∑ref + ∑pres)/2)). The macrophytes were rated as being 49% similar to what they were under reference conditions in 2017 (DWS 2017), but this has now dropped to 30% in 2024.

Table 4.10. Summary of how the macrophytes in the Present condition have changed relative to the Reference condition.

Estuary habitat	Reference	Area (ha) in 2016	Area (ha) in 2024
Open water	6.59	2.59	0.3
Reeds and sedges	2.57	6.57	7.01
Coastal forest	0.78	0.42	0.42
Floodplain	3.26		
Sand/mud banks	1.86	1.86	3.71
Development		3.42	3.42
Disturbed habitat		0.19	0.19
TOTAL	**15.05**	**15.05**	**15.05**

Table 4.11. Similarity scores of macrophytes in 2017 (DWS 2017) and Present condition (2024) relative to the Reference condition.

Variable	Change from natural	Score		Confidence
		2017	2024	
1. Species richness	Species have been lost because of the less dynamic environment, reed encroachment, disturbance of the floodplain areas and presence of invasive species.	80	70	M
2. Abundance	Development and disturbance have resulted in the loss of indigenous vegetation.	76	58	M
3. Community composition	Open water habitat has been lost to encroachment by reeds and sedges. Floodplain habitat has been lost due to development and invasive plant growth. Nutrient enrichment encourages the growth of macroalgae and invasive floating aquatic macrophytes.	49	30	M
Macrophyte health score		**49**	**30**	**M**
Health category		**D**	**E**	

4.3 INVERTEBRATES

4.3.1 BASELINE CONDITION

Estuarine invertebrates can be divided into a number of sub-groups based on where they reside in the estuary. Zooplankton live mostly in the water column, benthic organisms live in the sediments on the bottom and sides of the estuary channel, and hyperbenthic organisms live just above the sediment surface. Benthic organisms are frequently further subdivided into intertidal (those living between the high and low water marks on the banks of the estuary) and sub-tidal groups (those living below the low water mark).

There is no available information on the Zooplankton inhabiting the Onrus Estuary and very limited information on benthic and hyperbenthic invertebrates. The invertebrate information is restricted to the 1983 CSIR report on the Estuaries of the Cape (Heinecken & Damstra 1983) and forms the baseline description of the Onrus Estuary. The 1979-1980 survey identified 23 benthic and hyperbenthic invertebrate species from six taxonomic classes (Heinecken & Damstra 1983; Table 4-12). The seaward end of Onrus Estuary was predominantly inhabited by the sandprawn *Callichirus kraussi* in shallow areas, while Crown crabs, *Hymenosoma orbiculare* occurred in slightly deeper water (Heinecken & Damstra 1983). Amphipods, polychaetes, tanaids and chironomid larvae were also present in this area (Table 2.34).

The upper parts of the estuary were characterised by muddy substrate which was inhabited by Amphipods, polychaetes and chironomid larvae but in relatively low numbers. Mussels (*Brachidontes virgiliae)* attach to waterlogged branches and submerged rocks. In the upper reaches the amphipod, *Americorrophium triaeonyx* and tanaid, *Tanais stanfordi* were abundant with polychaetes, amphipods, isopods *Corixidae* sp. and Chironomid larvae being present. The anoxic blind arm supported populations of the polychaete, *Ceratonereis keiskama*; amphipod, *Americorrophium triaeonyx*; along with Chironomid larvae. The submerged algae *Chara* and macrophyte *Potamageton pectinatus,* provided habitat for several species of invertebrates (Heinecken & Damstra 1983; Table 4-12), although there were no noted submerged macrophytes in July 2016, which indicated the loss of this habitat type. Additionally, the island of *Scirpus littoralis* provided habitat for amphipods, isopods and numerous insect larvae while the *Phragmites* reed beds hosted a similar suite of invertebrates as well as two species of Arachnida (Heineken & Damstra 1983; Table 4-12).

Subsequent to the 1979-1980 survey, dredging was conducted in 1993, removing about 30 000 m^3 of sediment (Massie & Clark 2016). In this process the island of *Scirpus littoralis* was removed as well as a large area of *Phragmites* spp. reed beds. Dredging would have further impacted the submerged *Chara* and *Potamageton pectinatus* habitats as well as soft sediments used by benthic organisms as habitat.

Turpie et al. (2012) attempted to assess the health of the Onrus Estuary in 2012, based on the information available and some limited in situ observations. They rated the health condition of the invertebrate fauna in the estuary as being in fair condition. It has been noted since this time that prawn holes had disappeared from the lower reaches of the estuary (Massie & Clark 2016). This is likely due to the predominately semi-closed state of the estuary which had resulted in salinity remaining in the range 5-10 ppt (Table 3-10) which is below the requirements for *C. kraussi* breeding (minimum of 17 ppt; Massie & Clark 2016). It was considered likely that crown crabs, *Hymenosoma orbiculare* would still have been present in the lower reaches of the estuary as this species has been recorded in salinities as low as 1 ppt (Massie & Clark 2016).

Table 4.12. List of invertebrates found at the Onrus Estuary and associated habitats (Relative abundance: Rare (R)= 1, Present (P) = 2 – 10, Common (C) = 11 – 50, Abundant (A) = > 50 specimens collected; Heineken & Damstra 1983), SS = Sandy substrate, MS = muddy substrate.

Class	**SS**	**MS**	**Rock in MS**	**Log in MS**	***Chara***	***Potamogeton pectinatus***	**Blind arm**	**Decomposing kelp**	***Phragmites* bed**	***Scirpus littoralis* Island**
Polychaeta										
Ceratonereis keiskama	P	C		P			P			R
Crustacea (sub-phylum)										
Americorophium triaeonyx	C	C	C	A	P	P	P		R	R
Melita zeylanica			R	R					P	P
Pseudosphaeroma barnardi			P	A						
Cirolana africana				P					C	
Tanais stanfordi	P		P	C	A			R		
Callichirus kraussi	P									
Hymenosoma orbiculare	P									
Insecta										
Crocothemis erythraea					R					
Zygopteran nymph					P					
Cloeon lacunosum									R	
Coleopteran										R
Gyrinidae adult		R							C	P
Hydrophilide larvae										P
Corixidae			C						C	
Chironomus sp. 1 larvae								P	C	C
Chironomus sp. 2 larvae	R	R			R		P	P	C	C
Chironomid larvae	P	C		R	C	C	C	P		P
Chironomid larvae	R	R		R	C	P	P			R
Arachnida										
Araneae 1									R	
Araneae 2									R	
Gastropoda										
Helicon juveniles	P									
Bivalvia										
Brachidontes virgiliae		P	A	A		P				C

As part of this study, we sampled invertebrates at six stations up the length of the estuary in October 2024 (Figure 3-10 and Figure 4-6). Sampling was conducted with a hand corer which samples an area of 0.025 m^2 and volume of 0.76 m^3. Three replicate cores were collected at each site. Numbers of invertebrate taxa and their abundance in the estuary was extremely low. A total of only nine taxa and 31 individuals were recorded, with more than half of the samples (11 out of 18) being completely empty (Table 4-13). Most of the taxa recorded were freshwater species which is consistent with very low salinity levels recorded in the estuary (Table 3-8). The absence of sandprawns *Callichirus kraussi* is noteworthy. This represents a very dramatic reduction in health status of the invertebrate community in the estuary relative to that recorded by Heinecken & Damstra (1983). The recent flood and resultant deposition of sediment in the system has all but eliminated benthic invertebrate fauna from the estuary. Species that remain are mostly of freshwater origin.

Figure 4-6. Sampling the Onrus Estuary in 2024.

4.3.2 Reference condition

Under reference conditions the estuary would have had regular estuarine breaches due to high flow rates. Estuarine breaches would ensure input of seawater into the system which would have allowed the presence and persistence of marine invertebrate taxa (e.g. *C. kraussi*) both through increased salinities and recruitment from the marine environment. Scouring of the estuarine habitat under high flow rate regimes would prevent the build-up of dense anoxic muds which generally exclude benthic organisms. The *Scirpus littoralis* and *Phragmites* reed beds would've been present in the reference condition providing habitat for invertebrates.

Table 4.13. Species composition and abundance of benthic invertebrates from core samples collected from six sites in the estuary in 2024. Three replicate samples were collected at each site. FW = Freshwater, M/E = Marine/Estuarine.

Species	Origin	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Annelida																			
Capitellidae sp	FW	3											1						
Oligochaeta sp	FW								1	5			1						
Sipuncula sp	FW																1		
Arthropoda																			
Hymenosoma orbiculare	M/E	1																	
Caridea sp	M/E		1																
Talorchestia quadrisinasa	M/E			8															
Podocerus sp	M/E								1										
Insecta																			
Chironomus larvae	FW	4	2	1															
Insect larvae	FW		1																

4.3.3 INVERTEBRATE HEALTH

There has been a dramatic change in the invertebrate community of the Onrus Estuary between what was recorded by Heinecken & Damstra (1983) and that recorded in 2024. Numbers of species present and their abundance has declined dramatically. Heinecken & Damstra (1983) recorded individuals from more 23 taxa, several of which were described as being abundant (>50 specimens collected) or common (11-50 specimens collected) while surveys conducted in 2024 recorded a total of 31 individuals from only nine taxa. Freshwater taxa made up an important contribution to the number of taxa and individuals recorded by Heinecken & Damstra (1983) but were overwhelmingly dominant in 2024. It is likely that conditions in the estuary had already changed quite dramatically from Reference conditions when Heinecken & Damstra (1983) did their surveys. (DWS 2017) scored the health of the invertebrate community at 55% (D category) but this has clearly got very much worse since this time (Table 4-14). We suggest that invertebrate abundance has been most significantly affected (20%), followed by species richness (30%) and community composition (35%). This brings the overall health score for 2024 to 20% (minimum of these three metrics). Confidence in this assessment was rated as "Medium".

Table 4.14. Invertebrate health scores for 2017 (DWS 2017) and Present Day (2024) relative to the Reference Condition.

Variable	2017	Present (2024)	Confidence
a. Species richness	55	30	M
b Abundance	65	20	M
c. Community composition	55	35	M
Score min (a to c)	**55**	**20**	**M**

4.4 Fish

4.4.1 Baseline description

Three historic reports are available on the ichthyofauna of the Onrus Estuary; these include data collected during the 1980 ECRU survey (Heinecken & Damstra 1983), a survey undertaken by Harrison (1999) in 1994 and another by (Turpie & Clark 2007) in 2006. A total of 10 species were identified as being present in the estuary in these studies (Table 4-15). These include three estuarine resident species, Estuarine round herring *Gilchristella aestuaria*, Knysna sand goby *Psammagobius knysnaensis* and Silverside *Atherina breviceps,* all of which breed in estuaries (the latter two also have marine breeding populations). Juvenile flathead mullet *Mugil cephalus* are dependent on estuaries as nursery areas, whilst juvenile southern mullet *Chelon richardsonii (*formerly *Liza richardsonii)* and white stumpnose *Rhabdosargus globiceps* occur in estuaries but are generally more common at sea. The freshwater mullet *Myxus capensis* breeds at sea, but uses estuaries as nursery areas and spends much of its adult life in rivers (catadromy). Both Cape galaxias *Galaxias zebratus* and Mozambique tilapia *Oreochromis mossambicus* are euryhaline freshwater fish, although the latter has expanded its range, being native to the more tropical waters of Kwa-Zulu Natal and Eastern Cape (Whitfield 1994, Lamberth et al. 2008). The freshwater fish Cape kurper *Sandelia capensis* was only recorded in 1980.

Table 4.15. Relative abundance (average number per haul) of fish species list sampled in the Onrus Estuary during surveys conducted in 1980 (Heinecken & Damstra 1983), 1994 (Harrison 1999) and 2006 (Turpie & Clark 2007). EDC: Estuarine Dependence Category (Whitfield 1998).

Species	Common name	EDC	1980	1994	2006
Gilchristella aestuaria	Estuarine round herring	IA	<10	5	433
Atherina breviceps	Silverside	IB			1
Psammogobius knysnaensis	Knysna sandgoby	IB	>50	18	315
Mugil cephalus	Flathead mullet	IIA		36	250
Chelon richardsonii	Southern mullet	IIC	<50	515	313
Rhabdosargus globiceps	White stumpnose	IIC	<10		5
Sandelia capensis	Cape kurper	IV	<10		
Galaxias zebratus	Cape galaxias	IV	<10		
Oreochromis mossambicus	Mozambique tilapia	IV			12
Myxus capensis	Freshwater mullet	VB		1	1

In September 1994, the estuary mouth was open and salinity 200 m upstream of the mouth measured 31.7 PSU (Harrison 1999). Concurrently, the estuary had just been dredged and was likely to be highly disturbed at the time. In these conditions, the estuary was dominated by mullet, where *C. richardsonii* and *M. cephalus* represented 96% of four seine hauls with 90% and 6% respectively (Figure 4-7). The few large *M. cephalus* contributed the same biomass as *C. richardsonii*, together making up 91% of the total biomass caught. In comparison, *G. aestuaria* and *P. knysnaensis* were very scarce (Figure 4-7). The range of size classes of *M. cephalus* and *C. richardsonii* represented during this survey suggests regular recruitment of these species, indicating that the system was being utilised as a juvenile nursery area. The majority of specimens of *P. knysnaensis* were almost fully grown, which indicates that the Onrus was still a viable habitat for resident estuarine species.

The Onrus Estuary was sampled in March 2006, most likely during closed or semi-closed mouth conditions and 13 years after the estuary was dredged for the purpose of combating reed encroachment (Turpie & Clark 2007). Consequently, the estuary had much greater open water area than when Harrison had sampled, and the habitat would have had a chance to recover since 1993. In total, eight species were caught in four seine hauls (Table 4-15). It is evident that compared to dredged and open mouth conditions in 1994, the species composition was dominated by estuarine resident species including *G. aestuaria* and *P. knysnaensis* making up 69% of the total abundance (Figure 4-8). *C. richardsonii* was also very abundant with 29% and represented 73% of the total biomass recorded. Catadromous *M. capensis* and freshwater fish *O. mossambicus* were not very abundant but represented 4% of the total biomass, which is much higher than in 1994.

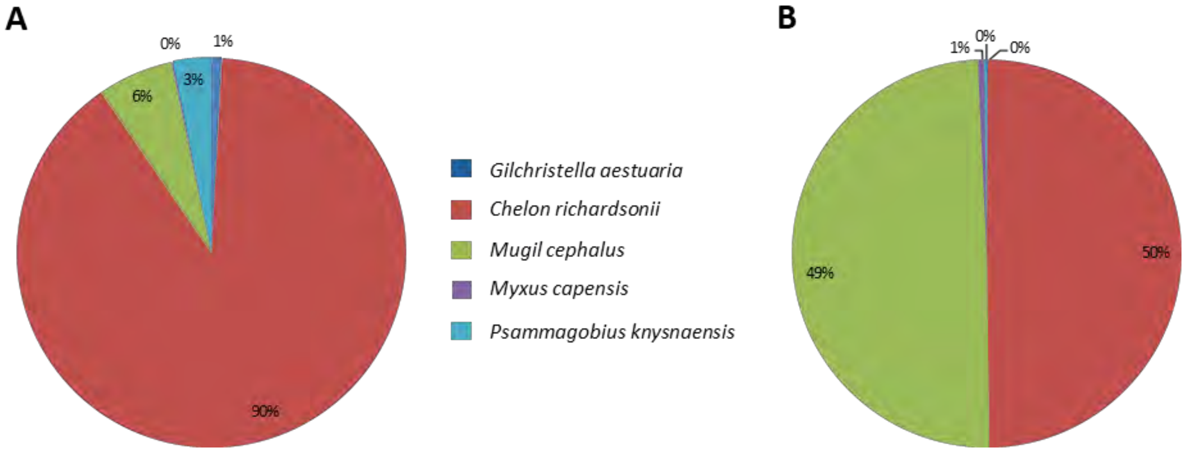

Figure 4-7. Fish species composition of the Onrus Estuary in September 1994 during open mouth conditions. Figure A and B show relative abundance and biomass, respectively (Data source: Harrison 1999).

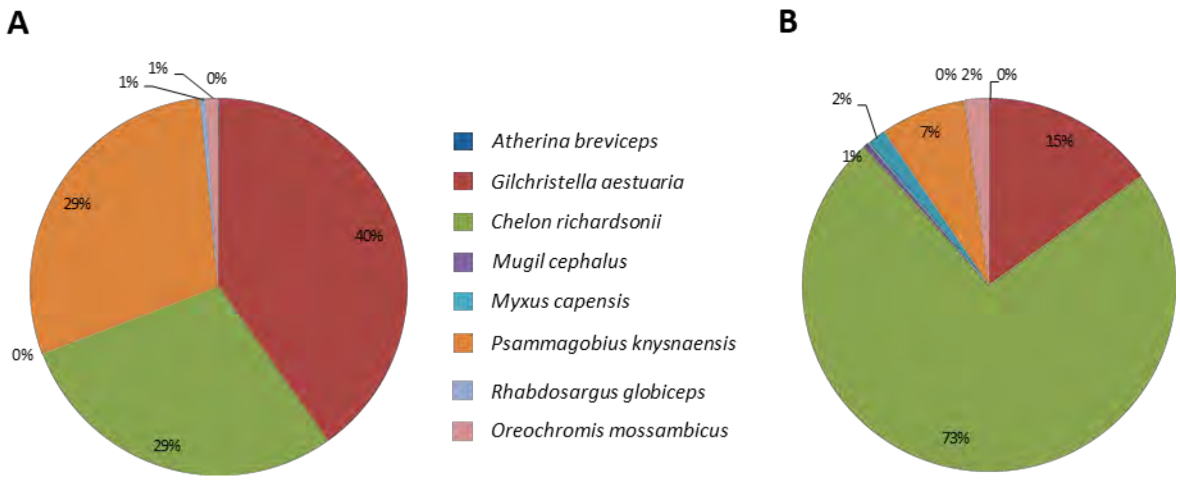

Figure 4-8. Fish species composition (A: based on abundance and B: Biomass) of the Onrus Estuary in March 2006 during suspected closed mouth conditions (Data source: Turpie & Clark 2007a).

A survey of the fish fauna of the Onrus Estuary was undertaken as part of this study in October 2024. Sampling was conducted using a beach seine net with samples taken at six sites up the length of the estuary (Figure 3-10). A total of only four species of fish were recorded with the most abundant being the mullet (*Chelon richardsonii* and *Mugil cephalus)* and estuarine round herring *Gilcristella aestuaria* (Table 4-16). Knysna sandgoby *Psammagobius knysnaensis* were caught in small numbers at one site right near the mouth only (Table 4-16). No fish were recorded above Site 3 in the estuary. Both the numbers of fish species and total abundance of fish present in the estuary have dropped quite dramatically since the earlier surveys in 1980, 1994 and 2006. Number of species ranged from 6-8 across these three surveys and total abundance ranged from around 70-1100 fish/haul. This must be contrasted with only 4 species recorded in 2024 and an average of 55 fish per haul (Table 4-16).

Table 4.16. Species composition and abundance of fish recorded in seine net hauls made at six sites in the Onrus Estuary in 2024. EDC: Estuarine Dependence Category (Whitfield 1998).

Species	Common name	EDC	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Gilcristella aestuaria	Estuarine round herring	IA	96					
Psammagobius knysnaensis	Knysna sandgoby	IB	4					
Chelon richardsonii	Southern mullet	IIA	164	33	16			
Mugil cephalus	Flathead mullet	IIC	18					

4.4.2 REFERENCE ICHTHYOFAUNAL COMMUNITY

Under reference conditions, the estuary was probably tidal just under half the time (43% open mouth phase), whilst marine connectivity was maintained during the semi-closed phase for much of the remaining time. Sandy marine derived sediments were probably more common in the lower estuary; the water was oligotrophic and clear and open water habitat was much greater than at present. These conditions would have provided suitable foraging and nursery areas for adults and juveniles of a wide range of marine migrant species, both estuary-associated marine species as well as marine 'vagrants' – e.g. white steenbras *Lithognathus lithognathus*, leervis *Lichia amia*, white stumpnose *Rhabdosargus globiceps* and elf *Pomatomus saltatrix*. These species, together with sand (as opposed to mud) associated estuarine resident species such as the Cape sole *Heteromycteris capensis* and knysna sand goby *Psammogobius knysnaensis* were most likely present, or much more abundant in the estuary under reference conditions. As was the case more recently, mullet species (mostly *Chelon richardsonii, Myxus capensis,* and *Mugil cephalus,* probably also *L. dumerilii*) would have been very important in the system. It is possible that mullet were more abundant due to the greater open water habitat available under Reference conditions. Alternatively, the waters were clear and oligotrophic, and the decreased productivity and increased predation by piscivorous marine fish may have had negative impacts on mullet (and other shoaling species such as silversides and estuarine roundherring) abundance under reference conditions. The silverside *Atherina breviceps* would probably have been more abundant in the clear, marine influenced water, whilst *Gilchristella aestuaria* (currently the most abundant species) would have probably been less dominant. Cape kurper and Cape galaxias would probably only rarely have entered the estuary during floods when freshwater conditions dominated.

Mozambique tilapia would not have been found and eels *Anguilla mossambica* and *A. marmorata* elvers and adults would probably have migrated through the estuary on a regular basis (their existence in the system under present conditions is unknown but considered very unlikely).

4.4.3 FISH HEALTH

Under present conditions, the mouth of the Onrus is predominantly closed or semi-closed (~95 % occurrence), but may break open for short periods after heavy rainfall several times during the year (See Section 3.2). The narrow channel that mostly functions as an overflow from the estuary can scour deeper, resulting in brief periods of tidal influence before it closes again. During closed or semi-closed mouth conditions seawater only enters the estuary via the overflow at spring tides if at all.

When the mouth is closed, seawater may enter the lagoon when waves break over the sand bar particularly during storm conditions (Heinecken & Damstra 1983). The fish composition described above demonstrates that even with limited interaction between the sea and the estuary, as was the case until last year, the Onrus Estuary still played a role in recruitment of larval and juvenile marine fish. It is possible that the removal of large areas of the common reed *Phragmites australis* in 1993/1994 temporarily improved the fish nursery function of the Onrus Estuary, but ongoing sedimentation and regrowth of reeds has negated much of the improvement in habitat associated with the dredging. However, this likely changed dramatically following the flood in September 2023.

The reduced flow, reduced open water area and depth, reduced seawater penetration (and hence salinity), increased nutrients and organically enriched, muddy sediments are anticipated to be primarily responsible for the major reduction in abundance and species richness of fish in the Onrus system. In particular estuarine dependent marine species (Category IIb species) were probably present under reference conditions but have been absent in all surveys conducted over the last three decades. Reduced recruitment due to limited connectivity with sea and reductions in open water habitat (due to siltation and reed encroachment) strongly suggest that present day fish abundance is much less than under reference conditions.

Health of the fish community in the Onrus Estuary is considered to be highly impoverished at present relative to conditions in 2017, but especially relative to Reference conditions (Table 4-17). Abundance has been most severely affected (down from 50% in 2017 to 25% now), followed by species richness (down from 65 to 30%) and community composition (down from 65 to 35%). Overall health score at present was judged to be an "E" category (25%).

Table 4.17. Fish health scores for 2017 (DWS 2017) and Present Day relative to the Reference Condition.

Variable	2017	Present (2024)	Confidence
a. Species richness	65	30	M
b Abundance	50	25	M
c. Community composition	65	35	M
Score (minimum a to c)	**50**	**25**	**M**

4.5 Birds

4.5.1 Baseline description

The Onrus Estuary is classified as a small, black water, sandy estuary, where very few bird species are expected to occur (Turpie & Clark 2007). Due to the lack of tidal influence and flood plain habitats, the estuary is not particularly important for waterbird species. The health of the Onrus Estuary avifaunal community was rated as "Fair" in the National Biodiversity Assessment (Van Niekerk & Turpie 2012), which is likely explained by the reduced flow rates resulting in increased mouth closure, as well as poor water quality and human disturbance. The most recent NBA (2020), rate's the avifaunal health of the estuary as "Moderately Modified (C)" compared with reference conditions.

Relatively little historic information is available on the avifauna of the Onrus Estuary for the pre-2000 period, yet this has improved greatly in the two decades preceding the drafting of this MMP. In November 1979, a total of 28 bird species were recorded by Damstra (1980) including the relatively uncommon Pied Avocet, Swift Tern and Water Thick-knee as well as Pied Kingfisher and Malachite Kingfisher.

A count of all waterbirds was carried out by Underhill & Cooper (1983). During this count in January 1981 a total of 10 waterbirds from four species were counted including five Red-knobbed Coots, one Water Thick-knee, three Hartlaub's Gulls and one Cape Wagtail. None of the species recorded are estuary-dependent species as defined by Turpie et al. (2012). The dense reed beds in the middle and upper reaches of the estuary support a high density of breeding passerines, including Yellow and Southern Red Bishops and Cape Weavers. The dense reed beds provide shelter and food. Red-knobbed Coots are the most common waterfowl in the estuary and feed on the *Potamogetan* and *Chara* beds (Heinecken & Damstra 1983).

More recent surveys at the Onrus River estuary have recorded a total of 171 bird species over the last two decades, including rare vagrants and summer migrants. While the reed beds support higher numbers of passerine species, the encroachment of *Phragmites* in the lower reaches of the estuary has led to a decrease in overall avian diversity by reducing the area of open water habitat available. Of the 171 species recorded, 53 of them have not been seen since around 2015; the vast majority of which are species that rely on open water habitat for feeding and foraging (Odendal 2019).

In addition to the encroachment of *Phragmites* reeds, the avian diversity at Onrus River estuary has been heavily impacted by the September 2023 flood event. Prior to the flooding event, an average of ~150 individuals representing ~27 species were recorded during Coordinated Waterbird Counts (CWAC) (Table 4.18). This dropped substantially after the flood event to only 8 individuals representing 3 species during the November 2023 counts. While the number of birds recorded had risen in the February 2025 counts (110 individuals), the species diversity is still low, with only 12 species being observed, and has not yet recovered to pre-flood levels (Odendal 2019). The high number of individuals is largely attributed to an influx of African Sacred Ibises in response to a sewage spill (pers. comms. Anton Odendal). The African Scared Ibis is an opportunistic feeder that preys on a variety of insects, crustaceans, worms, frogs, fish and carrion. The are often found around sewage works.

A survey of the estuary in 2024 was conducted as part of this study. Waterbirds present on the estuary were counted in five discrete areas encompassing the full extent of the estuary functional zone (Figure 4-9). A total of 39 water birds from nine species were recorded (Table 4-18). This is very similar to the numbers of birds recorded by Underhill & Cooper (1983) but is very much more depauperate than the bird fauna recorded by Damstra (1980). This suggests that bird number and species composition has changed quite dramatically since the 1970s but possibly not as much since the 1980s. Alternatively, the survey by Underhill & Cooper (1983) may have been conducted under suboptimal conditions. Low numbers of waders and absence of wading birds on the estuary is consistent with the poor (or absence of any) tidal exchange and low invertebrate and fish biomass in the estuary.

The most species-rich taxa observed on the estuary in the past were the Charadriiformes (waders, gulls and terns) and Passeriformes (warblers, wagtails, bishops, canaries, weavers etc.). The Onrus Estuary is/ has been home to species that are fairly difficult to find in many parts of the Overberg such as the Little Bittern *Ixobrychus minutus*, Purple Heron *Ardea purpurea*, Black-crowned Night-Heron *Nycticorax nycticorax* and African purple swamphen *Porphyrio madagascariensis*, and Southern tchagra *Tchagra tchagra.* Furthermore, large numbers of Barn Swallows *Hirundo rustica* were known to roost in the reedbeds in summer, while the many eucalyptus trees and other exotics along the Onrus River are used for breeding by a variety of raptors that include African Goshawk *Accipiter tachiro*, African Harrier-Hawk *Polyboroides typus*, Black sparrowhawk *Accipiter melanoleucus* and Little sparrowhawk *Accipiter minullus* (Massie & Clark 2016).

Table 4.18. Co-ordinated Waterbird Counts (CWAC) for Onrus River Estuary (provided courtesy of Anton Odendaal, birding@overberg.co.za)

Species (Roberts 7)	Scientific name	IUCN Status	Count Totals					
			05-Nov-22	10-Feb-23	16-Apr-23	September 2023 Flood	04-Nov-23	15-Feb-25
Coot, Red-knobbed	*Fulica cristata*	LC	7	4	2			
Cormorant, Reed	*Microcarbo africanus*	LC	2	4	6			2
Cormorant, White-breasted	*Phalacrocorax lucidus*	LC	5	2	3			4
Crake, Black	*Amaurornis flavirostra*	LC	1	.	.			
Darter,African	*Anhinga rufa*	LC	2	3	1			
Duck, Yellow-billed	*Anas undulata*	LC	9	6	6			
Egret, Cattle	*Bubulcus ibis*	LC	21	19	14			9
Egret, Little	*Egretta garzetta*	LC	3	4	1			
Goose, Egyptian	*Alopochen aegyptiaca*	LC	16	7	7		5	4
Grebe, Little	*Tachybaptus ruficollis*	LC	5	3	3			
Gull, Grey-headed	*Chroicocephalus cirrocephalus*	LC		1				
Gull, Hartlaub's	*Chroicocephalus hartlaubii*	LC	6	17	5			14
Gull, Kelp	*Larus dominicanus*	LC	1	8	4			4
Heron, Black-crowned Night-	*Nycticorax nycticorax*	LC	8	6	5			
Heron, Black-headed	*Ardea melanocephala*	LC	3	2	2			
Heron, Grey	*Ardea cinerea*	LC	1	1	3			
Heron, Purple	*Ardea purpurea*	LC			1			
Ibis, African Sacred	*Threskiornis aethiopicus*	LC	31	47	28			54*
Ibis, Hadeda	*Bostrychia hagedash*	LC	12	4	6		2	9
Kingfisher, Malachite	*Corythornis cristatus*	LC			1			
Kingfisher, Pied	*Ceryle rudis*	LC	2	2	2			
Lapwing, Blacksmith	*Vanellus armatus*	LC	2	4	3		1	4
Moorhen, Common	*Gallinula chloropus*	LC	5	4	5			
Oystercatcher, African Black	*Haematopus moquini*	NT	2					
Plover, White-fronted	*Charadrius marginatus*	LC	4	4	2			2
Shoveler, Cape	*Anas smithii*	LC	4	2	6			
Swamphen, African Purple	*Porphyrio porphyrio*	LC	1	1				
Teal, Cape	*Anas capensis*	LC	4		6			
Teal, Red-billed	*Anas erythrorhyncha*	LC	yes	2	2			
Thick-knee, Water	*Burhinus vermiculatus*	LC	2	2	2			1
Wagtail, Cape	*Motacilla capensis*	LC	5	6	4			3
TOTAL			164	165	130		8	110

Figure 4-9. Waterbird counting areas on the Onrus Estuary.

Table 4.19. Waterbirds recorded on the Onrus Estuary in a survey conducted in October 2024.

Scientific Name	Bird	Area 1	Area 2	Area 3	Area 4	Area 5	Total
Actitis hypoleucos	Common Sandpiper			2			2
Alopochen aegyptiaca	Egyptian goose	8					8
Anas undulata	Yellow-billed Duck				2		2
Bostrychia hagedash	Hadeda ibis			1			1
Burhinus vermiculatus	Water thick-knee			1			1
Chroicocephalus hartlaubii	Hartlaub's Gull	11					11
Larus dominicanus	Kelp gull	1			2		3
Motacilla capensis	Cape wagtail			1		2	3
Threskiornis aethiopicus	Sacred ibis			1	5	2	8
Total		20		6	9	4	39

4.5.2 Reference condition

Under reference conditions the estuary would have had higher freshwater flows and scouring of the estuary, resulting in greater connection with the marine environment. The reference condition would not have had the increased erosion and nutrient enrichment from catchment activities that has encouraged reed bed growth, and as a result more flood plain habitats that would have been favoured by invertebrate feeders and other waterfowl, would have been present. A higher incidence of breaching would have contributed to a more favourable environment for marine invertebrates and the scouring of the estuarine habitats would have prevented the build-up of anoxic muds. As a result, it is expected that under reference condition invertebrate feeding birds such as terns, gulls and waders would have been more abundant than they are under present conditions. It is possible that increased marine connectivity which provided a more suitable foraging and nursery areas for adult and juvenile fish species compared to present day contributed to a more abundant and diverse piscivore community.

Under reference conditions, there would also be an absence of the high levels of human disturbance seen during the holiday periods, which could have had a significant impact on bird fauna. However, the waterbird community at this estuary would not have ever been particularly abundant or diverse.

4.5.3 Avifauna health

The overall health of the avifauna of the Onrus Estuary is considered to be poor at present (40% of Reference) mainly due to changes in the community composition of the birds on the estuary (virtual absence of waders and wading birds, 40%) but also due to low abundance (50%) and species richness (55%) (Table 4-19).

Table 4.20. Bird health scores for Present Day and the four alternative scenarios relative to the Reference Condition.

Variable	2017	Present (2024)	Confidence
a. Species richness	70	55	M
b Abundance	65	50	M
c. Community composition	70	40	M
Score (minimum a to c)	**65**	**40**	

5 OVERALL EVALUATION

5.1 Present Ecological Status

In 2017, using minimum scores for each component, the overall present ecological status for the Onrus Estuary was found to be 56%, with abiotic scores being slightly higher (60%) than biotic scores (52%). Re-evaluation of the system in 2024 after the major flood in September 2023 based on sampling undertaken for this study in October 2024, suggests that overall health of the estuary has declined dramatically (now 27% overall) (Table 5-1). Declines in physical health (hydrodynamics and mouth condition, physical habitat alteration and water quality) played a major role here, but the drop in all biotic health parameters was also significant (Table 5-1).

Table 5.1. Present ecological status of the Onrus Estuary.

Component	2017	2024
Hydrology	48	48
Hydrodynamics and mouth condition	86	13
Water quality	56	36
Physical habitat alteration	50	15
Habitat health score	**60**	**28**
Microalgae	40	20
Macrophytes	49	30
Invertebrates	55	20
Fish	50	25
Birds	65	40
Biotic health score	**52**	**27**
Estuary Health Score	**56**	**28**
Ecological Category	**D**	**E**

5.2 Recommended Ecological Category

Recommended Ecological Category is decided on the basis of conservation importance, using a set of rules. Conservation importance, in turn, comprises biodiversity importance, a score which is taken from an existing dataset, and functional importance (Table 5-2). The Recommended Ecological Category and Conservation importance of the Onrus Estuary was evaluated in the estuary flow assessment workshop undertaken by DWS (2017). At the time, a biodiversity importance score of 60 was assigned to the estuary. The functional importance was estimated to be 20, given its small size and lack of connection to the sea (Table 5-2). Using these scores in conjunction with national scores on size, zonal type rarity, and habitat diversity, the overall importance score for the Onrus was determined as 46 (DWS 2017). This puts it in the category of "low to average importance". We do not believe that there is any reason to change these scores at this stage.

Since the estuary is not on the list of existing or desired protected areas (Turpie et al. 2012), the rule for REC is to maintain the PES. However, the minimum PES for any estuary in South Africa is set at a D category (40%), therefore the REC is a D. As such, there is an urgent need to improve the health of this estuary from its current status of E (27%).

Table 5.2. Estuary importance score. Source: DWS (2017).

Biodiversity importance score	**Score**	**Wt**	**Estuary Importance (look up remaining scores)**	**Score**	**Wt**
Plants	70	30	Size	70	15
Invertebrates	10	10	Zonal Type Rarity	10	10
Fish	40	30	Habitat diversity	60	25
Birds	50	30	Biodiversity	60	25
Weighted mean	49		Functional importance	20	25
Max	70				
Biodiversity Importance Score	**60**		**Estuary Importance Score**	**46**	

5.3 Overall confidence

The confidence in the abiotic and biotic scores was medium (average 65 and 63, respectively), with the overall level of confidence being "medium" (weighted average = 64).

6 REFERENCES

CSIR 1991. A review of potential rehabilitation options for Onrus Lagoon. Cerff EC & Geustyn L (eds). CSIR Report EMA C91125. Council for Scientific and Industrial Research, Stellenbosch.

CSIR 1993. A management plan for the Onrus Lagoon and immediate environs. By Lochner P & Morant P. CSIR Report EMAS C93010. Council for Scientific and Industrial Research, Stellenbosch.

Cross, Diana H. & Fleming, Karen L. 1989. Control of Phragmites or Common Reed. Waterfowl Management Handbook. 32.CSIR 2000. Guidelines for Human Settlement Planning and Design. Available online at http://www.csir.co.za/Built_environment/RedBook/

Department of Water Affairs (DWA) 2012. Resource Directed Measures for protection of water resources: Methods for the Determination of the Ecological Reserve for Estuaries. Version 3. Pretoria.

Department of Water and Sanitation, South Africa. 2017. Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz Water Management Area: Quantification of the Ecological Water Requirements and changes in Ecosystem Goods, Services and Attributes. Report No: RDM/WMA8/00/CON/CLA/0117.

Du Plessis JA 1995. Onrusrivier Opvanggebied Studie: Stelselontleding. (Onrus River Catchment Study: Systems Analysis). December 1995. Department of Water Affairs, South Africa.

Heinecken, TJE and Damstra K St J. 1983. Estuaries of the Cape: Part II: Synopses of available information on individual Systems. Report number 24: Onrus (CSW 14). Heydorn, AEF and Morant, PD (eds.). Stellenbosch, CSIR Report 423.

LissnerJørgen, J. & L.H-H. Schierup. 1997. Effects of Salinity on the Growth of Phragmites australis. Aquatic Botany 55(4):247-260.

Overstrand Municipality 2010. Water Services Development Plan for 2010/2011. 16 March 2010. Available online at www.overstrand.gov.za > Strategic Documents.

Overstrand Municipality 2012. Integrated Development Plan 2012-2017. 30 May 2012. Available online at www.overstrand.gov.za > Strategic Documents.

Overstrand Municipality 2014b. Overstrand IDF: Towards 2050. Environmental Management Framework. Urban Dynamics Western Cape and Withers Environmental Consultants, prepared for the Overstrand Municipality.

Massie, V and Clark, BM. 2016. Onrus Estuarine Management Plan, Situation Assessment Report. Report prepared for the Overstrand Municipality and the Lagoon Preservation Trust by Anchor Environmental Consultants (Pty) Ltd.

Ninham Shand 1973. Letter to 'Die Sekretaris van Waterwese' 24 August 1973. In: Ninham Shand 1993.

Ninham Shand 1987. De Bos Dam Yield Study. Report 1279/2561. June 1987. Ninham Shand Consulting Engineers, Cape Town.

Ninham Shand 1991. Report on the potential of De Bos Dam. Report No 1871/5348 for Hermanus Municipality, November 1991. Ninham Shand Consulting Engineers, Cape Town.

Ninham Shand 1993. Report on the future demand on the De Bos Dam. Report No 1871A/5348 for Hermanus Municipality, February 1993. Ninham Shand Consulting Engineers, Cape Town. Available online at www.overstrand.gov.za > Strategic Documents.

Turpie, J.K. 2012. The Estuary Health Index: a standardised metric for use in estuary management and the determination of ecological water requirements. WRC Report No. 1930/1/12

Van Niekerk, L, Huizinga, P and Ramjukadh, C-L. 2016. Onrus Estuary Mouth Management Plan. Report for the Western Cape Government.

Yu, J., Wang, X. Ning, K., Li1, Y., Wu, H. Fu, Y., Zhou, D. Guan, B. & Q. Lin. 2012. Effects of Salinity and Water Depth on Germination of Phragmites australis in Coastal Wetland of the Yellow River Delta. Clean – Soil, Air, Water, 40 (10), 1154–1158.

7 APPENDIX

Monthly flows for Reference State

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.179	0.331	0.166	0.055	0.069	0.034	0.103	0.055	7.210	4.506	5.099	3.795	21.602
1921	0.959	0.179	0.124	1.021	0.359	0.090	0.083	0.124	5.106	1.835	7.300	2.546	19.726
1922	0.241	4.485	1.566	0.110	0.097	0.090	1.870	4.244	2.712	9.481	6.479	1.428	32.803
1923	0.290	2.525	0.890	0.124	0.103	0.097	0.097	0.124	3.629	1.332	1.056	0.524	10.791
1924	0.255	0.297	0.124	0.097	0.090	0.076	0.069	0.076	4.485	2.277	0.524	0.428	8.798
1925	1.332	0.545	0.124	0.090	0.076	0.069	0.069	0.166	0.290	2.463	1.166	0.311	6.701
1926	3.761	1.387	0.124	0.090	0.076	0.076	0.069	0.324	0.324	0.145	1.808	0.759	8.943
1927	0.179	0.200	0.110	0.069	0.055	0.055	0.048	0.048	0.621	0.255	0.200	0.580	2.420
1928	0.255	0.131	0.062	0.041	0.034	0.034	0.131	0.124	0.117	1.490	0.690	0.200	3.309
1929	0.145	0.090	0.145	0.069	0.041	0.145	0.076	0.110	0.124	0.124	0.669	0.780	2.518
1930	0.359	0.166	0.090	0.055	0.048	0.041	1.035	0.407	0.090	0.911	2.104	0.869	6.175
1931	1.690	0.649	0.110	0.076	0.124	0.069	0.062	0.497	0.476	0.331	0.186	1.780	6.050
1932	0.745	0.131	0.090	0.069	0.055	0.048	0.048	0.124	1.594	0.945	2.180	0.869	6.898
1933	0.200	0.124	0.076	0.055	0.055	0.048	0.048	0.055	0.097	0.759	1.014	1.449	3.980
1934	0.738	0.200	0.090	0.069	0.055	0.048	0.214	0.918	0.621	0.566	0.345	0.469	4.333
1935	0.269	0.159	0.090	0.455	0.166	0.055	0.055	0.131	0.442	0.635	0.421	0.380	3.258
1936	0.248	0.269	0.214	0.069	0.055	0.055	0.062	0.055	0.690	2.684	1.000	0.531	5.932
1937	0.311	0.145	0.090	0.069	0.055	0.262	0.276	0.545	0.331	0.435	0.642	2.905	6.066
1938	1.277	0.221	0.110	0.076	0.166	0.138	0.110	0.269	0.145	0.800	2.325	0.911	6.548
1939	0.235	0.145	0.090	0.069	2.180	0.821	0.366	0.179	0.835	0.580	0.255	0.324	6.079
1940	0.214	0.531	0.200	0.076	0.062	0.055	1.891	2.449	2.111	2.870	1.490	3.761	15.710
1941	1.470	0.200	0.131	0.103	0.090	0.076	0.076	1.325	1.470	0.497	0.442	0.359	6.239
1942	0.255	0.159	0.166	2.698	0.945	0.110	0.159	0.221	0.179	0.366	0.835	1.290	7.383
1943	0.511	0.166	0.110	0.076	0.069	0.055	0.055	0.731	2.650	0.945	3.629	6.210	15.207
1944	1.828	0.179	0.110	0.090	0.076	0.069	0.221	5.209	3.105	3.933	5.444	1.615	21.879
1945	1.766	0.676	0.131	0.097	0.090	0.690	0.255	0.110	0.248	0.359	0.276	2.305	7.003
1946	0.925	0.159	0.097	0.076	0.069	0.241	0.110	0.097	0.124	2.249	0.925	0.235	5.307
1947	0.255	0.152	0.090	0.069	0.055	0.221	0.159	0.076	0.235	0.600	0.304	0.269	2.485
1948	3.153	1.132	0.103	0.076	0.055	0.055	0.359	0.200	0.159	0.255	0.766	0.455	6.768
1949	0.207	1.000	0.366	0.069	0.055	0.048	0.469	0.179	0.076	0.380	0.200	0.524	3.573
1950	0.731	1.635	0.600	0.380	0.131	0.055	1.021	0.469	5.334	4.740	3.560	5.610	24.266
1951	1.946	0.235	0.131	0.097	0.090	0.076	0.090	0.124	0.345	1.111	3.015	2.995	10.255
1952	1.069	1.801	0.655	0.110	0.090	0.076	1.546	0.711	0.352	1.704	1.325	0.421	9.860
1953	0.228	0.248	0.110	0.083	0.076	0.069	0.179	2.905	1.656	5.527	6.162	1.677	18.920
1954	0.255	0.179	0.110	0.090	3.740	1.290	0.097	0.103	0.435	1.863	4.216	1.449	13.827
1955	0.904	0.380	0.124	0.090	0.076	0.090	0.076	2.284	1.960	1.290	2.256	0.835	10.365
1956	0.352	0.166	0.110	0.090	0.076	0.200	0.166	2.615	4.485	3.685	4.409	2.794	19.148
1957	3.153	0.987	0.124	0.103	0.090	0.221	0.179	2.194	0.959	0.221	1.173	0.621	10.025
1958	0.311	0.179	0.110	0.090	0.076	0.076	3.484	2.325	0.511	0.235	2.056	0.849	10.302
1959	0.669	0.290	0.110	0.090	0.076	0.138	0.076	0.200	0.731	0.421	0.214	0.207	3.222
1960	0.166	0.110	0.110	0.331	0.110	0.055	0.048	0.152	0.214	0.331	0.600	0.945	3.172
1961	0.552	0.179	0.076	0.062	0.055	0.145	0.566	0.235	2.836	1.194	5.196	1.856	12.952
1962	3.381	1.304	0.131	0.124	0.090	0.076	0.090	0.179	0.214	0.821	1.635	0.621	8.666
1963	0.228	0.193	0.103	0.076	0.069	0.380	0.166	0.110	2.035	1.228	4.754	1.759	11.101
1964	0.255	0.380	0.145	0.083	0.076	0.166	0.290	0.304	0.186	0.448	0.393	0.241	2.967
1965	0.207	0.138	0.090	0.069	0.055	0.055	0.055	0.090	0.076	0.635	4.540	3.250	9.260
1966	0.759	0.131	0.090	0.069	0.055	0.055	1.249	0.655	1.090	0.690	1.628	0.752	7.223
1967	0.304	0.186	0.103	0.076	0.069	0.062	0.055	0.241	0.690	0.400	0.614	0.331	3.131
1968	0.241	0.131	0.076	0.055	0.055	0.055	0.200	0.090	0.221	0.152	0.145	0.131	1.552
1969	0.200	0.097	0.048	0.034	0.407	0.145	0.034	0.034	0.235	0.683	1.132	0.497	3.546
1970	0.276	0.138	0.076	0.055	0.041	0.041	0.041	0.241	0.511	1.090	3.898	1.345	7.753
1971	0.207	0.200	0.103	0.076	0.110	0.090	0.531	0.745	0.448	0.386	2.381	1.035	6.312
1972	0.235	0.138	0.090	0.069	0.055	0.055	0.055	0.076	0.110	0.311	0.241	0.255	1.690
1973	0.145	0.090	0.055	0.041	0.034	0.034	0.034	0.780	0.366	0.110	6.251	4.030	11.970
1974	1.069	0.221	0.097	0.076	0.062	0.055	0.055	0.780	0.338	0.621	1.601	0.676	5.651
1975	0.290	0.159	0.090	0.062	0.055	0.076	0.083	0.166	4.340	1.835	1.470	1.035	9.661
1976	0.462	0.414	0.166	0.090	0.614	0.235	0.241	1.049	0.911	4.775	4.616	1.263	14.836
1977	0.241	0.166	0.207	0.090	0.076	0.076	0.166	0.090	0.097	2.035	1.870	1.304	6.418
1978	0.504	0.166	0.103	0.083	1.704	0.600	0.076	0.821	0.545	0.366	0.380	0.255	5.603
1979	0.483	0.214	0.090	0.069	0.055	0.055	0.048	0.159	1.035	0.421	0.179	0.166	2.974
1980	0.207	0.766	0.297	0.980	0.876	0.290	1.021	0.400	0.124	1.649	1.339	1.684	9.633
1981	0.614	0.159	0.103	0.076	0.069	0.062	1.132	0.428	0.614	0.338	0.483	0.311	4.389
1982	0.200	0.124	0.076	0.055	0.704	0.262	0.062	2.781	2.236	2.560	2.470	0.980	12.510
1983	0.255	0.159	0.097	0.076	0.076	0.069	0.110	2.629	0.994	0.490	0.304	0.455	5.714
1984	1.014	0.386	0.455	0.380	0.110	0.152	0.655	0.248	0.110	3.602	1.456	0.276	8.844
1985	0.780	0.331	0.110	0.076	0.069	0.193	0.145	0.076	0.331	0.428	7.790	3.340	13.669
1986	0.566	0.248	0.110	0.083	0.069	0.069	0.366	0.269	0.580	0.393	3.464	2.808	9.025
1987	0.711	0.145	0.097	0.076	0.069	0.062	0.235	0.166	0.380	0.331	1.325	0.655	4.252
1988	0.235	0.138	0.083	0.069	0.055	1.414	3.919	1.290	1.345	4.375	4.519	3.360	20.802
1989	1.849	0.455	0.131	0.103	0.428	0.159	0.897	1.090	2.470	3.609	1.180	0.297	12.668
1990	0.235	0.159	0.110	0.090	0.076	0.076	0.069	0.131	0.635	2.525	0.966	0.255	5.327
1991	3.761	1.366	0.117	0.090	0.076	0.076	0.138	0.414	1.973	0.904	1.566	2.104	12.585
1992	2.160	0.655	0.124	0.097	0.090	0.083	3.105	1.256	0.655	5.948	4.209	0.938	19.320
1993	0.207	0.145	0.166	0.090	0.083	0.076	0.103	0.228	5.299	1.980	1.014	0.476	9.867
1994	0.283	0.159	0.269	0.124	0.076	0.124	0.124	0.856	0.621	1.725	2.815	0.938	8.114
1995	0.324	0.179	0.966	0.331	0.090	0.076	0.069	0.069	0.490	0.918	0.483	0.393	4.388
1996	1.414	1.069	0.311	0.097	0.076	0.069	0.062	1.842	1.325	0.380	0.511	0.297	7.453
1997	0.186	0.345	0.131	0.076	0.069	0.055	0.290	2.553	1.000	0.566	1.435	0.593	7.299
1998	0.200	1.249	2.049	0.607	0.090	0.076	0.359	0.221	0.131	0.138	1.132	3.726	9.978
1999	1.277	0.145	0.097	0.076	0.069	0.317	0.124	0.076	0.179	0.883	0.511	0.980	4.734
2000	0.435	0.131	0.090	0.069	0.055	0.055	0.145	0.200	0.090	2.870	2.629	1.394	8.163
2001	0.545	0.166	0.097	0.635	0.235	0.069	0.366	0.511	0.925	2.249	3.167	1.069	10.034
2002	0.241	0.159	0.103	0.076	0.069	0.856	0.311	1.021	0.414	0.145	4.706	1.815	9.916
2003	0.290	0.166	0.103	0.083	0.069	0.069	0.103	0.069	0.228	0.780	0.386	0.221	2.567
2004	3.498	1.256	0.138	0.235	0.083	0.069	8.011	3.029	3.374	1.290	1.739	0.752	23.474
2005	0.235	0.166	0.110	0.090	0.076	0.069	0.110	0.800	0.359	2.594	3.153	0.973	8.735
2006	0.345	0.200	0.110	0.083	0.076	0.076	0.241	0.241	1.477	2.939	3.160	0.980	9.928
2007	0.304	3.409	1.201	0.110	0.090	0.090	0.083	0.083	0.435	2.180	2.056	3.264	13.305
2008	1.104	4.996	1.739	0.110	0.090	0.090	0.083	0.152	0.814	1.490	1.504	1.345	13.517
2009	0.835	0.283	0.124	0.090	0.076	0.069	0.069	0.235	0.711	0.552	0.248	0.207	3.499

Monthly flows for Present Day

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	0.097	0.152	0.090	0.041	0.048	0.034	0.055	0.041	3.988	2.291	3.208	3.271	13.316
1921	0.580	0.103	0.076	0.469	0.166	0.062	0.062	0.076	2.719	0.987	4.030	1.428	10.758
1922	0.172	3.202	0.821	0.076	0.069	0.062	0.897	2.146	1.414	6.893	6.031	1.145	22.928
1923	0.186	1.249	0.455	0.076	0.069	0.069	0.062	0.083	1.849	0.697	0.607	0.283	5.685
1924	0.159	0.159	0.083	0.062	0.048	0.041	0.041	0.041	2.339	1.145	0.269	0.228	4.615
1925	0.614	0.269	0.076	0.055	0.048	0.041	0.041	0.076	0.131	1.194	0.573	0.179	3.297
1926	1.842	0.690	0.076	0.055	0.048	0.041	0.041	0.145	0.152	0.090	0.862	0.386	4.428
1927	0.090	0.097	0.062	0.041	0.034	0.034	0.034	0.028	0.283	0.124	0.097	0.262	1.186
1928	0.131	0.069	0.041	0.028	0.021	0.021	0.062	0.062	0.062	0.697	0.331	0.110	1.635
1929	0.076	0.055	0.069	0.041	0.028	0.069	0.041	0.062	0.062	0.069	0.311	0.366	1.249
1930	0.186	0.090	0.048	0.034	0.028	0.028	0.462	0.193	0.055	0.421	0.945	0.421	2.911
1931	0.787	0.324	0.069	0.048	0.062	0.041	0.034	0.221	0.221	0.159	0.110	0.856	2.932
1932	0.380	0.076	0.048	0.041	0.034	0.028	0.028	0.062	0.745	0.448	0.925	0.407	3.222
1933	0.110	0.069	0.048	0.034	0.028	0.028	0.028	0.028	0.048	0.345	0.469	0.635	1.870
1934	0.352	0.110	0.055	0.041	0.028	0.028	0.090	0.414	0.290	0.276	0.186	0.235	2.105
1935	0.152	0.083	0.055	0.186	0.076	0.034	0.034	0.062	0.200	0.297	0.207	0.193	1.579
1936	0.138	0.131	0.103	0.048	0.034	0.034	0.041	0.041	0.317	1.304	0.504	0.269	2.964
1937	0.179	0.083	0.055	0.041	0.034	0.110	0.117	0.248	0.166	0.214	0.304	1.214	2.765
1938	0.573	0.138	0.069	0.048	0.076	0.069	0.055	0.124	0.076	0.380	1.021	0.442	3.071
1939	0.138	0.083	0.055	0.041	1.028	0.380	0.166	0.097	0.393	0.290	0.159	0.186	3.016
1940	0.131	0.255	0.097	0.041	0.034	0.034	0.890	1.166	1.007	1.277	0.724	2.229	7.885
1941	0.856	0.117	0.076	0.069	0.055	0.048	0.048	0.621	0.690	0.262	0.235	0.207	3.284
1942	0.152	0.083	0.083	1.304	0.455	0.062	0.083	0.110	0.097	0.179	0.393	0.566	3.567
1943	0.255	0.097	0.062	0.041	0.034	0.028	0.028	0.324	1.283	0.469	1.690	3.409	7.720
1944	1.042	0.097	0.069	0.062	0.055	0.041	0.097	2.760	1.573	1.815	3.774	1.097	12.482
1945	1.228	0.366	0.083	0.069	0.069	0.311	0.131	0.069	0.131	0.186	0.159	1.069	3.871
1946	0.469	0.090	0.062	0.048	0.041	0.103	0.062	0.055	0.062	1.090	0.455	0.124	2.661
1947	0.138	0.083	0.055	0.041	0.034	0.097	0.076	0.048	0.117	0.283	0.159	0.145	1.276
1948	1.573	0.573	0.069	0.048	0.034	0.034	0.152	0.097	0.076	0.124	0.359	0.235	3.374
1949	0.117	0.455	0.166	0.041	0.034	0.028	0.200	0.083	0.041	0.179	0.103	0.241	1.688
1950	0.338	0.766	0.283	0.166	0.069	0.034	0.462	0.221	2.843	2.201	1.946	4.733	14.062
1951	1.449	0.152	0.076	0.062	0.062	0.055	0.055	0.069	0.166	0.524	1.297	1.352	5.319
1952	0.531	0.883	0.338	0.076	0.055	0.048	0.718	0.338	0.172	0.807	0.600	0.235	4.801
1953	0.124	0.124	0.062	0.048	0.041	0.041	0.083	1.428	0.807	2.601	3.547	1.277	10.183
1954	0.152	0.097	0.076	0.062	1.898	0.649	0.062	0.062	0.214	0.890	1.842	0.676	6.680
1955	0.476	0.221	0.076	0.055	0.048	0.048	0.048	1.104	0.938	0.580	0.931	0.400	4.925
1956	0.207	0.110	0.069	0.055	0.048	0.097	0.083	1.277	2.242	1.808	2.546	2.256	10.798
1957	2.753	0.586	0.076	0.069	0.062	0.110	0.097	1.069	0.483	0.131	0.573	0.331	6.340
1958	0.193	0.103	0.069	0.048	0.048	0.041	1.753	1.132	0.262	0.138	0.897	0.414	5.098
1959	0.345	0.166	0.069	0.048	0.041	0.062	0.041	0.090	0.331	0.207	0.117	0.110	1.627
1960	0.090	0.062	0.062	0.138	0.055	0.034	0.028	0.069	0.097	0.159	0.283	0.421	1.498
1961	0.269	0.090	0.048	0.034	0.028	0.062	0.241	0.110	1.401	0.593	2.449	0.918	6.243
1962	1.918	0.738	0.083	0.076	0.062	0.055	0.055	0.090	0.110	0.386	0.718	0.311	4.602
1963	0.138	0.103	0.062	0.048	0.041	0.159	0.083	0.062	0.980	0.593	2.194	0.849	5.312
1964	0.172	0.207	0.083	0.055	0.048	0.083	0.124	0.145	0.103	0.221	0.200	0.138	1.579
1965	0.117	0.076	0.055	0.041	0.034	0.028	0.034	0.048	0.048	0.297	2.270	1.470	4.518
1966	0.359	0.083	0.055	0.041	0.034	0.034	0.566	0.297	0.504	0.345	0.669	0.352	3.339
1967	0.179	0.110	0.062	0.041	0.034	0.034	0.034	0.103	0.317	0.193	0.290	0.179	1.576
1968	0.131	0.069	0.048	0.034	0.034	0.028	0.090	0.048	0.103	0.076	0.076	0.069	0.806
1969	0.097	0.055	0.034	0.021	0.159	0.069	0.021	0.021	0.103	0.311	0.524	0.255	1.670
1970	0.145	0.076	0.048	0.034	0.028	0.028	0.028	0.103	0.228	0.504	1.670	0.621	3.513
1971	0.124	0.110	0.062	0.048	0.055	0.048	0.235	0.345	0.221	0.200	0.980	0.469	2.897
1972	0.145	0.076	0.055	0.041	0.034	0.028	0.028	0.041	0.055	0.145	0.117	0.124	0.889
1973	0.076	0.048	0.034	0.028	0.028	0.021	0.021	0.352	0.172	0.062	3.395	1.925	6.162
1974	0.483	0.131	0.062	0.048	0.041	0.034	0.034	0.359	0.166	0.290	0.738	0.345	2.731
1975	0.166	0.090	0.055	0.034	0.028	0.041	0.041	0.076	2.249	0.938	0.614	0.462	4.794
1976	0.248	0.214	0.090	0.055	0.269	0.103	0.110	0.483	0.435	2.125	2.519	0.752	7.403
1977	0.152	0.097	0.110	0.062	0.055	0.048	0.083	0.055	0.062	0.987	0.890	0.586	3.187
1978	0.262	0.097	0.069	0.055	0.787	0.276	0.041	0.373	0.255	0.179	0.193	0.152	2.739
1979	0.241	0.110	0.055	0.041	0.034	0.028	0.028	0.069	0.469	0.207	0.097	0.083	1.462
1980	0.103	0.345	0.131	0.428	0.386	0.131	0.469	0.200	0.069	0.787	0.614	0.724	4.387
1981	0.311	0.090	0.062	0.048	0.041	0.034	0.511	0.200	0.283	0.172	0.235	0.166	2.153
1982	0.097	0.069	0.048	0.034	0.297	0.110	0.041	1.373	1.076	1.090	1.290	0.552	6.077
1983	0.179	0.090	0.062	0.055	0.048	0.041	0.055	1.290	0.497	0.241	0.172	0.235	2.965
1984	0.490	0.200	0.200	0.159	0.062	0.076	0.297	0.124	0.062	1.835	0.745	0.166	4.416
1985	0.386	0.179	0.069	0.048	0.041	0.090	0.069	0.048	0.152	0.207	4.126	1.697	7.112
1986	0.290	0.145	0.076	0.062	0.055	0.048	0.166	0.131	0.276	0.200	1.525	1.297	4.271
1987	0.380	0.090	0.062	0.048	0.041	0.034	0.103	0.083	0.179	0.166	0.600	0.324	2.110
1988	0.131	0.076	0.048	0.034	0.034	0.642	1.953	0.649	0.642	2.173	2.567	2.698	11.647
1989	1.380	0.262	0.076	0.062	0.186	0.083	0.414	0.504	1.201	1.615	0.573	0.179	6.535
1990	0.131	0.090	0.069	0.055	0.041	0.041	0.041	0.062	0.290	1.221	0.483	0.145	2.669
1991	1.925	0.704	0.069	0.055	0.048	0.041	0.069	0.186	0.938	0.442	0.655	0.876	6.008
1992	1.166	0.400	0.076	0.055	0.055	0.048	1.539	0.614	0.311	2.870	2.277	0.580	9.991
1993	0.117	0.083	0.090	0.062	0.055	0.048	0.055	0.110	2.815	1.049	0.448	0.255	5.187
1994	0.172	0.097	0.131	0.069	0.048	0.062	0.069	0.393	0.297	0.773	1.159	0.435	3.705
1995	0.193	0.110	0.448	0.152	0.048	0.048	0.041	0.041	0.228	0.428	0.241	0.200	2.178
1996	0.669	0.511	0.152	0.055	0.041	0.034	0.034	0.869	0.621	0.200	0.255	0.172	3.613
1997	0.103	0.159	0.069	0.041	0.034	0.034	0.124	1.242	0.490	0.283	0.607	0.290	3.476
1998	0.110	0.586	0.959	0.290	0.048	0.041	0.152	0.103	0.076	0.076	0.531	1.690	4.662
1999	0.614	0.083	0.062	0.048	0.041	0.131	0.062	0.048	0.090	0.414	0.255	0.442	2.290
2000	0.221	0.076	0.048	0.041	0.034	0.028	0.062	0.090	0.048	1.421	1.214	0.614	3.897
2001	0.276	0.103	0.062	0.269	0.103	0.041	0.159	0.241	0.428	0.973	1.421	0.531	4.607
2002	0.152	0.090	0.062	0.048	0.041	0.373	0.145	0.469	0.207	0.076	2.477	0.959	5.099
2003	0.172	0.090	0.069	0.055	0.041	0.041	0.055	0.041	0.110	0.359	0.193	0.124	1.350
2004	1.766	0.642	0.076	0.110	0.048	0.041	4.471	1.649	1.677	0.731	1.180	0.400	12.791
2005	0.145	0.090	0.069	0.062	0.055	0.048	0.062	0.366	0.179	1.277	1.352	0.448	4.153
2006	0.207	0.124	0.069	0.048	0.041	0.041	0.110	0.117	0.697	1.283	1.435	0.504	4.676
2007	0.186	1.732	0.621	0.069	0.055	0.055	0.048	0.048	0.200	1.049	0.931	1.449	6.443
2008	0.531	2.656	0.918	0.069	0.062	0.055	0.048	0.076	0.380	0.704	0.662	0.580	6.741
2009	0.407	0.166	0.069	0.048	0.041	0.041	0.041	0.103	0.324	0.262	0.138	0.103	1.743

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