Environmental Impact Assessment (EIA) for the Proposed Construction, Operation and Decommissioning of a Sea Water Reverse Osmosis Plant and Associated Infrastructure Proposed at Lovu on the KwaZulu-Natal South Coast

# DRAFT EIA REPORT

# CHAPTER 7: ESTUARINE ECOLOGY

# ABBREVIATIONS, UNITS & GLOSSARY

| | |
|---|---|
| BIR | Botanical Importance Rating |
| EIA | Environmental Impact Assessment |

# EXECUTIVE SUMMARY

The purpose of this assessment was to determine the potential impacts of Umgeni Water's proposed desalination plant to be located on the upper south side of the Lovu Estuary. A literature review and an off field study of estuarine vegetation and the fish community was undertaken to determine the current state and functional integrity of the system as an estuary. It is clear from the review and findings of the field survey that the Lovu Estuary, which although small in national terms, is an important functional estuary which is contributing significantly to the estuarine resources in this section of the coastline. As estuarine resources are under threat, nationally and internationally through development pressure, these environments are identified as conservation worthy and any further impacts on these systems must be critically assessed.

Having established that the estuary is worthy of protection an Environmental Impact Assessment (EIA) of envisaged potential impacts arising from the proposed development was completed for the proposed desalination plant and associated infrastructure. This assessment of potential impacts did not indicate any fatal flaws for any individual impact and most were assessed with a high degree of confidence. The following impacts were identified and assessed in this Estuarine Ecological Impact Assessment:

**Construction Phase**

- Loss of vegetation during the construction of the proposed plant and installation of pipelines. For the most part, vegetation of little conservation significance i.e. sugar cane would be impacted by the proposed development and is thus of low significance.
- Impacts on the ecological corridor between the proposed plant and the channel.
- Noise during proposed construction, installation of pipelines and decommissioning of the plant that would disturb fauna. The assessment concluded that noise had the potential to impact on local fauna but that the temporary nature mostly resulted in this impact having a medium significance score. However, the impacts on fish from vibrations due to tunnelling beneath the estuary are largely unknown and hence the assessment for this is made with a medium degree of confidence
- Potential for increased estuarine turbidity with consequent impacts on aquatic fauna during excavation for the proposed plant construction and installation of pipelines. The probability of this impact occurring is dependent on frequency, duration and intensity of rainfall events. The overall significance was nonetheless rated as low.
- Possible release of contaminants from the old dumpsite during excavation for pipeline installation. Due to the unknown nature of the contaminants that may be present in the dumpsite effects could not be predicted with a high level of confidence. It is thus recommended that a toxicity study be conducted on sediment leachates from the dumpsite.

**Operational Phase**

- Impacts on the ecological corridor between the proposed plant and the channel.
- Possible entrainment of brine into the surf zone that could potentially impact on recruitment of juvenile fish into the estuary. The frequency and duration and intensity of

these conditions were predicted to be very low and the impact scored an overall low significance rating.

- Noise during plant operation. It is expected that with the measures to dampen noise in the plant design, impacts will be of low significance.

The following key mitigation measures are recommended:

- A setback distance of 25 m for the Preferred site to increase the ecological corridor between the development and the estuarine channel.
- Re-vegetate as soon as possible with appropriate species such as fast growing indigenous grasses following excavation and installation of pipelines.
- Reduce vehicle speed limits to reduce noise.
- Use sandtraps and geotextile blankets to prevent excavated material and building sand being washed into the estuary during rainfall events.
- Limit construction footprint and undertake awareness training for all staff (flora and fauna).

Assessment of the potential impact associated with release of contaminants from the old dumpsite could not be made with a high degree of confidence since the nature, concentrations and hence possible effects on biota are unknown. As the contaminants, if present, are unknown it is difficult to determine what parameters should be analysed chemically to assess potential effects on biota. The specialists thus strongly recommend that sediment leachates from the dumpsite be tested for toxicity prior to installation of the pipelines. This will inform the developer about correct handling of excavated material from the dumpsite.

The construction of the proposed desalination plant at the Preferred site or at the Alternative site is anticipated to result is estuarine impacts of similar significance, providing that the recommended management actions are effectively implemented, in particular a setback distance of 25 m for the Preferred site to increase the ecological corridor between the development and the channel. Note that the Alternative site has slightly lower risk of being impacted by major floods. In the event of a major cyclonic storm event this would entail less risk in terms of damage to the facility and this in turn will reduce the risk of any chemicals that are used and stored in the facility being washed into the estuary with the storm flows.

The alternatives proposed for the sea water pipeline routing scored similarly in terms of vegetation impacts as there is no substantial loss of indigenous vegetation. While impacts of noise levels on fauna also scored similarly, it is uncertain if noise levels and vibrations due to the use of tunnelling equipment for Alternative 2 are expected to have greater impact than the Preferred route or Alternative 1. The assessment in this case was made with a medium degree of confidence.

In conclusion, from a perspective of potential estuarine impacts, the specialists recommend:

- A setback distance of 25 m for the Preferred site to increase the ecological corridor between the development and the estuarine channel.
- While there is no strong indication for selection of any of the various pipeline routes in terms of vegetation impacts, there is some uncertainty regarding potential impacts on groundwater (although anticipated to be unlikely) and impacts of vibrations and noise from tunnelling

especially for Alternative 2 which crosses sensitive area of estuary. Given this, selection of the options that involve north bank routing (Preferred and Alternatives 1 and 3) are recommended over alternative 2.

- For Alternative 2, the reception pit for tunnelling on the south bank should be moved by at least 100 to 130 m further west.
- If any of the tunnelling options are selected for pipeline routing (Alternatives 2 and 3), it is imperative that there is **no disposal** of excavated material, slurry (including bentonite mixes) wastewater (including waters treated with flocculants) within the floodplain of the estuary or the waterbody. All wastes should be appropriately disposed of (at registered dumpsites or recycled if appropriate). While the only toxicity reference to bentonite was an $LC_{50}$ of 19 g/l for rainbow trout, the author has previously tested a range of drilling fluids which indicated potential toxicity to sensitive species or more especially to early life stages such as gametes, larvae and juveniles.

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# 7. LOVU ESTUARINE IMPACT SPECIALIST STUDY

## 7.1 INTRODUCTION

The Coastal systems group of the CSIR was appointed to undertake an Estuarine Ecological Impact study as part of the Environmental Impact Assessment (EIA) for the Umgeni Water's proposed desalination plant and associated infrastructure located at the Lovu Estuary, south of central Durban.

### 7.1.1 Scope of Work

The scope of work of this assessment includes:

- A general description of the local environment;
- A literature review of environmental information;
- A field survey to ground truth estuarine vegetation and identify sensitive species/ communities. Mapping of the vegetation communities to determine botanical importance;
- A once off field study of estuarine fish species for comparison with existing data;
- Impact assessment with and without mitigation of the proposed development on the estuarine resources; and
- If the proposed project is not found to be fatally flawed and if applicable, additional relevant recommendations on possible rehabilitation procedures/ management guidelines are to be proposed.

### 7.1.2 Study Approach

#### *7.1.2.1 Desktop Study*

A review of available environmental information was undertaken to describe the Lovu Estuary (including floodplain) in terms of the estuarine functioning. This included biotic composition, physicochemical conditions, current status, relative conservation importance etc. These data were compared to the data collected during the field survey undertaken as part of this assessment.

#### *7.1.2.2 Estuarine Surveys*

A field survey of the Lovu estuary was undertaken on 30th April 2015 to conduct fish and vegetation surveys for the purpose of accessing current state and for comparison with historical information where available. The following methods were employed:

- Land coverage was verified and designated on orthophotographs and aerial views (Google Earth) of the estuary. These data were later digitized using Google Earth and coverage of estuarine vegetation was determined for calculation of the botanical importance of the Lovu Estuary.
- Fish surveys were conducted at 6 sites from the lagoon to the upper section of the Lovu Estuary using gill and seine nets. At each site a YSI multiparameter sonde was deployed

through the water column to measure a range of physicochemical water quality parameters of relevance to the health of estuarine biota.

#### *7.1.2.3 Impact Assessment/mitigation and management recommendations*

The impact assessment, without and with recommended mitigation measures, was conducted according to the standard protocol described in Chapter 4 of the Draft EIA Report. Based on this, recommendations on the preferred options are made. Where relevant, additional management actions to avoid or reduce the significance of negative impacts are also recommended.

### 7.1.3 Information Sources

Mapping of land cover was done using orthophotographs and Google Earth images. All other information was obtained from published papers or reports which are appropriately referenced within this report. A field survey was conducted to provide additional data on estuarine status.

### 7.1.4 Assumptions and Limitations

The following assumptions and limitations apply:

- Only one baseline monitoring study was undertaken for the fish resources as part of this assessment. As such seasonal variations cannot be accounted for but data from previous studies have been included in the review of the estuarine components to provide a more comprehensive assessment of fish communities.
- No estuarine water or sediment quality assessment was undertaken for this study, with the exception of physicochemical water quality measurements taken during fish sampling as these are of relevance to biological health. However the turbidity measurements will be of relevance should there be a need for monitoring this parameter during construction.
- The release of contaminants from the old dumpsite has not been specifically addressed in terms of measurement of particular parameters. This is due to the unknown nature of the contaminants and thus difficulty in determining what parameters should be measured. However mitigation will be proposed regarding this potential impact.
- Assessment of the impacts of tunnelling is based on the assumption that all waste materials including excavated materials, bentonite slurry and any wastewater will be removed and disposed off appropriately (e.g. registered dumpsite or recycled where possible) i.e. no disposal within the estuarine floodplain or waterbody.
- It is assumed that mitigation measures inherent to the project design, as detailed in the project description, will be implemented regardless of additional mitigation measures recommended in this study (i.e. ratings for impact significance 'without additional mitigation' is assumed to already include mitigation measures inherent to the design). Mitigation measures pertaining to this specific field of study and that are assumed to be inherent to the project design include:
- Engineering design of the proposed plant will include noise reduction measures that will efficiently damp down noise during operation of the plant.

- The authors are not aware of any additional proposed developments that may impact on the Lovu Estuary. In addition, there are no permanent (irreversible) impacts envisaged in terms of estuarine ecological functioning due to the current proposed development if the recommended alternatives are selected. Based on this no cumulative effects are envisaged. However, it must be noted that estuaries along the coast have been variously impacted with some being in poor state (e.g. the Isipingo). It is thus assumed that recommended mitigation measures will be implemented to prevent additional stresses on the estuarine resources locally and nationally.

## 7.2 PROJECT DESCRIPTION: ESTUARINE ECOLOGICAL IMPACT STUDY

Development along the coastline of South Africa has in many instances resulted in impacts and stresses on the limited estuarine environmental resources in South Africa. Estuaries are amongst the most productive ecosystems on earth, far more so than their inflowing riverine and adjacent marine ecosystems (e.g. Costanza *et al*. 1997, Kimmerer 2002, Simenstad *et al*. 2000, Kennish 2004, Robins *et al*. 2006). They are critical migration links between marine spawning grounds and freshwater habitats for several species (such as anguillid eels). They support diverse resident fauna and flora, but importantly also provide critical nursery habitat for marine fish and shellfish, and therefore have ecological roles affecting resources at wider coastal scales. Many South Africans are directly or indirectly reliant on coastal ecosystems for their livelihoods, while others use these ecosystems for recreational purposes. The importance of estuaries and the goods and services they provide to humans is now widely recognised. With a decline of these systems at all scales (worldwide, regional, national and local), both in terms of direct losses due to coastal development and indirect losses due to flow modifications and pollution, increasing obligation and public pressure is placed on relevant authorities, managers and users to manage these resources wisely for wider and greater societal benefit. Thus any proposed developments that could affect estuarine resources must be adequately assessed for potential impacts.

This study provides an Estuarine Ecological Impact Assessment of Umgeni Water's proposed desalination plant and associated infrastructure, the details of which are described in Chapter 2 of the Draft EIA Report. In this study the status of the various estuarine components is firstly described through a review of information and data from previous studies of the Lovu Estuary. Further data to update this was collected through a once off field survey of the fish community and determination of coverage by estuarine plant communities to characterize the estuary and floodplain components. These data are used to describe the health and importance of this system in terms of estuarine resources and functioning.

Several aspects of the proposed development, such as noise and excavation and construction activities on or near the flood plain for construction and operation of the desalination plant and intake and effluent pipelines, are expected to have some impact on estuarine resources. These are identified and assessed in this study to determine if there are fatal flaws that would result in rejection of the project or parts thereof. For identified impacts which are not considered to present flaws to the project, mitigation measures to remove or reduce severity of such impacts are recommended. Additional management recommendations to protect estuarine resources are also indicated as necessary.

## 7.3 DESCRIPTION OF THE AFFECTED ENVIRONMENT

The Lovu Estuary (30° 06' 34.87"S : 30° 51' 01.33"E) is located some 37 km south of central Durban and is one of 16 estuaries located in the eThekwini Municipality. The Lovu River may be regarded as a small to medium sized system being approximately 135km in length (Begg, 1978) and delivering a mean annual flow of 6.2 $m^3sec^{-1}$. Given these flows it is not unexpected that the mouth remains open for most of the time and the system is thus classified as a temporarily open/closed system. The major part of the estuarine water body varies in depth from < 0.5 to 2.3m (Begg, 1984) depending on rainfall, river flow and mouth and tidal conditions. However for most part the water level is about 1m and large areas of exposed sand/mud banks are present. Both vertical and horizontal salinity gradients are apparent in the system (CSIR unpublished; Forbes and Demetriades, 2008).

Like all estuaries associated with surrounding urban and/or agricultural development the Lovu estuary has been subject to severe impacts that have reduced the ecological goods and services that such systems provide. Major impacts on the system included causeways, road and rail bridges that impact both the floodplain and channel characteristics. Evidence of sand mining along the northern bank was also observed in 2012 during a site visit by Aurecon (Photos 9.1a & b). A dumpsite for solid waste was also created within the wetland on the north bank in the early days when authorities were less sensitive to the value of estuarine resources. Historically the system was subject to pollution from the adjacent sugar mill. Currently there is still a carpark and sports field on the north bank. With the exception of the lowermost reaches, the floodplain of the estuary has been cleared for sugar cane cultivation, which has occurred at least since the early 1900s. In spite of these changes the determination of the estuarine health index for KwaZulu-Natal (KZN) estuaries (Cooper *et. al.*, 1994) resulted in an aesthetic value (which makes up part of the health index) of 7.5 out of maximum of 10.

Figure 7.1a Disturbance from sand mining operations along the northern bank of the Lovu River


Figure 7.1b Evidence of sand mining along the northern bank of the Lovu River

## 7.3.1 Review of previous studies of the Lovu Estuary

### *7.3.1.1 Water Quality*

As indicated above the usually open mouth conditions results in a tidal prism and recent measurements (Forbes and Demetriades, 2008) indicated salinity intrusion some 3.6 km upstream from the mouth. Surface waters in the upper reaches are usually fresh but salinity stratification occurs even in waters below a metre in depth (Begg, 1984). Historically water quality was often impaired in the system due to leachate from the dumpsite, accidental discharges from the sugar mill and possibly sewage from septic tanks since very high faecal coliforms have been recorded. Low dissolved oxygen in bottom waters was also a common feature of the system and still occurs in backwater areas. More recently it would appear that there has been substantial improvement in water quality in that relatively low levels of nutrients and oxygen impairment were measured (Forbes and Demetriades, 2008). This is probably due lower levels of contamination from the dumpsite leachates and fewer accidental spillages into the system. However, there was indication of algal blooms at the time (i.e. 2007/2008) so the low nutrient levels could have been a result of these being bound in algal biomass. This study confirmed the findings of surveys made in 1992 (CSIR, unpublished) where relatively low levels of nutrients were present, but some chlorophyll records were higher than 15µg.l- indicating elevated algal productivity. There are no records for organic contaminants such as herbicides and pesticides or heavy metals for the system. In the estuarine health index score for KZN estuaries (Cooper *et. al.*, 1994) the water quality component for the Lovu scored 6.8 out of maximum of 10.

### *7.3.1.2 Floodplain Vegetation*

Estuarine vegetation has been previously assessed by the current author (S Pillay, unpublished). As indicated above the floodplain of Lovu has been severely impacted. Bank alteration and encroachment of sugar plantation onto the floodplain is evident in the earliest (1937) aerial

photographs. Other interventions (use as a dumpsite, sports field, recreational and parking area) further degraded the floodplain by the infilling of wetland area. A *Phragmites* reedswamp community occurs along the north bank of the estuary and along the south bank west of the N2 freeway. A very narrow fringe of reeds is present along the waters' edge at the south bank of lower estuary and along the north bank up to the mid estuary. A stand of *Hibiscus tiliaceus* occurs along the south bank of the lower estuary but its distribution is limited by the steep rise in terrain on the landward side. Upstream a fringe of riverine vegetation occurs along the banks of the river and the coastal vegetation surrounding this on both the north and south sides are disturbed and alien infested. Dune thicket occurs along the coast on either side of the estuary. Further upstream the area is characterized by agricultural development.

Estuarine vegetation in terms of community composition/habitat type at the Lovu is considered less important than some of the other local (eThekwini area) systems as the most significant habitat in the system in terms of coverage is reed swamp which is common to most estuaries. Nonetheless the ecological services (nutrient and contaminant assimilation, filtering capacity, detritus supply) contributed by floodplain vegetation i.e. its functional importance in terms of overall estuarine ecology and functioning, must not be under estimated.

#### *7.3.1.3 Algal Communities*

No studies on phytoplankton species or algal community composition for the Lovu could be found, but the author (SP) noted during several visits to the estuary in the early 1990s that both phytoplankton blooms and blue green algae scums on the exposed sand/mud banks were present. Nutrient enrichment from runoff from the adjacent cane fields, sewage contaminated stormwater and seepage and previously accidental discharges from the mill are likely to have been sources of nutrient enrichment into the system.

#### *7.3.1.4 Invertebrates*

Begg (1984) conducted several trawl surveys (essentially sampling larger epibenthic fauna) and found that the fauna was dominated by *Metapenaeus monoceros* but that the three migratory penaeid prawn species were also present. Three estuarine crab species (which included *Paratylodiplax blephariskios* and *Scylla serrata* which have an obligatory marine breeding phase) and one intertidal species were noted. During visits to the estuary in the early 1990s the author (SP) of this report notes the presence of an abundance of amphipods and *Callianassa* on the central intertidal sandbank.

Benthic analyses of grab samples taken at the mouth, mid and upper estuary in August 2007 and January 2008 (Forbes and Demetriades, 2008) indicated highest diversity in more more marine influenced areas of the estuary. Highest diversity occurred amongst the polychaetes (5 species) followed by amphipods (4 species) and high abundance of the tanaid *Apsuedes digitalis* was recorded at the mouth and mid reaches of the estuary in winter, and at the mouth in summer. The invasive alien gastropod *Tarebia granifera* was also present at the Lovu Estuary. The authors of these surveys rated the estuary as being fair in terms of the benthic invertebrate community as higher diversity was expected given the frequency of open mouth conditions.

Dr Allan Connell (pers. comm. – unpublished data) conducted zooplankton surveys of all the estuaries from the Mtamvuna to the Mhlathuze in September 1999 and found that the Lovu was one of the richest estuaries with settled zooplankton volume from a standard 50 m haul being 20 $cm^3$. This high

volume was largely due to a high density of the mysid *Mesopodopsis africana* and the two estuarine copepods *Psudeodiaptomus hessei* and *Acartia natalensis*. Repeat surveys in October 2000 showed slightly lower settled volumes due largely to an almost complete absence of the mysid.

#### *7.3.1.5 Fish*

Several fish surveys have been conducted at the Lovu Estuary. Begg (1984) sampled 27 species by beam trawling over seven months in 1980 and 1981. Overall, the fish assemblage was dominated by small estuarine species, including most notable the goby Oligolepis acutipennis and estuarine roundherring Gilchristella aestuaria. Sampling gear undoubtedly had an impact on the actual and relative abundances of fishes sampled, and larger, more mobile marine species were under sampled during these surveys. Harrison and co-workers (CSIR unpublished data) used seine and gill nets to sample the estuary in 1998 and recorded a much wider variety of species (32) with overall fish abundance dominated by marine dependant estuarine species (mullet). Gilchristella aestuaria nevertheless remained a significant component of the fish assemblage. Based on these results, and comparing them with data from other estuaries sampled in the subtropical bioregions, Harrison *et al.* (2000) categorised the Lovu estuarine fish assemblage as being in a moderate condition.

More recently the system was sampled as part of a post graduate research at the University of KwaZulu-Natal (winter and summer surveys in 2006). Twenty-two taxa were recorded, with mullet dominating fish abundance (Mclean *et al*., 2006, cited in Forbes and Detmetriades, 2008). Surveys that followed in winter 2007 and summer 2008 (Forbes and Detmetriades, 2008) yielded 16 taxa, again dominated by mullet.

Dr Allan Connell (pers. comm. - unpublished data) conducted larval recruitment studies at the estuary over incoming spring tides from October 2005 to February 2006 and April 2007 to January 2008). Large numbers of several species were found to recruit into the system from the marine environment. These included springer Elops machnata and tarpon Megalops cyprinoides in summer months and glassies Ambassis spp. in autumn months. Moonies Monodactylus spp. and Cape stumpnose Rhabdosargus holubi recruited throughout the year, along with several species of mullet. Goby larvae were also abundant at times. Most larvae were approximately thirty days old and the predominance of species with strong estuarine associations indicated that recruitment was not passive. This is supported by research conducted elsewhere which has shown that estuarine dependent marine spawning species actively follow fresh- and estuarine water cues to locate and recruit into estuarine nurseries (Boehlert and Mundy 1988, James *et al*. 2008). The predominance of open mouth conditions in the Lovu Estuary and its relatively large size render it important as a fish nursery area on the eThekwini and KwaZulu-Natal coast, where small temporary open/closed estuaries numerically dominate the wider estuarine resource.

#### *7.3.1.6 Birds*

In an exercise to prioritize estuaries for conservation using bird populations as an indicator (Turpie, 1995) the Lovu Estuary was ranked 41 out of 42 estuaries based on a species richness score of 20. By way of comparison the highest ranking estuary was the Mhlathuze with a score of 68. In more recent surveys conducted in the winter of 2007 and summer of 2008 (Forbes and Demetriades, 2008) 14 species (total count 69) and 28 species (total count 195) were recorded respectively. The highest

abundances were for the sanderling and common ringed plover in summer and the swift tern in both surveys.

## 7.3.2 Results of the Vegetation and Fish Surveys

### *7.3.2.1 Vegetation Community Survey*

As indicated in the review above the author (SP) has previously surveyed the floodplain for estuarine vegetation and mapped these communities onto orthophotographs. During this study the land cover along the estuary was categorized and digitized in Google Earth (Figure 7.2). No significant qualitative or quantitative changes in estuarine vegetation cover were noted during this survey and hence the reader is referred to section 9.3.1.2 for a general account of these communities. It would however appear that alien infestation of the riparian/dune communities along the estuary has increased. Invasive species include both shrubs (e.g. *Chromolaena odorata*, *Lantana camara*, *Riccinus communis*) and trees (e.g. *Melia azedarach*, *Syzygium cumini, Litsea sebifera*). The most invasive tree species, however, was the Brazilian pepper tree *Schinus terebinthifolius*, with severe infestation throughout the estuarine floodplain.

Figure 7.3 indicates the planned siting of infrastructure for the proposed desalination project overlayed onto the landcover map for clarity regarding vegetation communities that may be impacted.

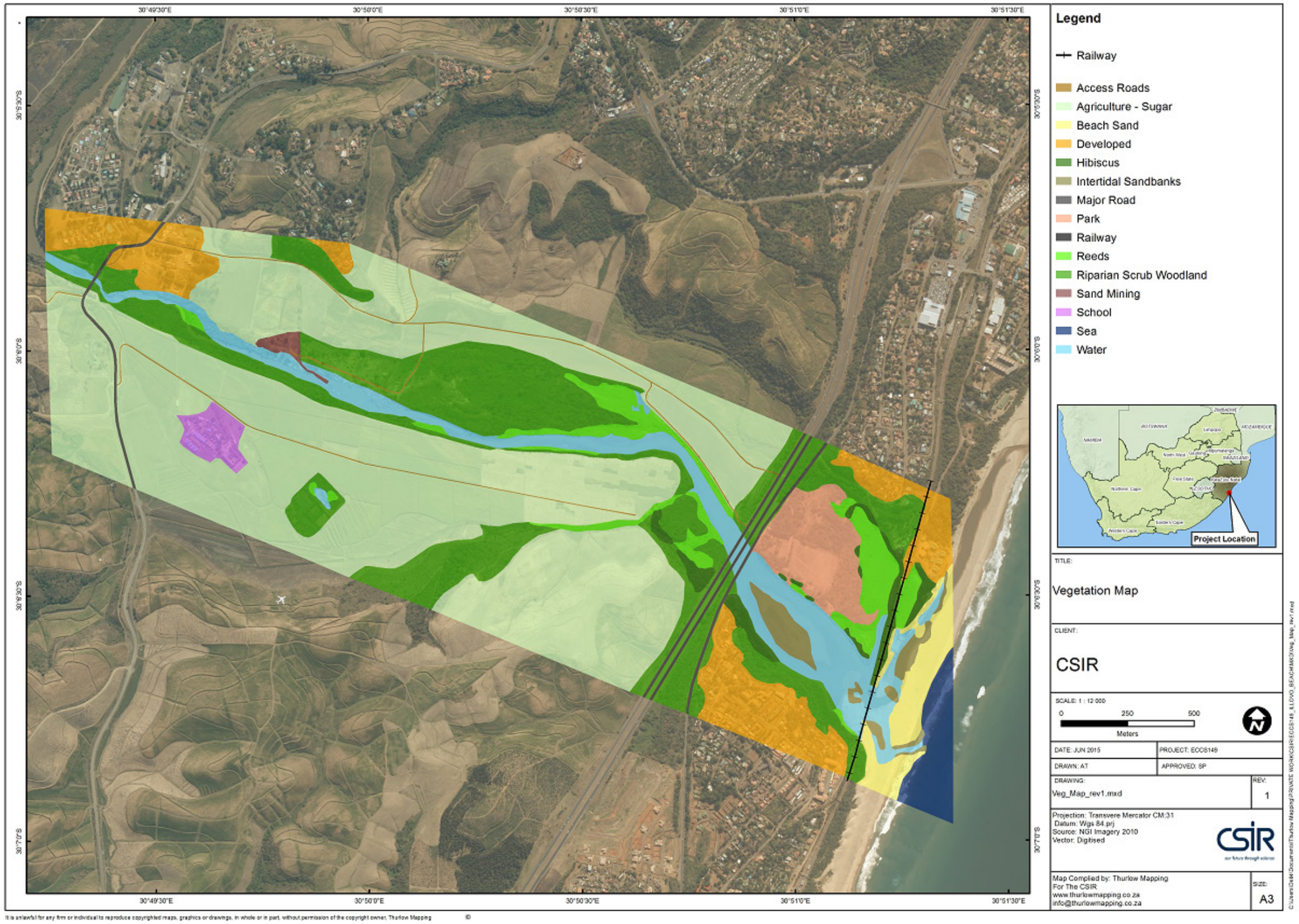


Figure 7.2 Land cover along the Lovu Estuary digitized in Google Earth to indicate distribution of estuarine vegetation along the floodplain

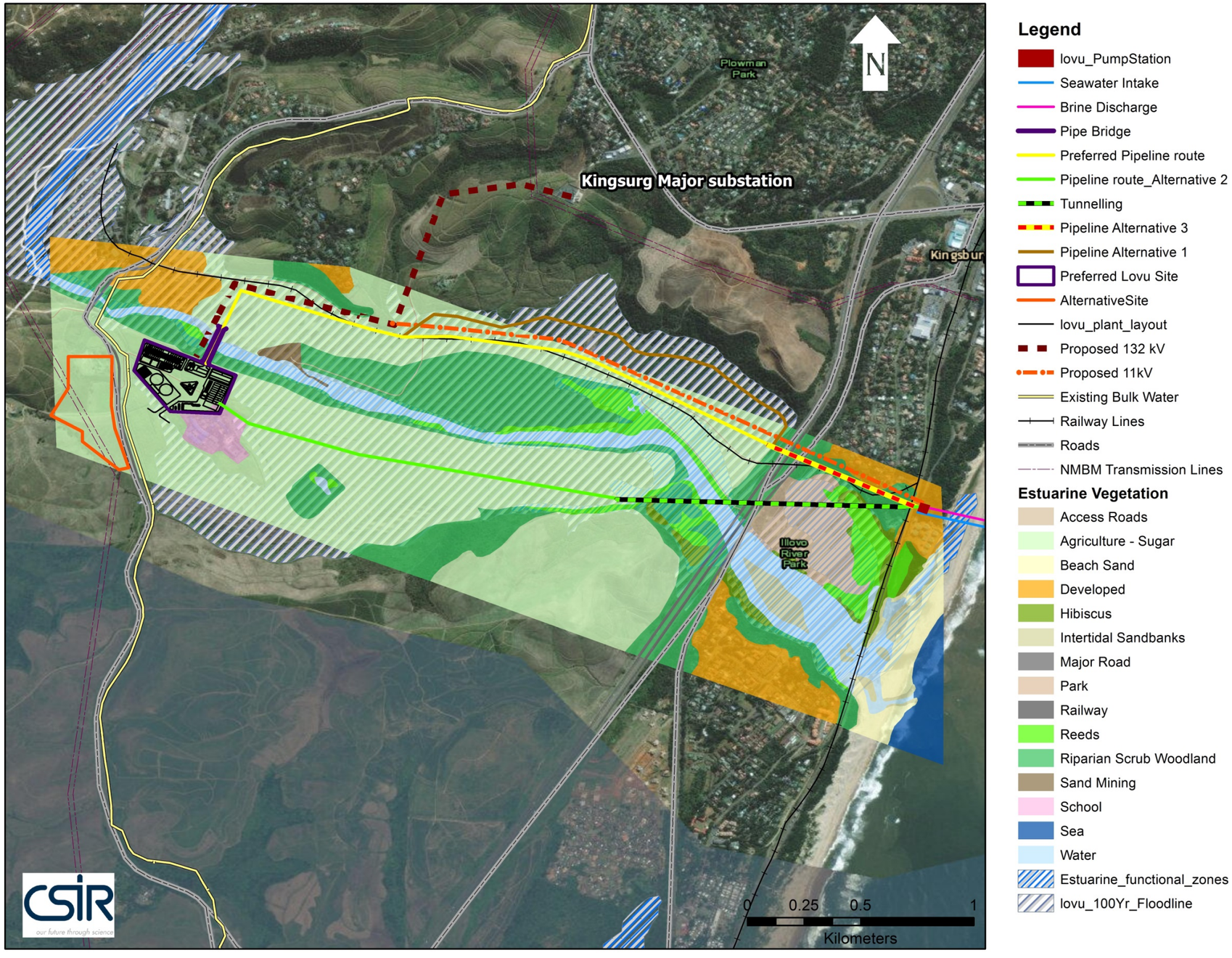


Figure 7.3 Planned infrastructure overlayed onto land cover map

As illustrated in Figure 7.2 the only communities of relevance for determination of estuarine botanical importance of the Lovu Estuary are reeds, small stands of hibiscus (lagoon swamp forest), intertidal sandbanks (benthic algae) and the water body (phytoplankton). When determining the botanical importance of a particular estuary the scores obtained are compared to the highest scoring estuary regionally or nationally whichever is appropriate for the purpose. The development and use of botanical importance ratings have undergone various developments over the years (Coetzee *et al*., 1997; Colloty *et al*., 2000) to incorporate habitat degradation, community rarity etc. For the purpose of this study, the Lovu will just be compared to the uMgeni, the highest scoring and one of the larger estuaries within the eThekwini Municipality. This will provide an importance rating in the context of the local region. Comparison with much larger estuaries such as the St Lucia and Kosi Bay systems, which by virtue of size, would result in irrelevant functional importance evaluation of smaller systems along this section of the coast. A simplified botanical index using coverage (areas), the standard productivity factor for each community type and the weighted community importance of each community type has been used to compare these estuaries. Usually botanical importance includes a degradation index but comparison of the uMgeni with the Lovu indicates that both these systems have been significantly degraded due to floodplain land use, the existence and bridges, water quality impacts, other anthropogenic effects such as littering and footpaths, and in the former, large dams in the catchment. The degradation index has thus been excluded. The coverage in hectares of each community type and the productivity score {community importance factor x coverage (area in hectares) x community productivity factor} is given in Table 7.1. The botanical importance Rating represents the sum of these according to the formula:

$$BIR = 1.5(area_{RS}X1384) + 1.5(area_{IS}X\ 124) + 1.75(area_{LSF}\ X\ 1890) + 1(area_{w}\ X\ 163) + 2(area_{M}\ X\ 1835)$$

*Where:* $_{RS}$ = Reed Swamp; $_{IS}$ = Intertidal Sandbanks; $_{LSF}$ = Lagoon Swamp Forest; $_{W}$ = Water; $_{M}$ = Mangroves

Table 7.1 Coverage by community type and productivity scores for estuarine communities

| **Community Type** | **A. Community Importance Factor** | **B. Coverage** (hectares) | **C. Productivity Factor** | **Productivity score (AxBxC)** |
|---|---|---|---|---|
| **Lovu Estuary** | | | | |
| Reed Swamp (reeds and sedges) | 1.5 | 16.415 | 1 384 | 34 077.54 |
| Intertidal Sandbanks (benthic algae) | 1.5 | 5.483 | 124 | 1 019.84 |
| Lagoon Swamp Forest (hibiscus) | 1.75 | 6.224 | 1 890 | 20 585.88 |
| Water (phytoplankton) | 1 | 30.452 | 163 | 4 963.68 |
| **Botanical Importance Rating (=Total Productivity Score)** | | | | **60 646.94** |
| **uMgeni Estuary** | | | | |
| Reed Swamp (reeds and sedges) | 1.5 | 9.841 | 1 384 | 20 429.91 |
| Intertidal Sandbanks (benthic algae) | 1.5 | 4.142 | 124 | 770.42 |
| Lagoon Swamp Forest (hibiscus) | 1.75 | 5.679 | 1 890 | 18 783.29 |
| Water (phytoplankton) | 1 | 36.993 | 163 | 6 029.86 |
| Mangroves | 2 | 20.284 | 1 835 | 74 442.28 |
| **Botanical Importance Rating (=Total Productivity Score)** | | | | **120 455.76** |

The calculated botanical importance score for the Lovu estuary is thus 60 646.94 and that of the uMgeni is 120 455.76. When comparing estuaries these large numbers are converted to percentages of the highest scoring estuary. The practice is thus to produce a normalised botanical importance

score by reducing the score of the highest ranking estuary to 100 so that all other estuaries are ranked as a percentage of 100. Therefore in this instance if the uMgeni is given a score of 100 then the Lovu would achieve a botanical importance score of 50. The difference is mostly due to the large mangrove stand present in the uMgeni and the scoring provides some context of value in terms of the larger estuaries situated within this local region of the coastline. Thus although the Lovu would score relatively low if compared on a national basis due to relatively small size and low community diversity, it is clear that it is of significant value in a local context where several smaller estuaries collectively provide this habitat and the relevant goods and services in this area of the coastline. All these estuaries have furthermore been subjected to development impacts and are currently in various states of degradation making it imperative that estuarine resources in this area are appropriately protected against further trajectory of negative environmental change.

#### *7.3.2.2 Physicochemical Water Quality Parameters*

Physicochemical water quality parameters of significance to estuarine biota were measured *in situ* at sites where seine nets were deployed for the fish assessment (S1-S7, Figure 7.3). The results obtained for surface and bottom waters (with the exception of site S4 which was very shallow) are presented in Table 7.2. As seine netting was conducted along the shoreline, depths sampled were generally shallow and bottom readings were typically taken at ~1 m.

Table 7.2 Results for physicochemical parameters measured along the Lovu Estuary

| Site | Temperature (°C) | Salinity | pH | Turbidity (NTU) | Chlorophyll-a (µg/L) | Dissolved Oxygen Saturation (%) | Dissolved Oxygen (mg/L) |
|---|---|---|---|---|---|---|---|
| S1 surface | 22.37 | 15.12 | 8.21 | 4.60 | 7.97 | 107.18 | 8.53 |
| S1 bottom | 23.06 | 18.99 | 8.21 | 4.82 | 13.72 | 108.94 | 8.37 |
| S2 surface | 23.45 | 16.48 | 8.21 | 4.52 | 10.34 | 116.83 | 9.04 |
| S2 bottom | 23.51 | 16.64 | 8.17 | 5.81 | 13.35 | 117.92 | 9.10 |
| S3 surface | 24.17 | 16.79 | 7.32 | 5.34 | 8.15 | 115.09 | 8.77 |
| S3 bottom | 24.84 | 23.94 | 7.34 | 8.36 | 31.84 | 124.87 | 9.03 |
| S4 surface | 25.92 | 13.75 | 8.21 | 10.24 | 3.20 | 130.55 | 9.82 |
| S5 surface | 24.42 | 13.06 | 7.84 | 6.11 | 9.43 | 111.44 | 8.64 |
| S5 bottom | 26.04 | 21.96 | 7.80 | 9.58 | 19.04 | 104.24 | 7.47 |
| S6 surface | 25.08 | 13.18 | 8.13 | 5.91 | 11.00 | 120.21 | 9.20 |
| S6 bottom | 27.25 | 21.86 | 7.83 | 10.55 | 24.63 | 110.60 | 7.77 |
| S7 surface | 26.04 | 11.19 | 7.96 | 8.31 | 13.64 | 117.04 | 8.91 |
| S7 bottom | 27.12 | 15.65 | 7.80 | 15.30 | 22.41 | 110.61 | 8.06 |

Salinity measurements indicated tidal influence throughout the sampling area which extended to approximately 4 km upstream from the mouth. Although the multi parameter probe was deployed in relatively shallow areas there was evidence of vertical salinity gradient with greater salinity recorded in bottom waters at each site. The highest salinity (>23) was measured in bottom water at the site S3 in the lower reaches of the estuary.

Turbidity measurements were relatively throughout the estuary, typically <10NTU. Turbidities in KwaZulu-Natal estuaries are generally higher than those in open marine water. The highest turbidity measure in the Lovu in April 2015 was 15.3 NTU in bottom waters at the uppermost sampling site (S7). The generally low turbidity measurements in the system were the result of sampling being conducted during a relative dry period with little preceding rainfall and riverine sediments being delivered into the estuary.

Chlorophyll-a measurements indicated nutrient enrichment in the system with the highest levels being recorded in the more saline bottom waters. Algal productivity resulted in the supersaturated oxygen concentrations measured in the system. The highest oxygen saturation level was measured at Site s4 (surface waters) where intertidal and shallow subtidal benthic algae probably contributed to oxygen levels in the water.

One water sample from the lower estuary was examined qualitatively to determine the dominant phytoplankton present in the system. The algal community was essentially composed of diatoms with a single species of *Navicula* being numerically dominant. Two unknown species of dinoflagellates and three species of euglenoids were also present in the sample. The absence of cyanophytes (blue green algae) such as *Osillatoria* indicated that the system was not severely eutrophic.

During this survey none of the measured physicochemical parameters were expected to impact adversely on the biota in the system.


Figure 7.4 Physicochemical water quality and fish sampling sites (Google Earth, 2015)

#### *7.3.2.3 Fish community survey*

Twenty-one species were sampled in the Lovu Estuary in April 2015 (Table 7.3). Estuarine dependent marine species dominated seine net catches numerically, either in the form of Cape stumpnose *Rhabdosargus holubi*, Natal stumpnose *Rhabdosargus sarba*, or groovy head mullet *Liza dumerilii*. These species are typical of KwaZulu-Natal temporary open/closed estuaries, but the relative abundance of *L. dumerilii*, together with the presence of several marine species such the slimy *Leiognathus equula* and blacktail *Diplodus sargus* is indicative of a system which is subject to frequent penetration by marine (saline) water and which has a mouth which is frequently open to the marine environment. Surprisingly few estuarine resident fishes were recorded in April 2015, and those that did occur were sampled in relatively low abundances. This suggests possible system degradation and with the high algal productivity noted during fish sampling is a source of some concern, although more frequent sampling would be needed to make a more confident assessment of the system's state. Based on the data at hand there is little to suggest that the system has changed from being in a "Fair" condition as assigned by Forbes and Demetriades (2008) based on their field work in 2007 and 2008.

Although impacted, the estuary has considerable more value as an estuarine resource than indicated by Begg (1978). Turpie *et al*. (2002) ranked the Lovu 80$^{th}$ of ~ 250 South African estuaries in terms of its conservation status. On a more localised scale, given the estuary's relative large size and the degradation of nearby systems, the Lovu must be regarded as an important system. Several of the fishes reported from the estuary are important in estuarine- and shore fisheries. These included the stumpnoses *Rhabdosargus* spp., river bream *Acanthopagrus vegas*, spotted grunter *Pomadasys commersonnii*, kingfishes *Caranyx* spp. and barracuda *Sphyraena* spp. All of these species have populations which are declining, in part because of overexploitation, but also because of habitat losses and particularly because of loss of estuarine nursery area. At least one species listed under the National Environmental Management: Biodiversity Act 10 of 2004: Amendment R1187 of 2007 occurs in the estuary (*Myxus capensis*, vulnerable). Conservation importance and vulnerability of estuarine fishesin South Africa is better reflected in the IUCN Red List of Threatened Species (IUCN 2015), which includes several fish species which have been sampled in the Lovu Estuary. These include fishery species (such as *A. vegas*) but are more commonly small estuarine fishes with a high degree of habitat specificity (e.g. *Oligolepis acutipennis*). Fish surveys of the Lovu are generally limited to fish sampling gears that are historically used in South African systems, and which target fishes in open habitats. Despite being in a highly modified state, and having undergone significant habitat alteration and destruction over the years, there is still a good deal of structured reed habitat in the Lovu Estuary which undoubtedly supports fish species which have not yet been reported in the system. These will be small cryptic estuarine residents and are likely to include several Red Listed species not currently reported from the estuary, such as checked goby *Redigobius dewaali*, dusky sleeper *Eleotris fusca*, and barbelly pipefine *Hippichthys spicifer*.

Table 7.3 Relative abundance (%) of different fishes sampled (% abundance) by seine net at sites (Figure 7.3) on the Lovu Estuary (April 2015). (IUCN 2015 Red List category (version 3.1) indicated, LC = Least Concern, DD = Data Deficient)

| Species | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|
| **Estuarine resident species** | | | | | | | |
| *Ambassis ambassis (LC)* | | | | | 3.8 | | |
| *Ambassis natalensis* | | | | 32.0 | | | |
| *Oligolepis acutipennis (DD)* | | | | | | 3.1 | |
| **Estuarine dependant marine species** | | | | | | | |
| *Myxus capensis* | | | 14.3 | | 7.7 | 1.6 | |
| *Liza macrolepis* | | | 1.3 | 1.6 | | 16.3 | |
| *Mugil cephalus* | | | 1.3 | 0.8 | | | |
| *Pomadasys commersonnii* | | | | | | 2.3 | |
| *Rhabdosargus holubi* | 44.4 | 71.1 | 33.8 | 3.1 | 34.6 | 50.4 | 58.3 |
| *Terapon jarbua (LC)* | | | 23.4 | 3.9 | | 0.8 | |
| *Valamugil cunnesius* | | | | 7.0 | 3.8 | 17.1 | |
| *Gerres filamentosus (LC)* | | | 6.5 | | | | |
| *Gerres methueni* | | | 1.3 | | | 0.8 | |
| *Leiognathus equula* | | | | | 3.8 | 1.6 | 8.3 |
| *Liza dumerilii* | 50.0 | 7.9 | 6.5 | 50.0 | | | 8.3 |
| *Rhabdosargus sarba* | 2.8 | 18.4 | 6.5 | 1.6 | 42.3 | | 8.3 |
| *Caranx* sp. | | | 1.3 | | | 3.1 | 16.7 |
| *Diplodus sargus* | 2.8 | | | | | | |
| *Sphyraena* sp. | | 2.6 | | | | | |
| *Valamugil buchanani* | | | 3.9 | | | | |
| **Freshwater species** | | | | | | | |
| *Glossogobius giuris* | | | | | | 2.3 | |
| *Oreochromis mossambicus* | | | | | 3.8 | 0.8 | |

## 7.4 IDENTIFICATION OF KEY ISSUES AND POTENTIAL IMPACTS

### 7.4.1 Key Issues Identified During the Scoping Phase

**Phase 1 (Construction phase):**

1. Destruction and disturbance of floodplain vegetation especially significant for Alternative 2 of the pipeline route.
2. Permanent destruction of on-site vegetation and disturbance of adjacent floodplain vegetation during construction of the proposed desalination plant.
3. Increased turbidity in the estuary during excavation and construction activities. Resultant effects on fauna and possible increased siltation and smothering of benthic fauna.
4. Potential release of contaminants from old dumpsite into the estuary during excavation for pipelines on the north bank.

5. Disturbance to bird populations (noise, movement of machinery and workers).

**Phase 2 (Operational phase): Discharge of wastewater (brine) to the nearshore environment**

1. Possible entrainment of brine into the nearshore environment at the mouth of estuary. If salinities are increased at the mouth then there are potential impacts on recruitment into the estuary due to loss of cues such as reduced salinity.

**Phase 2 (Operational Phase): Noise from operation of the desalination plant**

1. Noise can result in disturbance to fauna especially birds

It is important to note that the impact of noise on sensitive areas and receptors (such as residential areas, construction personnel etc.) is the subject of a separate Noise Impact Assessment specialist study (Chapter 9 of this Draft EIA Report).

The following key issues were identified during the public consultation period on the scoping report:

eThekwini's Environmental Planning and Climate Protection Department presents the following comments:

- This Department is concerned as to the proximity of the northern edge of the proposed plant to the Ilovu Estuary. Further comment will be provided once a detailed site layout is provided. However on principle all structures must be located as far from the river as possible.
- Impacts associated with the proposed crossing of the Ilovu Estuary must be addressed as part of the EIR.

### 7.4.2 Identification of Potential Impacts

**Phase 1 (Construction phase): Construction of the proposed desalination plant and associated infrastructures**

1. Destruction and disturbance of floodplain vegetation as a result of the construction of the seawater intake and brine discharge pipelines.
2. Permanent destruction of on-site vegetation and disturbance of adjacent floodplain vegetation during construction of the proposed desalination plant
3. Increased turbidity in the estuary during excavation and construction of the pipelines and desalination plant, resulting in effects on fauna and possible increased siltation and smothering of benthic fauna.
4. Potential release of contaminants from old dumpsite into the estuary as a result of the construction of the seawater intake and brine discharge pipelines.
5. Disturbance to bird populations and other fauna (noise, movement of machinery and workers).

**Phase 2 (Operational phase): Discharge of wastewater (brine) to the nearshore environment**

1. Possible entrainment of brine into the nearshore environment at the mouth of estuary. If salinities are increased at the mouth then there are potential impacts on recruitment into the estuary due to loss of cues such as reduced salinity.
2. Possible contamination in the region of mouth of the estuary from chemicals used in the treatment process that may still be present in residual concentrations in the discharged brine.

**Phase 2 (Operational phase): Stormwater**

1. Increased hard surfaces at the proposed plant will cause an increased runoff coefficient and the discharge point into the estuary could be subject to erosion.

**Phase 2 (Operational phase): Noise during plant operation**

**1.** Mitigation is provided by the engineering design of the plant but there is uncertainty about the actual noise level that would occur during operation

**Phase 3 (Decommissioning phase): Noise during decommissioning of plant**

1. Noise during removal of equipment etc. from the plant and increased traffic.

## 7.5 PERMIT REQUIREMENTS

No permit applications have been submitted as part of this specialist study. Potential development and consequent impacts on the estuary may be subject to the following legislative requirements:

The legislative context is provided by two conventions of which South Africa is signatory:

1. The Convention on Biological Diversity (1992) ensures that every effort is made to conserve all species; and
2. The Action Plan of the Environmental Initiative of the New Partnership for Africa's Development (NEPAD of 2003) promotes sustainable development and implies the need to conserve biodiversity while advocating wise use of our natural resources.

South African legislation applicable to estuarine fauna and flora are:

1. The National Environmental Management: Biodiversity Act 10 of 2004: Amendment R1187 of 2007 ensures the protection of all species and prohibits any destruction of or damage to any threatened or keystone species and ecosystems. (Threatened fish species, including species listed under the National Environmental Management Biodiversity Act, have been recorded in the Lovu Estuary –see fish report section 7.3.2.3)
2. The National Environmental Management: Integrated Coastal Management Act 24 of 2008; Section 33- The Estuarine Management Protocol. The protocol provides guidance for the management of estuaries through the development of individual estuarine management plans (Note that the local authority is responsible to develop such plan together with stakeholder contributions).

3. KZN Provincial Nature Conservation Ordinance (1974): Protected indigenous plants are controlled under the relevant provincial Ordinances or Acts. In terms of this Ordinance, a permit must be obtained from *Ezemvelo* KZN Wildlife to remove or destroy any plants listed in the Ordinance (*Hibiscus tiliaceus* is of relevance in this study).

## 7.6 ASSESSMENT OF IMPACTS AND IDENTIFICATION OF MANAGEMENT ACTIONS

### 7.6.1 Construction Phase

#### *7.6.1.1 Potential Impact 1: Increased estuarine turbidity due to the construction of the proposed desalination plant (direct impact).*

Construction activities for the proposed desalination plant for both site alternatives will entail excavation for foundations as well as transport and storage of building sand. Rainfall events during construction may result in discharge of sediments into the estuary. The resultant effect would be increased turbidity and potential for increased sedimentation in the estuary should large volumes enter the estuary. This would lead to impacts on biota in the system including:

- Loss of visual cues affecting feeding in predatory fish;
- In the case of a severe event there is potential for clogging of fish gills and filter feeding structure in invertebrates;
- High sediment inputs will result in smothering of benthic fauna; and
- Aesthetic quality will be reduced.

While these effects are expected to be largely temporary, large inputs of sediments, should they occur, will impact benthic fauna which may require greater than two years to recover. Without mitigation increased turbidity in the estuary is likely to occur especially if intense rainfall events occur during the construction period. The intensity of the impact is also dependent on severity and frequency of rainfall events. The intensity is rated as medium as the area covered by the development is low in relation to the remaining floodplain and the current land use i.e. sugar cane farming is likely to be currently causing similar impacts. The overall significance of this negative impact is rated as **low** with a high level of confidence, without the implementation of key mitigation measures.

Key mitigation measures proposed include:

- The use of sediment traps and geotextile blankets to prevent discharge of sediments into the estuary during construction.

Additionally mitigation measures recommended by specialist to manage this impact include:

- If possible, excavation and trenching should be planned to occur during the low rainfall period (winter).

The effective implementation of the above key mitigation measures is likely to reduce the significance of this potential impact to **very low**.

#### *7.6.1.2 Potential Impact 2: Increased estuarine turbidity during installation of seawater intake and brine discharge pipelines (direct impact).*

**Preferred pipeline route and Alternatives 1 and 3- North bank routing and bridging over upper estuary with and without tunnelling**

Excavation for installation of the proposed seawater intake and brine discharge pipelines along a current service line and bridging of these across the upper estuary, indicated as the preferred option (in yellow) in Figure 7.3, will cause similar risk of increased turbidity as described in section 7.6.1.1 above. The slightly northward deviated route option linking to the preferred option (and shown in brown in Figure 7.3) is not expected to have any significant reduction in impacts and hereafter both options are simply treated similarly in terms of envisaged impacts. Effects of increased turbidity on water quality and biota will be the same as described in Section 7.6.1.1 above. The impact assessment is thus also the same and is predicted to have an overall **low** significance without the implementation of key mitigation measures. The level of confidence in the assessment is high.

Key mitigation measures proposed include:

- The use of sediment traps and geotextile blankets to prevent discharge of sediments into the estuary during construction.
- Revegetate excavated areas with appropriate species (see section 7.6.1.3)

Additionally mitigation measures proposed by specialist include:

- If possible, excavation and trenching should be planned to occur during the low rainfall period (winter).

Implementation of the above key mitigation measures will slightly reduce the significance of the impact to **very low** through reduced severity and probability of occurrence.

**Alternative 2 - Tunnelling beneath the estuary and routing across the lower estuary**

For Alternative 2, the installation of the proposed sea water intake and brine discharge pipelines across the lower estuary is also expected to result in turbidity impacts during excavation activities for the non-tunnelled section and during the establishment of temporary work areas at the proposed entry and exit sites on either side of the estuary for the tunnelled section. The effects on the water quality and biota may be similar to those described for Alternative 1 but proximity to the mouth of the estuary could also result in a risk of turbidity effects in the nearshore environment. Furthermore, for this alternative the proximity of construction activities to the estuarine water's edge increases the probability, and possibly severity, of turbidity impacts on the estuary. Given the above, impacts associated with increased estuarine turbidity during the construction of Alternative 2 pipeline route are predicted to be of **medium** significance without the implementation of key mitigation measures.

A concern associated with drilling is the possibility of frac-outs, which are generally defined as an inadvertent return of drilling fluids to the surface or into the adjacent soil or rock. Frac-outs generally occur in very coarse-grained sands containing material in the size range of pebbles to cobbles. Given the anticipated geology along the proposed route (i.e. mostly consolidated materials/bedrock), it is very unlikely that this type of material could be encountered in the course of the drilling operations.

Umgeni is planning to use water based drilling muds which are biodegradable and typically consist of a mixture of water and bentonite. It might however contain very minute quantities of trace metals. Bentonite is an inert clay material and is considered essentially non-toxic to aquatic organisms, although it can have adverse physical effects on organisms that might become coated with the clay. Drilling mud losses could cause temporary and localised increases in turbidity and suspended solids concentrations in surface water and also promote siltation within underlying shallow alluvial aquifers. Although the occurrence of frac-outs associated with drilling is possible, the potential related impact on surface and groundwater quality, and knock-on effects on aquatic fauna and flora, is anticipated to be of low-medium intensity, spatially localized and will persist in the short-term. Overall, the significance of the potential impacts associated with frac-outs is anticipated to be **low**.

Key mitigation measures proposed include:

- The use of sediment traps and geotextile blankets to prevent discharge of sediments into the estuary during construction.
- Re-vegetate impacted areas as soon as possible (see section 7.6.1.3).
- Monitor local water quality prior to and during drilling operations

Additionally mitigation measures proposed by specialist include:

- If possible excavation and trenching should be planned to occur during the low rainfall period (winter).

Implementation of key mitigation measures will reduce the overall significance of this negative impact to **low**.

#### *7.6.1.3 Potential Impact 3: Removal of indigenous vegetation for construction of the proposed desalination plant*

Both site alternatives (Figure 7.3) have similar impacts regarding removal/disturbance of vegetation at, and adjacent to, the proposed desalination plant and thus the impact assessment is the same for both sites. Both sites are currently under sugar cane cultivation which has no value in terms of conservation. However, the preferred option is very close to the channel allowing very limited space for terrestrial vertebrates and invertebrates to move around the channel, therefore impacting on the ecological corridor between the proposed plant and the channel. Loss of any indigenous species and impact on the ecological corridor for the Preferred site and adjacent areas is considered probable, resulting in an overall significance assessment of **Medium**. For the Alternative site, this impact is predicted to be of **very Low** significance.

Key mitigation measure is limited to:

- For the preferred site move the development back to create at least a 25 metre extension between the development and the channel
- Endeavour to control the footprint of the development

The overall rating with mitigation is expected to be **low** to **very Low** and the confidence level in the assessment is high.

#### *7.6.1.4 Potential Impact 4: Removal/disturbance of indigenous vegetation during pipeline installation*

***Preferred pipeline route and alternatives 1 and 3 – North Bank Routing***

These alternatives essentially route the pipelines along a current service line and thus, impacts on surrounding vegetation are expected to be minimal. Furthermore, with the exception of some riparian vegetation (which is severely alien infested) in the vicinity of the proposed bridge (i.e. where the pipeline is proposed to cross the estuary) and similar communities between the proposed pump station and the N2 freeway, the proposed route is located within sugar cultivation areas which are of little conservation significance. The loss of some indigenous species is however considered probable and this results in an overall **very low** significance.

Key mitigation measures proposed include:

- Rehabilitate the riparian vegetation community in the region of the proposed bridge as soon as construction activities are completed. Use indigenous groundcover such as the grass *Stenotaphrum secundatum* and trees such as *Brachylaena discolor*, *Acacia karoo* etc.
- Following the installation of the proposed pipelines, re-vegetate the surface with a fast growing coastal grass such as *S. secundatum*. This is mainly to protect against erosion and inputs of sediment into the estuary.

With the effective implementation of the above key mitigation measures, the overall significance of this impact remains **very Low**. The confidence level for this impact assessment is high.

**Alternative 2 - Tunnelling beneath the estuary and routing across the lower estuary**

Ecologically the most important estuarine habitats are located at the lower sections of the estuary. Habitat diversity is thus generally greatest in this area. The proposed routing in this alternative traverses ecologically significant reed swamp and swamp forest along both the south and north banks (see Figure 7.2) and crosses the channel of the estuary. However, since it is proposed that this section of the route will be tunnelled beneath these sensitive habitats no major impacts are envisaged and the vegetation loss would be low significance for most of the route. However, the reception pit for tunnelling on the south bank is currently located at the edge of the sensitive area and almost within a drainage line. Given the thread to this sensitive environment, the significance in terms of vegetation loss without additional mitigation is **medium**.

Key mitigation measure proposed includes:

- The reception pit for tunnelling on the south bank should be moved by at least 100-130m further west
- Following the installation of the proposed trenched section of the pipeline re-vegetate the surface with a fast growing coastal grass such as *S. secundatum*. This is mainly to protect against erosion and inputs of sediment into the estuary.

The overall significance assessment remains **low** with the implementation of the key mitigation measure.

#### *7.6.1.5 Potential Impact 5: Noise and removal of vegetation during construction of the proposed desalination plant resulting in disturbance to fauna*

Increased noise from construction activities, machinery and vehicles during the construction of the desalination plant (preferred and alternative site) and removal of vegetation is a certainty. This would impact on bird populations, as well as, small reptiles and mammals currently inhabiting the cane fields. The impact is temporary and animals that move away from the source are expected to return to the area on cessation of these activities. The intensity has been assessed as medium-low and the overall significance is rated as **low** (without the implementation of key mitigation measures).

There can be little done to reduce expected noise levels during construction. The only key mitigation measure proposed is:

- Limit vehicle speed in and around the construction site.
- Endeavour to control the footprint of the development
- Awareness training of all staff regarding fauna disturbance

Mitigation is not expected to have substantial reduction in noise levels and the assessment with key mitigation is **low** and is made with a high degree of confidence.

#### *7.6.1.6 Potential Impact 6: Noise and removal of vegetation during installation of the proposed pipelines resulting in disturbance to fauna*

The impacts on fauna associated with noise and removal of vegetation during the construction activities for the Preferred route and Alternatives 1 and 3 (north bank routing) are similar to those associated with the construction of the desalination plant (Section 9.6.1.5 above) and are anticipated to be of **low** significance without the implementation of key mitigation measures. The slight increase compared to that of noise during construction of the proposed desalination plant is due to a wider area of impact which includes the lower estuary where the ecologically important habitats occur.

For Alternative 2 (south bank routing and tunnelling beneath lower estuary), these impacts are similar to those associated with the construction of the preferred route. However, there is some uncertainty regarding impacts from vibrations that may be produced by tunnelling equipment i.e. the effects on fish behaviour in particular is not known. The only reference to impacts on aquatic organisms was for the Corrib Gas Pipeline (www.**corribgaspipelineabpapplication**.ie/...%20Environental%20**Impact**/) which indicated potential temporary impacts on behaviour of benthic organisms and, based on the low levels of vibrations, impacts on fish were expected to be "imperceptible and temporary". It is however noted that this assessment was not based on any actual observations or data. Due to these uncertainties this assessment remains conservative (**medium** significance) and of medium confidence level.

There can be little done to reduce expected noise levels during the proposed installation of the pipelines. The following key mitigation measures are proposed:

- Limit vehicle speed in and around the pipeline route.
- Endeavour to control the footprint of the development
- Awareness training of all staff regarding fauna disturbance

Mitigation is not expected to have substantial reduction in noise levels and the significance of these impacts with the implementation of key mitigation remains **low** for the preferred route and for all the alternative routes.

#### *7.6.1.7 Potential Impact 7: Release of potential contaminants from the old dumpsite during proposed pipeline installation*

This potential impact is limited to the preferred route and Alternatives 1 and 3 pipeline routes only as the dumpsite is located on the north bank. During excavation for installation of the proposed pipelines high rainfall events could wash sediments containing contaminants into the estuary and these could have effects on estuarine biota. However, there has been no study undertaken concerning the type or concentration of contaminants potentially present in sediments at the dumpsite. The significance assessment of this impact can thus only be made with a low level of confidence and is thus largely based on probability of occurrence which would be due to frequency and intensity of rainfall events. This potential negative impact is predicted as short term with a medium intensity and the overall significance is assessed as **low** without the implementation of key mitigation measures.

Proposed key mitigation measures include:

- Use sandtraps and geotextile blankets to prevent excavated material from entering the adjacent water body. However if contaminants are highly soluble the efficacy of this mitigation will be reduced.

Given that the solubility of contaminants that may potentially be released from the old dumpsite is unknown, the potential impacts associated with those release in the estuarine environment during construction activities are anticipated to remain of **low** significance with the effective implementation of the above key mitigations. Given this uncertainty it is further recommended that:

- A sediment toxicity assay should be conducted prior to the proposed pipeline installation. Toxicity is recommended as it serves as a risk assessment tool to determine potential biological availability of any contaminants that may be present. Chemical analyses cannot be recommended as the types of the contaminants are unknown and therefore it is not possible to determine which parameters should be analysed. Toxicity should be conducted on sediments leachates from at least two random sites within the dumpsite using the sea urchin toxicity test. It is recommended that samples be collected from surface, mid depth and bottom (bottom being the depth at which the pipeline is to be buried) at each site along the proposed pipeline route where it traverses the dumpsite. Samples from each of these depths may be collected through digging of a pit or coring at each site.

With the implementation of the above additional mitigation measures, the significance of this negative impact is still anticipated to be **very low**.

### 7.6.2 Operational Phase

No significant impact from increased runoff due to increased hard surfaces at the proposed desalination plant is expected as this forms a very small footprint (area) in relation to the surrounding catchment. No further assessment of this impact is therefore considered necessary.

#### *7.6.2.1 Potential Impact 8: Impacts on the ecological corridor between the plant and the estuarine channel*

The preferred option is very close to the channel allowing very limited space for terrestrial vertebrates and invertebrates to move around the channel, therefore impacting on the ecological corridor between the proposed plant and the channel. Impact on the ecological corridor for the Preferred site and adjacent areas is considered probable, resulting in an overall significance assessment of **Medium**. For the Alternative site, this impact is predicted to be of **very Low** significance.

Key mitigation measure is limited to:

- For the preferred site move the development back to create at least a 25 metre extension between the development and the estuarine channel

The overall rating with mitigation is expected to be **low** to **very Low** and the confidence level in the assessment is high.

#### *7.6.2.2 Potential Impact 9: Noise during plant operation*

This assessment is applicable to both alternatives for siting of the Desalination Plant. The design of the buildings of the desalination plant has inherent noise reduction measures. Noise will have the same effect on biota as described for the construction phase but the intensity of this impact is expected to much lower during plant operation. The duration is however long term, i.e. the lifespan of the project. The overall significance of this impact without additional mitigation measures has been assessed as **Low**. The confidence level however remains medium as it is difficult to predict the actual intensity of the noise and consequent impacts on the biota.

It is recommended that supply and waste removal vehicles are subjected to speed limits in and around the site. Additional mitigation measures to reduce noise due to plant operation are presented in the noise specialist study (refer to Chapter 9).

#### *7.6.2.3 Potential Impact 10: Possible entrainment of brine into the surf zone*

Estuarine environments are important nursery areas for several estuarine dependent fishes and crustaceans. Most of these species breed at sea and recruit into the estuaries as larvae and juveniles. Reduced salinity in the surf zone around estuary mouths is an important factor for these species to successfully locate estuaries and recruit into them. Increased salinity due to brine discharge has thus been identified as having the potential to negatively impact on fish recruitment. Assessment of this potential impact is based on the brine dispersion modelling report (WSP, 2013) from which the modelled worst case scenario (discharge of 3 040l/sec; salinity 57.57 ppt) was used to complete the impact assessment. The hydrodynamic model indicates that salinity above ambient conditions

occurred in the surf zone during the both summer and winter modelling periods (90 day) for 1% of the time which amounts to <1 day. The salinity exceedance was between 0.05 and 0.10ppt above ambient. Ambient salinity was assumed to be 35 ppt and no compensation for naturally occurring reduced salinity around estuary mouths were made. In addition, the diffuser is designed and placed at sufficient distance from the intake structure such as to prevent re-circulation of the brine stream. Dispersion modelling results indicate that the risk of entrainment of brine in the surf-zone is negligible (Aurecon, 2015). Given the low frequency of occurrence and low intensity of the predicted salinity increases, impact of entrainment of brine into the surf zone is assessed as being of **low** significance without the implementation of key mitigation measures. In addition, any other residual contaminants in the brine (as discussed in Section 7.1.4.2 of this chapter) are also expected to undergo significant dilution and this aspect has thus not been further assessed. Confidence in the assessment is medium as actual conditions may differ from modelled conditions.

No additional mitigation measures are recommended for this potential impact.

### 7.6.3 Decommissioning Phase

***It is noted that the facility will most probably be refurbished and will continue to operate beyond its predicted 25 year lifespan. The timing of final decommissioning is thus unknown. Nonetheless, it is assumed that all final disposal of waste materials (including chemicals) and redundant equipment and machinery will be handled according to best practices and legal requirements during decommissioning. These aspects will thus not be further assessed.***

#### *7.6.3.1 Potential Impact 10: Noise during decommissioning of the facility*

The impacts of noise during decommissioning are similar to those described for the construction phase above except that the intensity is expected to be lower. This impact is assessed as being of **low** significance without the implementation of key mitigation measures.

Key mitigation is limited to:

- Imposing speed limits on vehicles.

Mitigation is not expected to substantially reduce noise levels and the overall assessment of significance remains **low**.

### 7.6.4 Cumulative Impacts

As indicated previously there are no envisaged cumulative impacts associated with this project.

## 7.7 IMPACT ASSESSMENT SUMMARY

The summary of the impact assessment is shown in Table 7.4 below.

Table 7.4 Impact assessment summary for the Construction Phase

**Construction Phase**

| Impact Description | Status | Spatial Extent | Duration | Reversibility | Potential Intensity | Probability | Significance (Without Mitigation) | Key Management actions (i.e. actions that are not negotiable and have to be implemented to ensure that the significance of the associated impact is acceptable) | Significance (With Mitigation) | Confidence |
|---|---|---|---|---|---|---|---|---|---|---|
| **Preferred Desalination plant site, Preferred pipeline route & Alternatives 1 & 3 and powerline** | | | | | | | | | | |
| Impact 1 (Direct): Increased estuarine turbidity due to the proposed desalination plant construction | Negative | Local 2 | Temporary 1 | Highly Reversible | Medium 4 | Probable 0.5 | **Low 3.5** | Use sandtraps and geotextile blankets to prevent sediment entry to estuary waters | **Very Low 1.25** | High |
| Impact 2 (Direct) : Increased estuarine turbidity during pipeline installation | Negative | Local 2 | Temporary 1 | Highly Reversible | Medium 4 | Probable 0.5 | **Low 3.5** | Use sandtraps and geotextile blankets to prevent sediment entry into estuarine waters | **Very Low 1.25** | High |
| Impact 3 (Direct) : Removal of indigenous vegetation and disturbance to the ecological corridor between the site and the channel during construction activities for the desalination plant | Negative | Site Specific 1 | Long Term 4 | Low Reversibility | Medium 4 | Probable 0.5 | **Low 4.5** | Minimise construction footprint<br>Setback distance of 25m to increase the ecological corridor between the plant and the channel | **Low 3.5** | High |
| Impact 4 (Direct) : Removal/disturbance of Indigenous vegetation during pipeline installation and bridging | Negative | Local 2 | Short term 2 | Moderate Reversibility | Medium/ Low 2 | Probable 0.5 | **Low 3** | Rehabilitate riparian vegetation at bridge using indigenous species<br>Re-vegetate pipeline route with grasses once installation is complete. | **Low 3** | High |

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|---|---|---|---|---|---|---|---|---|---|---|
| Impact 5 (Direct): Impact on fauna due to noise and removal of vegetation during construction of desalination plant- | Negative | Site Specific 1 | Temporary 1 | Highly Reversible | Medium-Low 2 | Definite 1 | **Low 4** | Implement vehicle speed limits and limit construction footprint. Endeavour to control the footprint of the development Awareness training of all staff regarding fauna disturbance | **Low 3** | High |
| Impact 6 (Direct) : Impact on fauna due to noise and removal of vegetation during installation of pipelines | Negative | Local 2 | Temporary 1 | Highly Reversible | Low 1 | Definite 1 | **Low 4** | Limit vehicle speeds and limit construction footprint. Endeavour to control the footprint of the development Awareness training of all staff regarding fauna disturbance | **Low 3** | High |
| Impact 7(Direct): Impact on estuarine biota associated with the potential release of contaminants from the old dumpsite | Negative | Local 2 | Short term 2 | Moderate Reversibility | Medium 4 | Probable 0.5 | **Low 4** | Use sandtraps and geotextile blanket to prevent sediment entry into estuary Conduct toxicity testing If contaminated remove excess excavated material | **Very Low 1.5** | Low |
| **Alternative Desalination plant site and Alternative 2 pipeline route** | | | | | | | | | | |
| Impact 1(Direct) : Increased estuarine turbidity due to desalination plant construction | Negative | Local 2 | Temporary 1 | Highly Reversible | Medium 4 | Probable 0.5 | **Low 3.5** | Use sandtraps and geotextile blankets to prevent entry into estuarine waters | **Very low 1.25** | High |
| Impact 2 (Direct): Increased estuarine turbidity during pipeline installation | Negative | Local 2 | Temporary 1 | Highly Reversible | Medium 4 | Highly Probable 0.75 | **Medium 5.25** | Use sandtraps and geotextile blankets to prevent entry to estuary waters. Re-vegetate impacted areas as soon as possible. | **Low 2.5** | High |
| Impact 3(Direct) : Removal of indigenous vegetation for plant construction and impact on the ecological corridor | Negative | Site Specific 1 | Long Term 4 | Moderate Reversibility | Low 1 | Improbable 0.1 | **Very Low 0.6** | Minimise construction footprint | **Very Low 0.6** | High |
| Impact 4(Direct) : Removal/disturbance of | Negative | Local 2 | Long Term 4 | Low Reversibility | Medium 4 | Probable 0.5 | **Medium 5** | Re-vegetate with indigenous grasses | **Very Low 1** | High |

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|---|---|---|---|---|---|---|---|---|---|---|
| indigenous vegetation during pipeline installation | | | | | | | | Locate reception pit 100-130 m further west(away from drainage line) | | |
| Impact 5(Direct) : Impact on fauna due to noise and removal of vegetation during construction of desalination plant | Negative | Site Specific 1 | Temporary 1 | Highly Reversible | Medium-Low 2 | Definite 1 | **Low 4** | Mostly unavoidable Implement vehicle speed limits | **Low 3** | High |
| Impact 6 (Direct): Impact on fauna due to noise, vibrations (tunnelling) and removal of vegetation during installation of pipelines | Negative | Local 2 | Temporary 1 | Highly Reversible | Medium-Low 2 | Definite 1 | **Medium 5** | Implement vehicle speed limits | **Low 4** | Medium |

Table 7.5 Impact assessment summary for the Operational Phase

**Operational Phase**

| Impact Description | Status | Spatial Extent | Duration | Reversibility | Potential Intensity | Probability | Significance (Without Mitigation) | Key Management actions (i.e. actions that are not negotiable and have to be implemented to ensure that the significance of the associated impact is acceptable) | Significance (With Mitigation) | Confidence |
|---|---|---|---|---|---|---|---|---|---|---|
| **Preferred Site for the Desalination Plant (Eastern site)** | | | | | | | | | | |
| Impact 8 (Direct) : Decrease of the ecological corridor and associated impacts between the site and the channel | Negative | Local 2 | Long Term 4 | Low Reversibility | Medium 4 | Probable 0.5 | **Medium 5** | Remain within development footprint Setback distance of 25 m to increase the ecological corridor between the plant and the channel | **Low 3** | High |
| Impact 9(Direct): Noise during plant operation (with inherent measures in building design) | negative | Site Specific 1 | Long Term 4 | Highly Reversible | Low 1 | Probable 0.5 | **3 Low** | Implement speed limits for supply and waste removal vehicles | **3 Low** | Medium |
| Impact 10 (Direct): Entrainment of Brine into the surf zone | Negative | Local 2 | Long Term 4 | Highly Reversible | Low 1 | Low Probability 0.25 | **1.75 Very Low** | Recommend limiting maximum discharge volumes if possible | **1.75 Very Low** | Medium |
| **Alternative Site for the Desalination Plant (Western site)** | | | | | | | | | | |
| Impact 8 (Direct) : Decrease of the ecological corridor and associated impacts between the site and the channel | Negative | Local 2 | Long Term 4 | High Reversibility | Low 1 | Improbable 0.1 | **Very Low 0.7** | Remain within development footprint | **Very Low 0.7** | High |
| Impact 9(Direct): Noise during plant operation (with inherent measures in building design) | negative | Site Specific 1 | Long Term 4 | Highly Reversible | Low 1 | Probable 0.5 | **3 Low** | Implement speed limits for supply and waste removal vehicles | **3 Low** | Medium |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Impact 10(Direct) : Entrainment of Brine into the surf zone | Negative | Local 2 | Long Term 4 | Highly Reversible | Low 1 | Low Probability 0.25 | **1.75 Very Low** | Recommend limiting maximum discharge volumes if possible | **1.75 Very Low** | Medium |

Table 7.6 Impact assessment summary for the Decommissioning Phase

**Decommissioning Phase**

| **Impact Description**[1] | **Status** | **Spatial Extent** | **Duration** | **Reversibility** | **Potential Intensity** | **Probability** | **Significance (Without Mitigation)** | **Key Management actions (i.e. actions that are not negotiable and have to be implemented to ensure that the significance of the associated impact is acceptable)** | **Significance (With Mitigation)** | **Confidence** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Preferred Site for the Desalination Plant (Eastern site)** | | | | | | | | | | |
| Impact 10 (Direct): Noise during plant decommissioning | negative | Local 2 | Temporary 1 | Highly Reversible | Medium-Low 2 | Highly Probable 0.75 | **3.75 Low** | Implement vehicle speed limits | **Low 2** | High |
| Alternative Site for the Desalination Plant (Western Site) | | | | | | | | | | |
| Impact 10 (Direct): Noise during plant decommissioning | Negative | Local 2 | Temporary 1 | Highly Reversible | Medium-Low 2 | Highly Probable 0.75 | **3.75 Low** | Implement vehicle speed limits | **Low 2** | High |

[1] Please specify in this column whether the impact is direct or indirect.

## 7.8 CONCLUSION AND RECOMMENDATION

It is clear from the review and findings of the field survey conducted during this study that the Lovu Estuary, which although small in national terms, is an important functional estuary that contributes significantly to the estuarine resources in this section of the coastline. As estuarine resources are under threat, nationally and internationally through development pressure, these environments are identified as conservation worthy and any further impacts on these systems must be critically assessed.

The proposed desalination plant and associated infrastructure, like all developments, will have environmental impacts which may or may not be reduced by the implementation of mitigation measures. This assessment of potential impacts on the estuarine environment did not indicate any fatal flaws for any individual impact and most were assessed with a high degree of confidence. The key impacts (medium significance prior to the implementation of recommended mitigation measures) identified in this Estuarine Ecological Impact Assessment are associated with the construction phase of the proposed project:

- Impacts on the ecological corridor between the proposed plant and the channel.
- Potential for increased estuarine turbidity with consequent impacts on aquatic fauna during the installation of the Alternative 2 pipeline route.
- Loss of indigenous vegetation and disturbance of fauna due to noise and removal of vegetation during the construction of the proposed Alternative 2 Pipeline route.

The following key mitigation measures are recommended:

- A setback distance of 25 m for the Preferred site to increase the ecological corridor between the development and the channel
- Use sandtraps and geotextile blankets to prevent excavated material and building sand being washed into the estuary during rainfall events during the construction phase.
- Re-vegetate with appropriate indigenous species following excavation and installation of pipelines.
- Limit construction footprint and undertake awareness training for all staff (flora and fauna).
- Reduce vehicle speed limits during the construction phase of the proposed project to reduce noise.
- For Alternative 2, the reception pit for tunnelling on the south bank should be moved by at least 100-1 30m further west.

Assessment of the potential impact associated with release of contaminants from the old dumpsite could not be made with a high degree of confidence since the nature, concentrations and hence possible effects on biota are unknown. As the contaminants, if present, are unknown, it is difficult to determine what parameters should be analysed chemically to assess potential effects on biota. The specialists thus strongly recommend that sediment leachates from the dumpsite be tested for toxicity prior to installation of the pipelines. This will inform the developer about correct handling of excavated material from the dumpsite.

The construction of the proposed desalination plant at the Preferred site or at the Alternative site is anticipated to result is estuarine impacts of similar significance, providing that the recommended management actions are effectively implemented, in particular a setback distance of 25 m for the Preferred site to increase the ecological corridor between the development and the channel. Note that the Alternative site has slightly lower risk of being impacted by major floods.

The alternatives proposed for the sea water pipeline routing scored similarly in terms of impacts on vegetation as there is no substantial loss of indigenous vegetation. While impacts of noise levels on fauna also scored similarly, it is uncertain if noise levels and vibrations due to the use of tunnelling equipment for Alternative 2 are expected to have greater impact than the Preferred route or Alternative 1. The assessment in this case was made with a medium degree of confidence.

In conclusion, from a perspective of potential estuarine impacts, the specialists recommend:

- A setback distance of 25 m for the Preferred site to increase the ecological corridor between the development and the channel.
- While there is no strong indication for selection of any of the various pipeline routes in terms of vegetation impacts, there is some uncertainty regarding potential impacts on groundwater (although anticipated to be unlikely) and impacts of vibrations and noise from tunnelling especially for Alternative 2 which crosses sensitive area of estuary. Given this, selection of the options that involve north bank routing (Preferred and Alternatives 1 and 3) are recommended over alternative 2.
- If any of the tunnelling options are selected for pipeline routing (Alternatives 2 and 3), it is imperative that there is **no disposal** of excavated material, slurry (including bentonite mixes) wastewater (including waters treated with flocculants) within the floodplain of the estuary or the waterbody. All wastes should be appropriately disposed of (at registered landfill site or recycled if appropriate). While the only toxicity reference to bentonite was an $LC_{50}$ of 19 g/l for rainbow trout (http://www.pesticideinfo.org/List_AquireAcuteSum.jsp?Rec_Id=PC33789), the author has previously tested a range of drilling fluids which indicated potential toxicity to sensitive species or more especially to early life stages such as gametes, larvae and juveniles.

## 7.9 REFERENCES

Begg G.W., 1984. The estuaries of Natal. Part 2. Natal Town and Regional Planning Report 55: 631 pp.

Begg, G., 1978. The Estuaries of Natal. Natal Town and Regional Planning Commission.

Boehlert G.W. and Mundy B.C., 1988. Roles of behavioral and physical factors in larval and juvenile fish recruitment to estuarine nursery areas. In: Larval Fish and Shellfish Transport through Inlets. (Ed. Weinstein M.P.). American Fisheries Society Symposium 3: 51-67.

Coetzee, J.C., Adams, J.B. and Bate, G.C., 1997. A botanical importance rating of selected Cape estuaries.*Water SA* **23** 81-93.

Colloty, B.M., Adams, J.B. and Bate, G.C., 2000. The use of a botanical importance rating to assess changes in the flora of the Swartkops Estuary over time. *Water SA* 26 (4) 161-170.

Cooper, J.A.G., Ramm, A.E.L. and Harrison, T.D., 1994. The estuarine health index: A new approach to scientific information transfer, Ocean and Coastal Management 25: 103-141.

Costanza R., D'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P. & Van den Belt M. (1997). The value of the world's ecosystem services and natural capital. *Nature:* 387: 253-260.

Costanza R., D'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P. & Van den Belt M. (1997). The value of the world's ecosystem services and natural capital. *Nature:* 387: 253-260.

Forbes A.T. & Demetriades N.T. ,2008. Estuaries of Durban, KwaZulu-Natal, South Africa. Report for the Environmental Management Department, eThekwini Municipality.

Harrison, T.D., Cooper, J.A.G. & Ramm., 2000. State of South African estuaries: Geomorphology, ichthyofauna, water quality and aesthetics. Department of Environmental Affairs and Tourism. Pretoria. 127 pp.

IUCN, 2015. The IUCN Red List of Threatened Species. Version 2015.1. <www.iucnredlist.org>. Downloaded on 22 June 2015.

James N.C., Cowley P.D., Whitfield A.K. and Kaiser H., 2008. Choice chamber experiments to test the attraction of postflexion Rhabdosargus holubi larvae to water of estuarine and riverine origin. *Estuarine, Coastal and Shelf Science* 77: 143-149.

Kennish M.J., 2004. Estuarine Research Monitoring, and Resource Protection. CRC Press.

Kimmerer W.J., 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series* 243: 39-55.

McLean C.T., Forbes A.T. & Demetriades N.T. 2006 The fish fauna of four estuaries in the Thekwini municipal area: Indicators of system functioning. Honours degree thesis, University of KwaZulu-Natal.

McLean C.T., Forbes A.T. and Demetriades N.T., 2006 The fish fauna of four estuaries in the Thekwini municipal area: Indicators of system functioning. Honours degree thesis, University of KwaZulu-Natal.

Ramm, A.E.L., Cerff, E.C. and Harrison, T.D., 1986. The Lovu Estuary, Natal Estuary Status Report No. 64, Estuaries and Coastal Processes Division, National Institute for Water Research, CSIR, Durban.

Robins J., Mayer D., Staunton-Smith J., Halliday I., Sawynok B. and Sellin M., 2006. Variable growth rates of the tropical estuarine fish barramundi *Lates calcarifer* (Bloch) under different freshwater flow conditions. Journal of Fish Biology 69: 379-391.

Simenstad C.A., Brandt S.B., Chalmers A., Dame R., Deegan L.A., Hodson R. and Houde E.D., 2000. Habitat-Biotic Interactions. In: Hobbie J.E. (ed) Estuarine Science: A Synthetic Approach to Research and Practice. Island Press, Washington, D.C.

Turpie J.K., 1995. Prioritizing South African Estuaries for Consevation. A Practical Example using Waterbirds. Biological Consevation, 74: 175-185.

Turpie J.K., Adams J.B., Joubert A., Harrison T.D., Colloty B.M., Maree R.C., Whitfield A.K., Wooldridge T.H. , Lamberth S.J., Taljaard S. and van Niekerk L., 2002. An Assessment of the Conservation Priority Status of South African Estuaries for use in Management and Water Allocation. Water SA, 28 (2): 191-206

WSP, 2013. KZN east coast desalination plants detailed feasibility study: Lovu and Tongaat hydrodynamic and plume dispersion modelling.