Intended for
National Parks Board

Document type
TAC/NParks/20097/EIA

Date
23 December 2024

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR PROPOSED MANDAI MANGROVE & MUDFLAT NATURE PARK

Environmental Impact Assessment Report

Submitted by

TEMBUSU
Asia

Description **ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR PROPOSED MANDAI MANGROVE & MUDFLAT NATURE PARK**

Project Ref **TAC/NParks/20097/EIA Report**

Rev No	Date	Description	Prepared by	Checked by	Approved by
00	06/01/2025	Issued for public disclosure	ZD, ML, CW, JL, SP, XY, HS, GK, YW, DD, ST	EC	SC Tan

TEMBUSU Asia Consulting Pte Ltd
1 Commonwealth Lane #06-06
One Commonwealth Building
Singapore 149544
T +65 6238 4009
F +65 6570 5254
Co. Reg. No. 201732581C

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ABBREVIATIONS

Abbreviation	Definition
µg/m³	microgram per cubic meter
ASR	Air Sensitive Receptor
BMP	Best Management Practices
CA	Certified Arborist
CEMMP	Construction Environmental Management and Monitoring Plan
CF	Constant Frequency
CO	Carbon Monoxide
COP	Code of Practice
dB(A)	A-weighted decibel
EAAF	East Asian-Australasian Flyway
EBS	Environmental Baseline Study
ECM	Earth Control Measure
ECMO	Earth Control Measure Officer
ECO	Environmental Control Officer
EIA/S	Environmental Impact Assessment/Study
EMMP	Environmental Management and Monitoring Plan
ENSO	El Niño Southern Oscillation (ENSO)
EPH	Environmental Public Health
EPHA	Environmental Public Health Act
EPM	Environmental Protection and Management
ES	Environmental Score
FM	Frequency Modulated
FTA	Federal Transit Authority (USA)
GPS	Global Positioning System
ha	hectare
hr	hour
HKSQ	Hong Kong Sediment Quality
ISA	International Society of Arboriculture
IA	Impact Assessment
ITT	Invitation to Tender
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometre
KRP	Kranji Reservoir Park
Leq	equivalent continuous noise level
LTA	Land Transport Authority
LVA	Limited Visual Assessment
m	meter
m^2	meter square
mg/L	milligram per litre
mg/m^3	milligram per cubic meter
mins	minutes
MMM	Mandai Mangrove and Mudflat
ms	milliseconds

Abbreviation	Definition
MSS	Meteorological Service Singapore
NbS	Nature-based Solutions
NSR	Noise Sensitive Receptor
MPA	Maritime and Port Authority of Singapore
NEA	National Environment Agency
n.d.	no date
NO_2	nitrogen dioxide
NParks	National Parks Board
PCG	Police Coast Guard
PM_{10}	particulate matter with diameter ≤ 10 micrometres
$PM_{2.5}$	particulate matter with diameter ≤ 2.5 micrometres
PPE	Personal Protective Equipment
PSI	Pollutant Standards Index
PUB	Public Utilities Board
QCF	Quasi-constant Frequency
RIAM	Rapid Impact Assessment Matrix Importance (I), magnitude (M), permanence (P), reversibility (R), and cumulative impact (C)
s	seconds
SBNPN	Sungei Buloh Nature Park Network
SBWR	Sungei Buloh Wetland Reserve
SSC	Suspended Sediment Concentration
SSO	Singapore Statutes Online
STB	Singapore Tourism Board
TAC	TEMBUSU Asia Consulting Pte Ltd
TIW	Toxic Industrial Waste
TPZ	Tree Protection Zone
TSS	Total Suspended Solid
URA	Urban Redevelopment Authority
VSR	Vibration Sensitive Receptor
WHO	World Health Organisation

GLOSSARY

Abundance: The number of a single species recorded at any given time period or location.

Biodiversity: The variety of plant and animal life in the world, habitat or location, a high level of which is usually considered to be important and desirable. Biodiversity can be assessed at more focused taxonomic groups such as “bird biodiversity”, in which case it is interchangeably with “diversity”.

Conservation Status: A status given to a species that is threatened with becoming extinct either locally or globally. These species may be restricted to only a small area, show noticeable decline in abundance over time, or have a historically low global population size. Assessments can be made either at global level under the IUCN’s Red List of Threatened Species or at national level (e.g., Singapore’s Red Data Book of Threatened Plants and Animals).

Ecology: The pattern of relations between organisms and their environment.

Edge Effect: The effect of an abrupt transition between two quite different adjoining ecological communities on the numbers and kinds of organisms in the marginal habitat

Fauna: Referring to all animal life present in an area. Animals are defined as any species from the Kingdom Animalia.

Flora: Referring to all plant life present in an area. Plants are defined as any species from the Kingdom Plantae.

Genus: A taxonomic group above species. A genus consists of closely related species. For example, Grey Heron and Purple Heron are closely related species in the same genus *Ardea*, hence their scientific names are *Ardea cinerea* and *Ardea purpurea* respectively.

Habitat: The natural home or environment of an animal, plant, or other organisms.

Herpetofauna: A taxonomic sub-group that includes amphibians and reptiles.

Impact: Any positive or negative alteration of existing conditions caused directly or indirectly by the project.

kHz (kilohertz): A measure of frequency equivalent to 1,000 cycles per second. Human hearing may extend up to 20 kHz. Most bat calls are beyond 20 kHz, extending locally up to 245 in the case of *Kerivoula hardwickii*.

Microclimate: Local atmospheric zone where the climate differs from the surrounding area.

Mitigation Measure: Means to prevent, reduce, or control negative environmental effects of a project, and repair any damage to the environment caused by those effects through replacement, restoration, compensation, or any other means.

Ms (milliseconds): 1/1000 of a second. Duration of individual bat pulses typically range from 2 ms, in some species of *Myotis*, to more than 50 ms, in some local emballonurids such as *Saccolaimus saccolaimus*.

Odonates: A taxonomic sub-group of Insects that includes dragonflies and damselflies.

Population: The term population can be in reference to the total number of a species found in a given area (e.g., global population, or Singapore population). It is also used as a term to define distinct sub-sets of a species based on the level of inter-mixing. For example, an island may hold two populations of a species if there are two groups of the same species present and those groups are sufficiently prevented (geographically or behaviourally) from mixing, forming separate breeding populations.

Species: The standard classification of living organisms. It is defined as a group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding. It is represented by the second word of the scientific name of an organism. For example, the scientific name of a long-tailed macaque is *Macaca fascicularis*, where *fascicularis* is its species name.

Taxa: In reference to a specific taxonomic group. In order of specificity, the taxonomic groups are Kingdom, Phylum, Class, Order, Family, Genus, Species.

Transect: A predefined line or belt along which observations and/or measurements are taken.

EXECUTIVE SUMMARY

The National Parks Board (NParks) is establishing the Mandai Mangrove and Mudflat (MMM) as a Nature Park for the conservation of wetland habitats at the northern shore of Singapore. The project area is located in north-western Singapore, facing the western side of the Straits of Johor and adjacent to the Singapore-Johor Causeway. The site comprises of several important habitats, including secondary forest, mangrove habitat, and the most extensive mudflat habitat on the mainland of Singapore. Specifically, Mandai Mangrove and Mudflat area serves as an important site for migratory birds that lies within the East Asian-Australasian Flyway (EAAF). This site is also home to several globally and locally threatened fauna species. The MMM Nature Park will be conserved as a core area complementary to the Sungei Buloh Wetland Reserve (SBWR), while sensitively providing opportunities for research and education to increase awareness and stewardship for its rich biodiversity. Part of this project would include the redevelopment of Kranji Reservoir Park (KRP).

Given the sensitive nature of the natural environment within and around the project area, it is important to ensure that the development minimises any adverse impacts to the environment. Therefore, as part of these works, TEMBUSU Asia Consulting (TAC) has been commissioned to provide environmental consulting services including conducting a terrestrial and marine Environmental Baseline Study (EBS), undertaking an Environmental Impact Assessment (EIA), and developing an Environmental Management and Monitoring Plan (EMMP).

This report outlines the findings of the EIA. The following environmental aspects have been considered in this study:

- Biodiversity
- Hydrology and Water Quality
- Sediment Quality
- Noise
- Ambient Air Quality
- Ground-borne Vibration

A summary of the main findings on each environmental aspect is provided below.

Biodiversity

The Mandai Mangrove and Mudflat represents one of the last remaining areas in Singapore with significant tracts of healthy mangroves, secondary forest, and intertidal mudflats. The biodiversity on the site is diverse and unique and is significant for the conservation of a variety of locally and internationally rare and threatened flora and fauna species. This site forms a complementary habitat to the Sungei Buloh Wetland Reserve, particularly valuable for migratory shorebirds.

The project area is located in northern Singapore. Baseline surveys were conducted within the project area comprising various field survey methodologies including modified gentry plots for flora, visual fauna transects, camera trapping, netting, and trapping of aquatic fauna, and acoustic bat recording.

The aim of the current biodiversity study was to update the previous biodiversity baseline established by TAC in their feasibility studies surveys conducted in 2019 (TAC, 2020). The differences in project are shown in the image below.

Floristically, the current study and past feasibility study inclusive of historical records (TAC, 2020) observed a total of 212 flora entries, in which 196 were identified to species level. The study found several conservation significant mangrove and coastal species such as katong tree (*Cynometra ramiflora*), *Heptapleurum ellipticum*, sea putat (*Barringtonia asiatica*) and common putat (*Barringtonia racemosa*); and new localities of critically endangered mangrove species such as crabapple mangrove (*Sonneratia caseolaris*), kalak kambing (*Finlaysonia obovata*) and mangrove trumpet Tree (*Dolichandrone spathacea*). The project area comprises of four main habitat types which include mangrove forests, mudflats with patches of sandflats, secondary forests and urban vegetation. The project area is dominated by mudflats and mangrove forests, especially along the Eastern coastline. Mudflats with patches of sandflats stretch out from the coast for hundreds of meters.

A total of 384 terrestrial and aquatic fauna species (birds, mammals, reptiles, amphibians, butterflies, odonates, freshwater/brackish and marine fish, decapod crustaceans, and molluscs) were recorded within the project area from the past and present surveys. This area contains at least 60 threatened species across fauna taxonomic groups, including the straw-headed bulbul (*Pycnonotus zeylanicus*), the buffy fish owl (*Ketupa ketupu*), estuarine crocodile (*Crocodylus porosus*) and two species of horseshoe crabs (*Tachypleus gigas* and *Carcinoscorpius rotundicauda*). Many of these species depend on specific habitat requirements for their survival – the forest provides suitable conditions for birds to nest, such as the grey-headed fish eagle (*Haliaeetus ichthyaetus*), white-bellied sea eagle (*Haliaeetus leucogaster*), and Brahminy kite (*Haliastur indus*); while the mudflats serve as feeding grounds for shorebirds such as the great egret (*Ardea alba*), Pacific golden plover (*Pluvialis fulva*), common sandpiper (*Actitis hypoleucos*), bar-tailed godwit (*Limosa lapponica*), and common greenshank (*Tringa nebularia*). The shorebirds mentioned are winter visitors, for which the mudflats and mangroves serve as important stopover sites along their migratory flyways.

In terms of marine flora and fauna, the study focused on mangrove, seagrass, intertidal fauna and benthic invertebrate species. A total of 57 mangrove species (including associates) were found in Mandai Mangrove and Mudflat area from past and present studies. Within the fringing mangrove-mudflat transition zone, the locally endangered and globally vulnerable seagrass species Beccari's seagrass (*Halophila beccarii*) was known to be quite commonly found, particularly among pneumatophores and seedlings of *Sonneratia* sp. and *Avicennia* sp. Along the coastal region there are at least 26 species of intertidal and benthic fauna on the mudflats, across six faunal classes (Anthozoa, Cirripedia, Bivalvia, Gastropoda, Malacostraca, Merostomata).

Mandai Mangrove and Mudflat consists of 55 threatened true mangrove and mangrove associate plant species, including the locally critically endangered gedabu (*Sonneratia ovata*), locally endangered white teruntum (*Lumnitzera racemosa*) and globally vulnerable api-api bulu (*Avicennia rumphiana*). Only one species of seagrass, Beccari's seagrass (*Halophila beccarii*) is recorded in the intertidal zone.

The Nature Park is envisioned as a conservation-centric development. As such, impacts from the development are largely controlled through the key principle of low-impact design. During the pre-construction phase, the main concerns across most locations are loss of habitats due to site clearance, and disturbance to shorebirds. The use of sound barriers during shorebird breeding and nesting activities will help reduce the magnitude of disturbance from Minor Negative to Slight Negative after the implementation of mitigation measures.

During the construction phase, other predicted impacts across many locations include habitat loss, changes in soil and topography, sediment dispersion, soil erosion and species mortality. 288 flora records can be found within 2-m buffer zone around the development footprint, which includes locally critically endangered species likely a result of natural regeneration such as crabapple mangrove (*Sonneratia caseolaris*) and kalak kambing (*Finlaysonia obovata*). Mitigation measures such as clear demarcation of the work boundary to limit vegetation clearance; eventual habitat enhancement and reinstatement; and other measures listed in Section 5.6.2. Following which, the predicted impacts can be reduced from Minor Negative to Slight Negative range. During the operation phase, the main concern across most locations are human-wildlife conflict and litter and plastic pollution. Mitigation measures such as educational signs, implementation of visitors' rules and regulations, and proper bin systems can help reduce the magnitude of impact such that the residual impacts are reduced from Minor Negative to Slight Negative range.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate biodiversity impacts, residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Disturbance to shorebirds	Minor Negative	Slight Negative
	Ecological connectivity loss	Slight Negative	Slight Negative
	Habitat loss due to vegetation clearance for temporary working areas and hoarding	Minor Negative	Slight Negative
	Species and habitat disturbance	Slight Negative	Slight Negative
	Species mortality	Slight Negative	Slight Negative
Construction	Changes in soil and topography	Minor Negative	Slight Negative
	Ecological connectivity loss	Slight Negative	Slight Negative
	Edge effect	Slight Negative	Slight Negative
	Habitat loss	Minor Negative	Slight Negative
	Human-wildlife conflict	Slight Negative	No Impact
	Impact on mangrove biodiversity due to sediment dispersion	Minor Negative	Slight Negative
	Injury cause by tree falls	Slight Negative	Slight Negative
	Introduction of invasive species	Slight Negative	Slight Negative
	Roadkill	Slight Negative	Slight Negative
	Soil erosion, runoff, and silty discharge	Minor Negative	Slight Negative
	Species and habitat disturbance	Minor Negative	Slight Negative
	Disturbance to shorebirds	Minor Negative	Slight Negative
	Species mortality	Slight Negative	Slight Negative
	Coastal restoration	Slight Positive	Slight Positive
	Habitat enhancement	Slight Positive	Slight Positive
	Removal of invasive species	Slight Positive	Slight Positive
Operation	Edge effect	Slight Negative	Slight Negative
	Human-wildlife conflict	Minor Negative	Slight Negative
	Introduction of invasive species	Slight Negative	Slight Negative
	Light pollution	No Impact	No Impact
	Litter and plastic pollution	Minor Negative	Slight Negative
	Roadkill	No Impact	No Impact
	Soil compaction	Slight Negative	Slight Negative
	Species and habitat disturbance (e.g., light, noise)	Slight Negative	Slight Negative
	Coastal restoration	Slight Positive	Slight Positive
	Habitat enhancement	Slight Positive	Slight Positive

Water Quality & Coastal Hydraulics

There are three natural waterways, namely Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil, which pass through the project area. Baseline Water Quality sampling was conducted at nine accessible points covering all three water bodies, during neap and spring tides each. For the in-situ measured water quality parameters i.e., temperature, pH and dissolved oxygen, all samples were within the allowable water quality thresholds. For the ex-situ parameters, the surface water quality of the streams within the project area generally complied with the applicable standards (NEA, 2020; MONRE, 2011; ARMCANZ, 2000). There were however several instances where the readings of ammonia as NH3-N, phosphate, total suspended solids, nitrates, and mercury concentrations exceeded the threshold limits during both spring and neap tides. As for marine water quality, the standards used were based on the ASEAN Marine Water Quality Criteria. Generally, the testing results indicated rather poor water quality throughout the entire sampling area, with many points exceeding multiple test parameters. Generally, the parameters with exceedances consisted of ammonia as NH3-N, NO_3-N and NO_2-N, phosphate, phenolic compounds, enterococcus, faecal coliform and tributyltin. These exceedances are most likely explained by the high anthropogenic activity in the vicinity of the project area.

During both the pre-construction and construction phases, the main concern across most locations will be the potential impact from sediment runoff and siltation especially during construction. Mitigation measures such as proper implementation of ECM and limiting construction activities to the smallest possible footprint area will help to reduce the magnitude, thus reducing the impacts from Minor Negative to a lower score. During the operation phase, the impact component identified across most locations is the impact to water quality due to routine maintenance activities of the park facilities. Mitigation measures such as proper disposal of waste would lower the magnitude of impact such that the residual impacts are reduced from Slight Negative to No Impact range.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate impacts to water quality (top table) and coastal hydraulics (bottom table), residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Soil Erosions and Surface Runoff	Slight Negative	Slight Negative
	Increase in total suspended solids and turbidity	Slight Negative	Slight Negative
Construction	Sediment runoff and siltation	Minor Negative	Slight Negative
	Accidental spillage of oil & fuel and waste disposal	Slight Negative	No Impact
Operation	Routine maintenance	Slight Negative	No Impact

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	No predicted impact	-	-
Construction	Impact on water level	No Impact	No Impact
	Impact on current speed	No Impact	No Impact
Operation	Impact on floating fish farms	No Impact	No Impact
	Impact on current speed	No Impact	No Impact
	Routine maintenance	No Impact	No Impact

Sediment Quality and Dynamics

Baseline sediment quality was taken at eight locations for sediment grading and toxicity testing. Regional standards like the Hong Kong Sediment Quality (HKSQ) criteria for management of dredged/excavated sediment were utilised to compare the sediment samples baseline study results. Only a few exceedances for Arsenic, Copper and Zinc were observed in the collected sediment samples. Both within the project area and the nearby floating fish farms in Johor Strait, the suspended sediment concentrations due to construction of proposed Nature Park infrastructure are expected to be minor. As such, some sediment runoff and siltation impact are anticipated due to development of the proposed Nature Park, which however can be mitigated with the appropriate application of mitigation measures such as proper implementation of ECM and limiting construction activities to the smallest possible footprint area will help to reduce the magnitude, thus reducing the impacts from Minor Negative to a lower score.

In addition, numerical modelling of the impacts of the proposed wet infrastructure on the sediment dynamics and morphology in and around the Mandai Mangrove and Mudflat Nature Park show very limited effects for both normal monsoon conditions and for squall events. For the monsoon conditions and an extreme squall event, the impact due to the construction of the Experiential Walk on sediment concentrations is small and localised with the largest effect at the excavation site itself. During NE monsoon conditions, the system is more dynamic compared with SW monsoon conditions. Yet only 1-3 cm sediment deposition due to the excavation works during NE monsoon conditions is being projected, while no change is detected during SW monsoon conditions. The piles of the Experiential Walk and the excavation for the Sungei Pang Sua Pavilion will therefore cause negligible disturbances to the sediment dynamics and morphology of the system. Even under sea level rise conditions, the Experiential Walk is not expected to cause impacts to SSC, erosion, or sedimentation patterns.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate impacts to sediment quality, residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Sediment runoff and siltation	Slight Negative	Slight Negative
Construction	Sediment runoff and siltation	Minor Negative	Slight Negative
	Sediment dispersion	No Impact	No Impact
	Transboundary impact	No Impact	No Impact
Operation	No predicted Impact	NA	NA

Noise

The main sources of noise in the project area comes from the traffic along Kranji Way road, as well as activities conducted in the Kranji Industrial Estate. The project area thus has a fairly high baseline levels. The fauna found within project area is identified as a sensitive receptor, while disturbance to shorebirds is identified as the main impact during construction. Seven-day continuous (24x7) noise monitoring was carried out at three locations. The baseline noise monitoring established that baseline noise levels mostly complied with Singapore’s noise regulations.

It is anticipated that during pre-construction, construction and operation phase, the main concern across most locations is disturbance to shorebirds and threatened fauna species. During the pre-construction phase, mitigation measures such as avoiding construction works during peak migratory bird season and only carrying out works in the daytime will help to reduce the magnitude of disturbance to shorebirds, thus reducing the impacts from Minor Negative to Slight Negative range band. Operation of construction equipment will be the main source of noise during the construction phase. Specific mitigation measures such as avoiding heavy construction work during the peak migratory bird season (i.e., August to April), avoidance of night-time work, installation of noise barriers, continuous noise monitoring and reduced noise level threshold for birds are recommended to reduce the impact to acceptable level. During operation phase, the main concern across most locations is the disturbance to shorebirds and other fauna species due to visitor activity and traffic. Mitigation measures such as educational signs and the implementation of visitors' rules and regulations can help reduce the magnitude of impact such that the residual impacts are reduced from Minor Negative to Slight Negative range. After the application of suitable mitigation measures, the overall impact of noise has been assessed as Slight Negative.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate noise impacts, residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Disturbance to shorebirds and threatened fauna species	Minor Negative	Slight Negative
	Disturbance to other fauna species	Slight Negative	Slight Negative
Construction	Disturbance to shorebirds and threatened fauna species	Minor Negative	Slight Negative
	Disturbance to other fauna species	Slight Negative	Slight Negative
	Disturbance to construction workers due to exposure to high noise levels of construction activities	Slight Negative	Slight Negative
Operation	Disturbance to shorebirds and other fauna species in and around the project area	Minor Negative	Slight Negative

Ambient Air Quality

Seven-day continuous (24x7) air monitoring was carried out at three locations to establish baseline air quality levels. The baseline air quality monitoring results generally complied with Singapore Ambient Air Quality Targets (NEA, 2021) except for 24-hour PM2.5 average (µg/m^3) on several dates and one reading of hourly NO_2 mean. The baseline air quality findings confirmed that the project area has a relatively good air quality.

Throughout the pre-construction and construction phases, the main concern across most locations is the fugitive dust generated. Predicted impacts across many locations includes noxious vapours generated by the exhaust emissions from vehicles and construction equipment. Mitigation measures such as implementation of dust suppression plans and regular watering of site surface, proper storage of building materials and conducting periodic checks to prevent accumulation of unnecessary chemicals can help in reducing the environment score from Slight Negative to No Impact range band. During operation phase, the main concern across most locations are vehicle emissions from visitor cars or maintenance vehicles. As the future nature park is designed to keep to a limited number of cars, the residual impact is reduced from Slight Negative to No Impact range.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate impacts to air quality, no residual impacts are expected.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Fugitive dust	Slight Negative	No Impact
Construction	Fugitive dust	Slight Negative	No Impact
	Exhaust emissions in vehicles	Slight Negative	No Impact
	Noxious vapours from oils, glues, thinners, paints	Slight Negative	No Impact
Operation	Vehicle emissions from maintenance vehicles	Slight Negative	No Impact

Ground-borne Vibration

The closest major source of vibration is road traffic along the nearby Kranji Way road. Generally, the measured baseline ground-borne vibration levels were elevated. This may be due to the vibration stations being placed in close vicinity to areas with high heavy vehicle traffic. However, their 90th percentile was below 10mm/s and did not exceed the British Standards (BS-5228-2) threshold for what is likely intolerable to humans.

During pre-construction and construction phase, the main concern across most locations is disturbance to fauna especially during construction works. Mitigation measures such as restricting work areas and staggering work activities will help to reduce the magnitude of disturbance to shorebirds, thus reducing the impacts from Minor Negative to Slight Negative range band. During the operation phase, the main concern across most locations are the vibrations caused by visitor cars or maintenance vehicles. However, No Impacts are anticipated due to the limited number of vehicles. Furthermore, the use of low-noise asphalt for the development has been proposed as it will also help in reducing vibration.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate vibration impacts, residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Disturbance to the fauna due to vibration from construction activities	Slight Negative	Slight Negative
Construction	Disturbance to the fauna due to vibration from construction activities	Minor Negative	Slight Negative
	Disturbance/ annoyance to the VSR due vibration from construction activities	Minor Negative	Slight Negative

Operation	Vehicle emissions from visitor cars or maintenance vehicles	No Impact	No Impact

Light

As it is assumed that all construction activities will be limited to the daytime, light impacts during the construction phase are expected to be negligible since there will be no works after 6pm. All of the planned visitor facilities such as the Sungei Pang Sua and Sungei Kranji Pavilions will only be open during the daytime from 0700h to 1900h during the operation phase, hence no night-time lighting impacts from these site features is anticipated. As such, with the implementation of recommended mitigation measures such as the installation of shielded lights, and the adjustment of lights away from forested areas, it is expected that impacts from these components will be reduced to lower levels. Therefore, there are no predicted light impacts in the operation phase.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate light impacts, no residual impacts are expected.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	Slight Negative	No Impact
Construction	Disturbance to the flora and fauna due to construction lighting	Slight Negative	No Impact
	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	No Impact	No Impact
Operation	No predicted impact	NA	NA

Waste Management

It is anticipated that the main sources of waste during construction will be from vegetation removal, excavated material, general construction waste, personal waste and/or hazardous waste. With the implementation of the mitigation measures proposed – such as proper waste management plans, reusing timber wastes for wood industry, and properly disposing the waste through licensed collectors – any negative impact is expected to be reduced to Slight Negative level provided the identified and recommended environmental mitigation measures are diligently implemented, primarily during the construction phase.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate waste management impacts, residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts

Pre-construction	Disposal of woody vegetation	Slight Negative	Slight Negative
	Disposal of excavated material	Slight Negative	Slight Negative
	Disposal of general waste material	Slight Negative	No Impact
Construction	Disposal of woody vegetation	Slight Negative	Slight Negative
	Disposal of excavated material	Slight Negative	Slight Negative
	Disposal of general waste material	Slight Negative	No Impact
	Disposal of hazardous waste	Slight Negative	Slight Negative
	Human-wildlife conflict	Slight Negative	No Impact
Operation	Litter and plastic pollution	Slight Negative	Slight Negative
	Human-wildlife conflict	Slight Negative	No Impact

Vector Control

The primary impact of the construction phase of the project is the potential increase in the immediate vector population. Secondary to this, an increase in the number of vectors has the potential to increase the likelihood of human vector-borne diseases. Key mitigation measures include vector source reduction and effective drainage through implementation of a vector control plan. Thereafter, it is expected that these impacts can be reduced to Slight Negative level. Considering the sensitive nature of the area, thermal fogging is not recommended to be carried out as part of vector control measures.

A summary of the predicted and residual impacts for each type of impact component during each of the project phases is shown below. Impacts at locations throughout the project area were consolidated, and the degrees of predicted and residual impacts for each impact component correspond to the impacts with the lowest Environmental Score. With the implementation of measures to mitigate vector control impacts, residual impacts do not exceed Slight Negative levels.

Phase	Impact Component	RIAM for Predicted Impacts	RIAM for Residual Impacts
Pre-construction	Increase in the number of mosquitoes	Slight Negative	Slight Negative
	Increase in the number of other vectors (e.g. flies and rodents)	Slight Negative	No Impact
Construction	Increase in the number of mosquitoes	Slight Negative	Slight Negative
	Increase in the number of other vectors (e.g. flies and rodents)	Slight Negative	No Impact
	Increase in incidence of dengue fever and vector-related diseases (secondary impact)	Slight Negative	Slight Negative
Operation	Increase in the number of mosquitoes	Slight Negative	Slight Negative
	Increase in the number of other vectors (e.g. flies and rodents)	Slight Negative	Slight Negative

Environmental Management and Monitoring Plan

An Environmental Management and Monitoring Plan (EMMP) has been proposed to manage the identified environmental impacts during the construction phase. It also includes environmental monitoring requirements containing on-site visual compliance monitoring and physical monitoring, which will help to verify the effective implementation of mitigation measures during the construction stage. A Construction EMMP (CEMMP) will be developed based on the recommended EMMP framework in this EIA report. This will be strictly implemented throughout the construction phase to ensure the development of this project in environmentally sensitive manner.

Conclusion

Through the collection of data via environmental baseline field surveys, this EIA has described the environmental baseline conditions at the site. Environmental baseline parameters assessed in this EIA include biodiversity, water quality, sediment quality and dynamics, noise, ambient air quality, and ground-borne vibration. Based on these parameters, this EIA has identified predicted environmental impacts brought about by infrastructure works during the pre-construction, construction, and operation phases of the upcoming MMM Nature Park development on the environment, including predicted impacts for light, waste management, and vector control. The EIA assessed these impacts and recommended mitigation measures to reduce the level of each environmental impact, and an environmental management framework to monitor the implementation of mitigation measures during development.

1 INTRODUCTION

1.1 Objectives of the Environmental Impact Assessment Report

The EIA study was undertaken to identify sensitive environmental receptors around the premises and propose environmental quality objectives in consultation with relevant stakeholders.

The principal objective of the EIA study is to provide clear and concise technical information for decision-making on potential environmental impacts associated with the proposed work activities.

The key objectives of this EIA study are to:

- Understand and update the environmental baseline through the collection of primary and secondary data.
- Assess the impacts of the infrastructure works for the upcoming Mandai Mangrove and Mudflat Nature Park development during the construction and operation phases of the project on the environment.
- Present appropriate mitigation measures to reduce the level of impact for each activity assessed that has a moderate to major impact.
- Recommend an environmental management framework to monitor the mitigation measures implementation.

It is understood that the information presented in the EIA report will contribute to decisions on:

- The need to clear and remove vegetation for any proposed amenities
- The effects of earthworks in relation to compaction, settlement, erosion etc.
- Species conservation and overall well-being of flora and fauna in the immediate vicinity of the proposed amenities

The undertaking of the EIA study will therefore promote environmentally sound and sustainable development. The EIA study area denotes the project area where construction of the proposed project is predicted to have impacts on various environmental aspects within the site. Figure 1-1 below shows the extent of the project area. Both marine and terrestrial baseline surveys were carried out within this boundary as part of the 2022 baseline surveys. Figure 1-2. shows a series of points along the coastline to serve as reference for each section.

The Mandai Mangrove and Mudflat (about 73-hectare) is one of the last patches of mangroves in Singapore with an extensive mudflat habitat. MMM is located in northern Singapore, facing the West Johor Straits and just west of the Singapore-Johor Causeway. Three natural tidal rivers intersect through the project area: namely Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil. The MMM is ecologically connected with Sungei Buloh Wetland Reserve and Kranji Coastal Nature Park to its west and Kranji Marshes to the south-west, all of which form the Sungei Buloh Nature Park Network.

Figure 1-1. Map showing current project area.

Figure 1-2. Map showing Point of References along coastline.

1.2 Project Background

The National Parks Board (NParks) intends to develop Mandai Mangrove and Mudflat (MMM) as a Nature Park for the conservation of wetland habitats at the northern shore of Singapore. The Mandai Mangrove and Mudflat is envisioned to be an exemplary site for wetland ecology and migratory bird conservation. The MMM Nature Park will be conserved as a core area complementary to the Sungei Buloh Wetland Reserve (SBWR), while sensitively providing opportunities for research and education to increase awareness and stewardship for its rich biodiversity. The project also includes the redevelopment of Kranji Reservoir Park (KRP).

The scope of the multi-disciplinary consultancy services consists of the detailed design of the implementation of the MMM and KRP and includes the integration to adjacent conservation nodes and any upcoming developments where required.

Given the sensitive nature of the natural environment within and around the project area, it is important to ensure that the development minimises any adverse impacts to the environment. Therefore, as part of these works, environmental consultancy services are required, including conducting a terrestrial and marine Environmental Baseline Study (EBS), conducting a terrestrial and marine Impact Assessment (IA), and framing the Environmental Management and Monitoring Plan (EMMP) as part of the Environmental Impact Assessment (EIA) process. The EMMP is to be implemented during the construction and post construction stage. An Operation Environmental Audit of the terrestrial and marine components will also be carried out.

TEMBUSU Asia Consulting Pte Ltd (TAC) has been commissioned by NParks to provide the environmental consultancy services for this project.

1.3 Report Structure

The EIA report is structured as follows:

- Chapter 1 introduces the project background and the general information of the EIA, covering its objectives, report structure, and limitations.
- Chapter 2 provides the description of the proposed project, spatial layout and activities associated with the proposed project.
- Chapter 3 outlines the EIA approach, including its scope and impact assessment methodology that is applied in the preparation of this report.
- Chapter 4 presents the desktop study review.
- Chapter 5 presents an assessment of environmental impacts on biodiversity and its proposed mitigation measures.
- Chapter 6 describes the hydrology and water quality of the project area and provides the impacts and mitigation measures.
- Chapter 7 describes the coastal hydraulics and results of the hydrodynamic modelling.
- Chapter 8 provides a description of the sediment quality.
- Chapter 9 discusses the noise impacts and proposes mitigation measures.
- Chapter 10 provides a description of the ambient air quality impacts of the project and proposes mitigation measures.
- Chapter 11 discusses the impacts from ground-borne vibration and proposes mitigation measures.
- Chapter 12 discusses the impacts from light pollution and proposes mitigation measures.
- Chapter 13 discusses the waste impacts and proposes mitigation measures.
- Chapter 14 details the vector control assessment and mitigation requirements.
- Chapter 15 outlines the proposed Environmental Management and Monitoring Plan (EMMP) framework.

1.4 Limitations of the EIA Report

The EIA study is conducted as per the requirements specified by NParks in the Invitation to Tender (ITT), and outcome of consultancy with the relevant Technical Agencies. The extent of collection of baseline data is guided by these requirements.

In preparing this report, we relied, in whole or in part, on data and information provided by NParks, and third parties, which have been assumed to be accurate, complete, and reliable as of the time of writing.

2 PROJECT OVERVIEW

2.1 Project Objective

Sungei Buloh Nature Park Network (SBNPN) was announced in August 2020 to include Sungei Buloh Wetland Reserve (SBWR) and other important core habitats. These core habitats include, but are not limited to, the MMM, Kranji Marshes and complementary habitats such as Lim Chu Kang Nature Park and Kranji Coastal Nature Park, eco-corridors, and nature areas such as Jalan Gemala and Kranji Marshes (Figure 2-1).

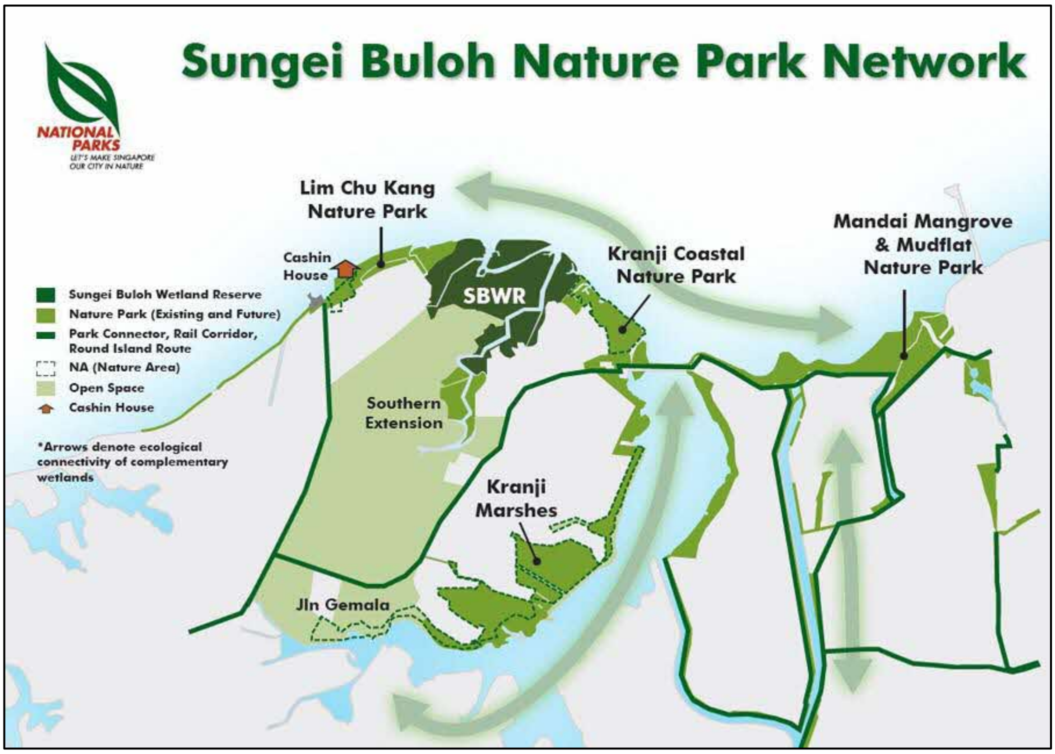


Figure 2-1. Map of Sungei Buloh Nature Park Network (NParks)[1]

MMM is intended to be a model location for the conservation of migrating shorebirds and wetland ecology. The Nature Park's core habitats will be preserved while thoughtfully offering possibilities for the study and education to raise awareness of the region's abundant biodiversity. In addition, the main objectives of the development of MMM are as follows:

- Conserve core habitats for migratory shorebirds and wetland-associated biodiversity,
- Provide excellent educational and recreational facilities that enables visitors to experience nature sensitively,
- Enhance integration and connection with other conservation nodes and key developments in the area,
- Implement Nature-based Solutions (NbS) to enhance coastal resilience.

[1] https://www.nparks.gov.sg/gardens-parks-and-nature/nature-park-network

2.2 Project Location

MMM is located in northern Singapore, facing the western side of the Johor Strait and immediately west of the Singapore-Johor Causeway. The 74-hectare nature area is ecologically connected with Sungei Buloh Wetland Reserve and Kranji Coastal Nature Park to its west and Kranji Marshes to the south-west, all of which are part of the Sungei Buloh Nature Park Network. MMM is bordered at the eastern edge by the Rail Corridor which links the park to the north and south of Singapore (Figure 2-2). The project area features mudflats, mangrove forests, sandflats, secondary forest, and urban vegetation.

Figure 2-2. Site boundary of development indicated by red dotted line

2.3 Project Spatial Layout Plan

2.3.1 Infrastructure Development

Besides safeguarding of the site, the proposal to develop the MMM into a Nature Park will allow for habitat enhancement initiatives and make the park accessible to the public for education and outreach purposes. Key design features of the proposed Nature Park development include (Figure 2-5):

A) Development of pavilions, buildings, and enhancement of existing infrastructure

- Kranji Reservoir Park (KRP) – to be redeveloped as a wetland-themed "sponge" park" with stormwater retention or detention areas. The existing park is to be enhanced with mangrove and coastal forest species at appropriate locations. Simple trails that allow for maintenance vehicles and installation of lookout points will be included as well. Nature-based Solutions will be implemented to safeguard part of the shoreline against erosion.
- Kranji Reservoir Dam (KRD) – landscape enhancement on the dam, north side of Kranji Road, to create a simple at-grade pedestrian connection from KRP to MMM.

- Sungei Kranji Pavilion (SKP) – to construct an elevated pavilion with public amenities such as toilets and a drinking fountain. The existing carpark to be reconfigured and will incorporate a coach drop-off.
- Sungei Pang Sua Pavilion (SPS) – to construct a lookout tower with a multi-purpose space for roving staff and officers and public amenities such as toilets, galleries. There will also be provision of a coach drop-off.

B) Development of trails, boardwalks, lookouts

- Trails and boardwalks are to be sensitively designed, taking into consideration existing site conditions and biodiversity. Lookout points will also punctuate the trail at strategic locations to create opportunities to view the mudflat.

C) Development of park user amenities

D) Connectivity between Kranji Reservoir Park and Kranji Nature Coastal Park.

E) Coastal restoration works along proposed Nature Park to address erosion and soil stability of coastlines and for safeguarding the Nature Park and its amenities. The activities shall mostly be carried out from land.

F) Installation of boundary markers to demarcate the intertidal boundary of MMM Nature Park.

2.3.2 The importance of coastal restoration works in Mandai Mangrove and Mudflat Nature Park

The Mandai Mangrove and Mudflat site has been affected by coastal erosion which is a result of past human activity in the area as well as changes in the natural environment such as waves, current, wind activity. Erosion of soil and the wearing away of land along the coastline has resulted in changes of topography. The loss of stable ground under the mangrove trees has negatively impacted tree stability and in some cases, led to the uprooting of mature mangrove trees. Figure 2-3 shows some photographs depicting the impact of the coastal erosion recently recorded at the Mandai Mangrove and Mudflat site.

Figure 2-3. Photographs depicting the soil erosion along Mandai coastline

Mangrove ecosystems act as natural buffers reducing impacts of coastal activity by stabilizing the shorelines and holding the substrate in place with their extensive root systems. Through coastal stabilization works (e.g. coastal revetments of coastal areas by interlocking rings, coir fibre logs, geobags) and the application of Nature-based Solutions (e.g. mangrove planting, assisted mangrove retreat), coastal erosion may be arrested, and further land and tree loss in the project area may be prevented. Examples of the implementation of coastal protection measures in Singapore are shown below in Figure 2-4. Coastal restoration alternatives to be applied in the development of the Mandai Mangrove Nature Park are described in Section 2.3.3.

Figure 2-4. Photographs of the existing coastal protection works used in Singapore: a) Kranji Coastal Nature Park[2], and b) Geobags applied at East Coast Park (NParks)[3]

[2] https://sealevelconference.org/wp-content/uploads/2022/06/3-KCNP-Flyer_NPark_24Jun2022-.pdf

[3] https://globalsynthetics.com.au/erosion-control/geolog-coirlogs/

2.3.3 *Detailed description of design features, trail profiles and coastal restoration options*

The Mandai Mangrove and Mudflat Nature Park development utilises multiple strategies to achieve a solution that will have a low impact on the environment. Figure 2-5 illustrates key infrastructure features of the future Nature Park development, specifically of enhancements to Kranji Reservoir Park, the proposed Kranji and Pang Sua Pavilion, guided and public trails. Various possible coastal restoration options have also been illustrated in the sectional profiles of the trails (Figure 2-8. to Figure 2-15).

Figure 2-5. Map showing location of key infrastructure features for Mandai Mangrove and Mudflat Nature Park – Letters and colours in map correspond to the profiles below the map. Details of each profile can be found from Figure 2-8. to Figure 2-15.

<u>Enhancement to Kranji Reservoir Park design concept</u>

Key design considerations for this park include reforestation with native vegetation at the central area to create a coastal forest zone, and sanctuary for birds. A Rookery is also proposed as part of the sanctuary experience, along with a simple lookout shelter. Design proposal includes restoring an existing eroded coastline into a demonstrative zone showcasing Nature-based Solutions.

A pedestrian bridge that connects from Kranji Coastal Nature Park has also been proposed as an optional site feature.

Proposed Sungei Kranji Pavilion

The existing Carpark A will be redeveloped to provide essential amenities for the new Mandai Mangrove and Mudflat Nature Park. The facilities will be integrated into a 2-storey pavilion. The entrance promenade at 1st Storey incorporates a coach drop off, public toilets and information counter. The 2nd Storey is primarily a viewing gallery to capture views towards the mudflat and the sandbar at KRP. Car parking lots will be reconfigured and planted with lush greenery to create a natural setting. Security fencing will also be realigned and designed to integrate with the pavilion without a jarring appearance.

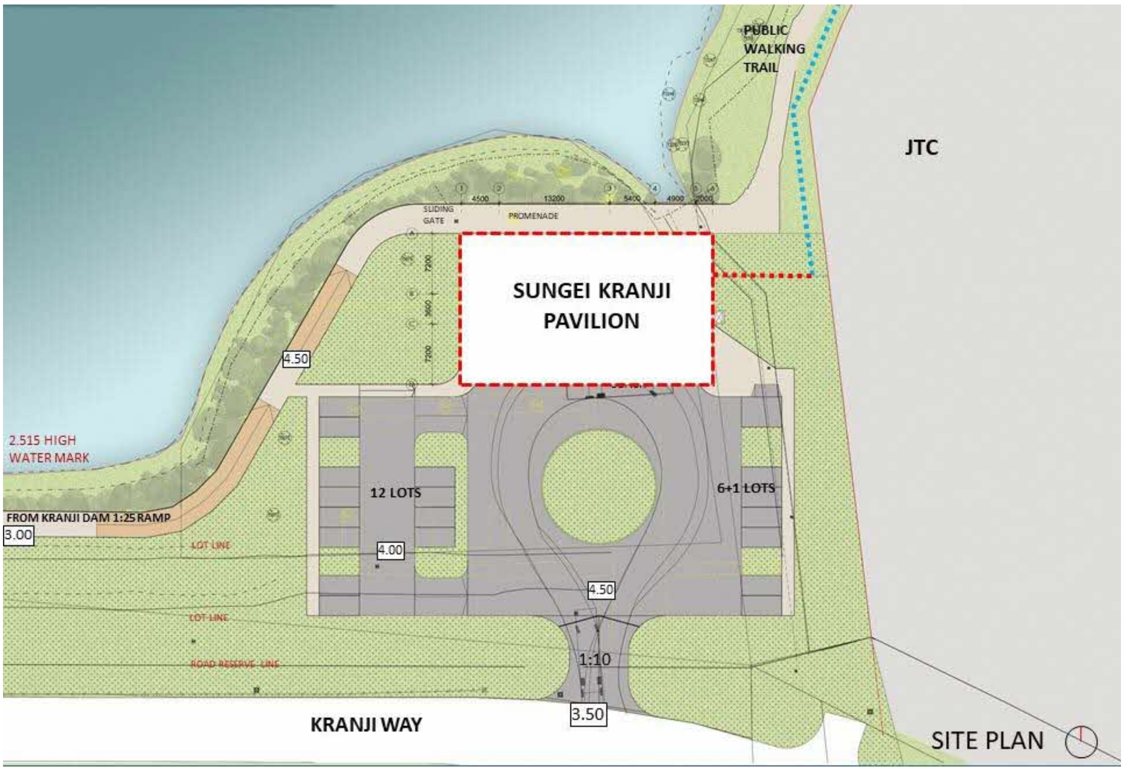


Figure 2-6. Site layout plan of Sungei Kranji Pavilion: A) 1st storey consists of washrooms and information counter, and B) 2nd storey consists of viewing pods and seats

Proposed Sungei Pang Sua Pavilion

The Sungei Pang Sua Pavilion will be the main node for the Nature Park. The pavilion will provide an introductory experience for park visitors to understand the mudflat context better before embarking on their visit. Part of the existing seawall will be adjusted to feature an experiential zone with a boardwalk over the water, showcasing Nature-based Solutions as part of coastal protection efforts. The interpretive gallery will provide educational panels with background information on the mudflat as well. Connected to the pavilion via a linkway, the existing disused building will be replaced by a 7-storey lookout tower to offer a different elevated experience for the park visitors. The top of the tower will provide a panoramic view with the opportunity to watch the shore birds on the mudflat.

Figure 2-7. Site layout plan of Sungei Pang Sua Pavilion

<u>Proposed Coastal trails and soil stabilisation options</u>

The profile sections of the trails are designed to account for higher future sea levels. Profiles A, B, C, E & F represent various sectional designs of the trails that will be normally open to the public, while Profile D represents the design of the section of the trail accessible only by guided walk. Other redevelopment works such as the removal and rebuilding of new PCG fences, as well as soil stabilisation options and treatment will also be discussed. As the details of the slope stabilisation are still in progress, this EIA shall consider the application of all various options.

<u>Profile A</u> is proposed as a typical section that consists of a 3 m wide compacted earth trail and the cutting back of the existing slope which will stabilise itself over time. Coir fibre logs (tubes filled with densely packed coconut fibre wrapped with coir netting) are placed at the toe of the slope to stabilise it and reduce the erosion on land[4]. The coir fibre logs are expected to biodegrade over two to five years (Figure 2-8.) and will be anchored with 50 mm diameter Bakau pins. The existing PCG fence and footing will also be removed and rebuilt at approximately 2 m away from the Jurong Town Corporation (JTC) boundary.

[4] Soil without any vegetation cover is prone to soil erosion by water and wind. Geotextiles (such as coir fibre) are permeable textile fabrics that are used to prevent the soil from migrating, while maintaining the water flow (Sonar et al., 2021). The ultimate objective of geotextiles is to establish a dense network of root system and re-establish the vegetation cover (Sonar et al., 2021).

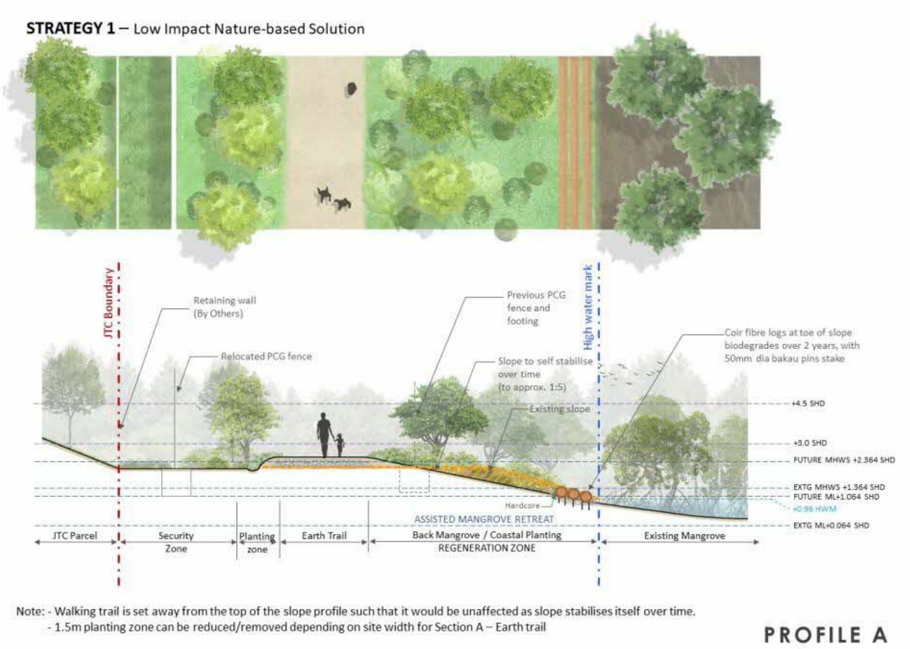


Figure 2-8. Profile A design strategy – compacted earth trail

Profile B is proposed along the public trail with width that is less than 14m. Together, three (3) possible profiles are being proposed for the trail depending on the available space. At pinch points where space is limited, Profile B1 (Figure 2-9) seeks to construct interlocking rings to stabilise the soil and facilitate mangrove regeneration. The existing slope will be cut back at a gradient of 1:5 for mangrove to retreat and the soil to stabilise naturally. Where there is sufficient space, Profile B2 with the earth trail combined with coastal protection strategies that includes gunny sacks and coastal shrubs. The earth trail shall meet a minimum level of 3.0m SHD and may require back filling along certain stretches (Figure 2-10). Profile B3 will make use of geobags to stabilise the slope (Figure 2-11).

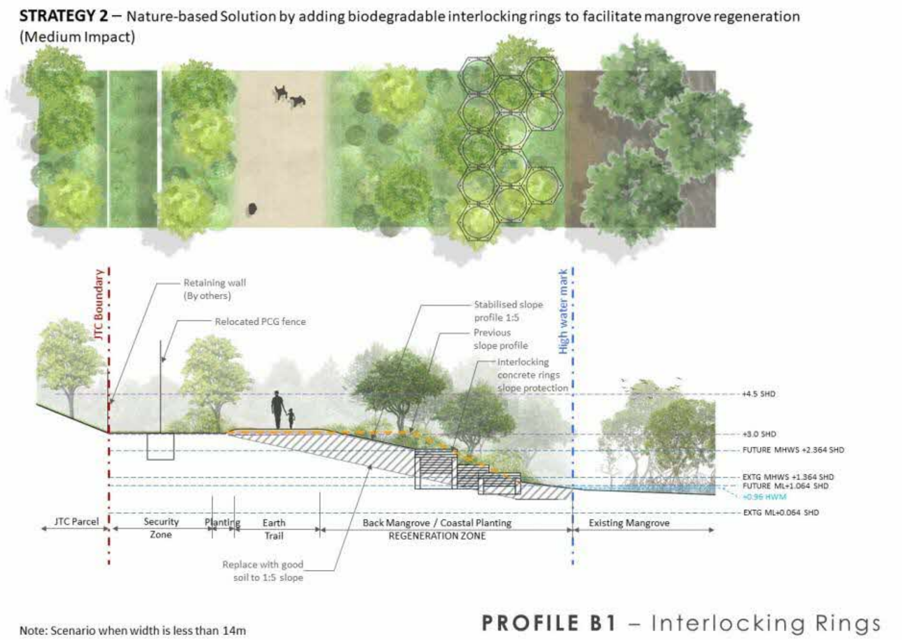


Figure 2-9. Profile B1 design strategy – compacted earth trail with interlocking rings

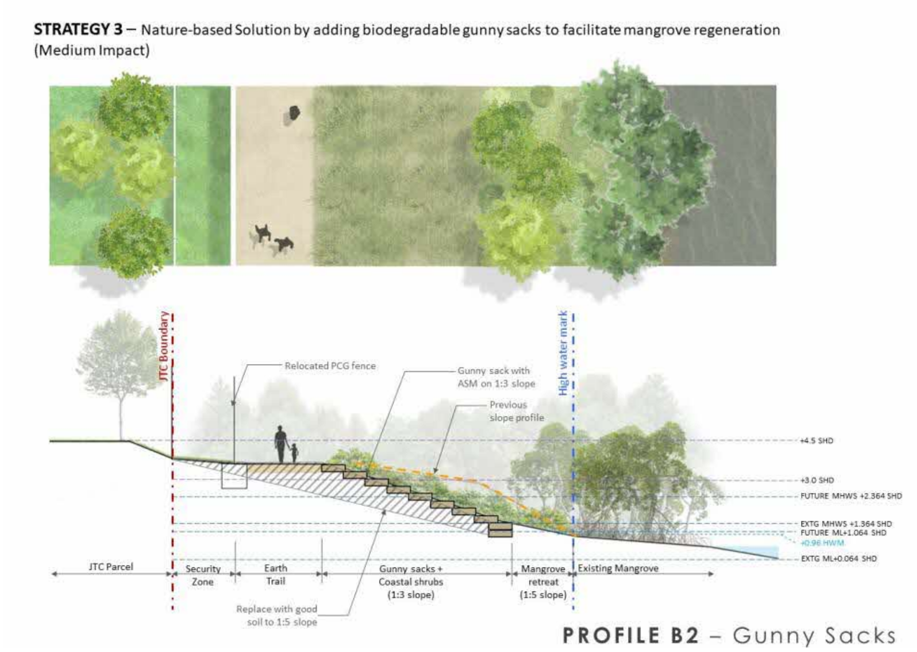


Figure 2-10. Profile B2 design strategy – compacted earth trail with gunny sacks and coastal shrubs

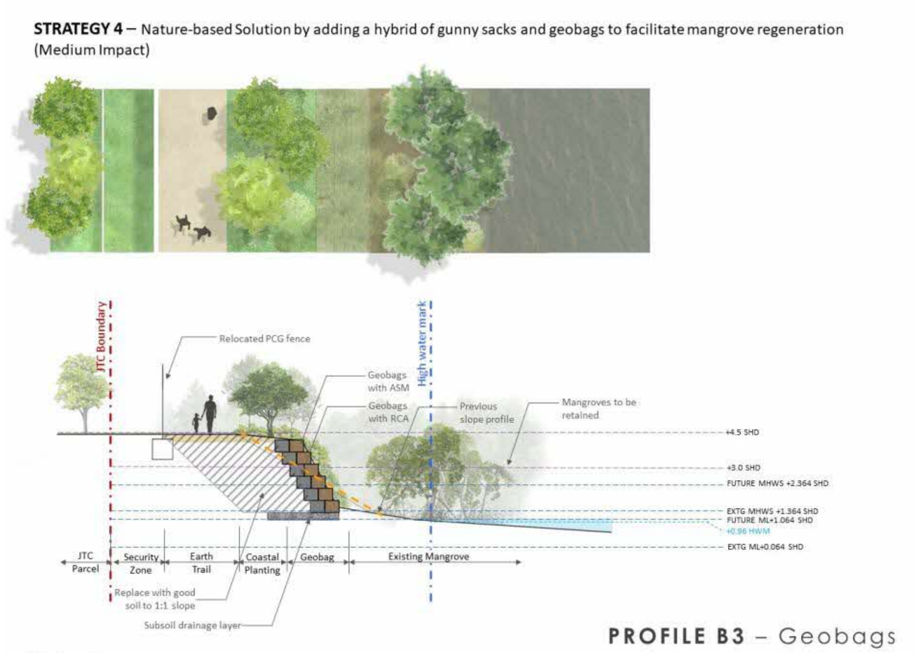


Figure 2-11. Profile B3 design strategy – compacted earth trail with geobags

Profile C is proposed at much narrower areas of lower elevation and could be subjected to tidal inundation as sea levels rise due to climate change. On new concrete footings, the boardwalk could be located next to the water body to create a different trail experience (Figure 2-12). Cutting of slope will not be required.

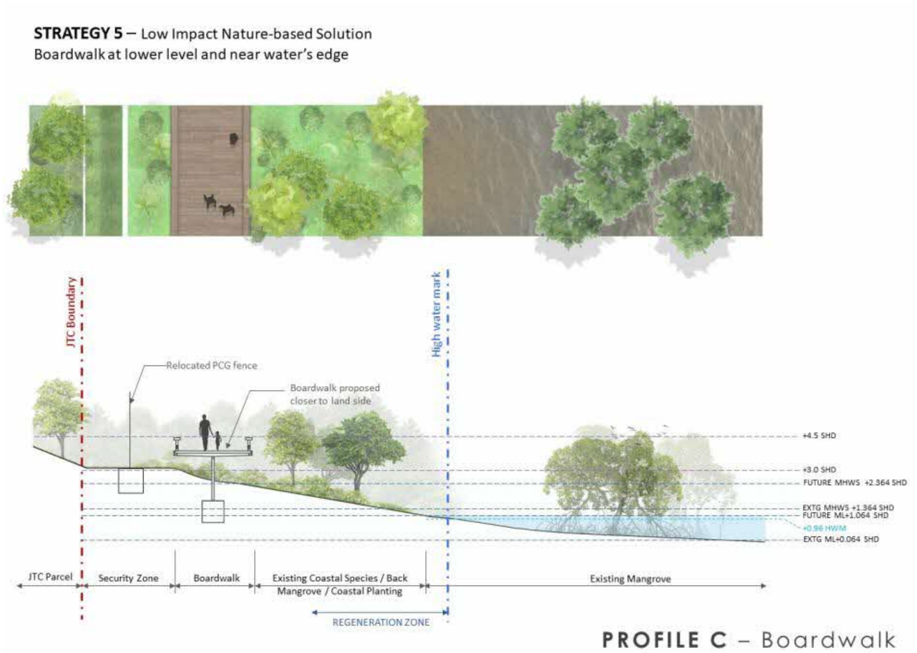


Figure 2-12. Profile C design strategy – boardwalk with concrete footings without cut back of existing slope

Profile D is part of the guided trail and represents a low-impact Nature-based Solution. Design Option 1 is represented by a 1.5 m wide earth trail and Option 2 by a 1.5 m wide elevated boardwalk. The two design Options aim to stabilise the slope after removal of the existing concrete footing to approximately 1:5 over time (Figure 2-13). Selection of options will also be subject to the type of mangrove species found at the specific site.

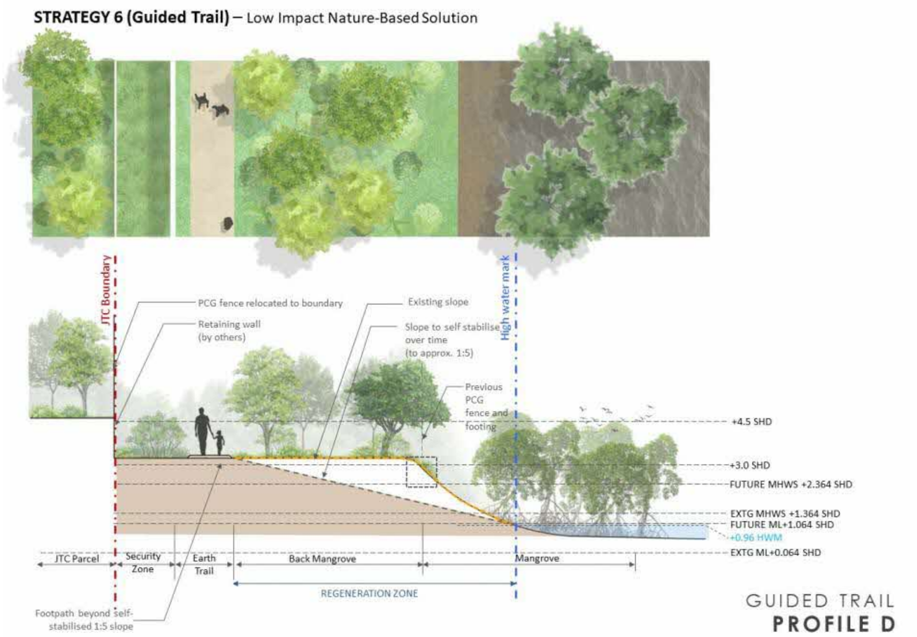


Figure 2-13. Profile D design strategy (Option 1) – compacted earth trail after slope stabilisation

Profile E is a 1.5 m wide trail consisting of landscape enhancement on the Kranji Reservoir dam, on the north side of Kranji Road, creating a simple at-grade pedestrian connection from Kranji Reservoir Park to Mandai Mangrove and Mudflat (Figure 2-14).

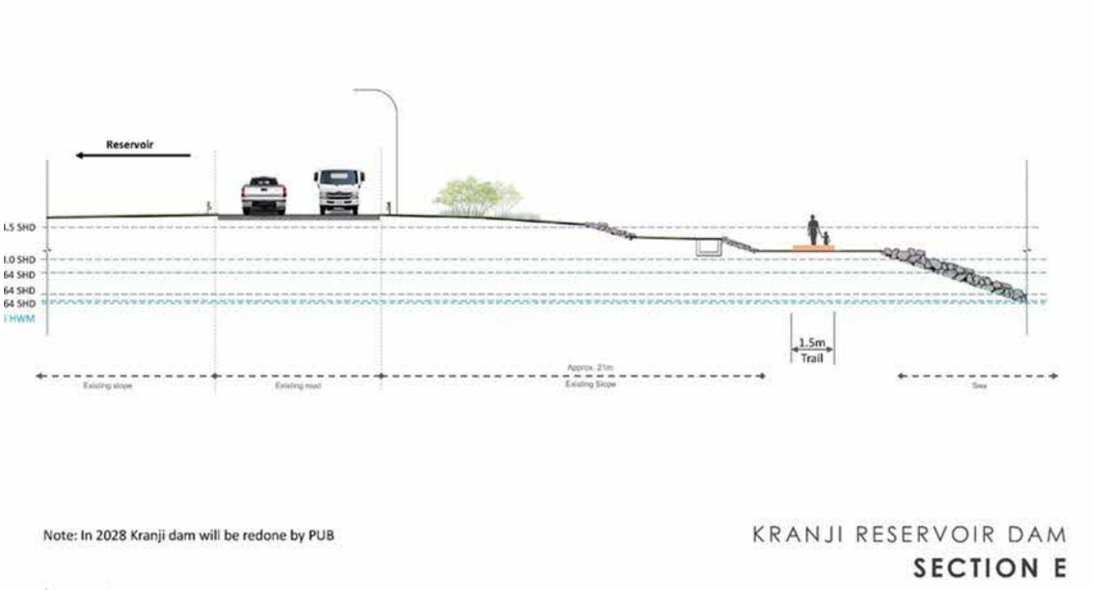


Figure 2-14. Profile E design strategy – trail along Kranji Reservoir dam

Profile F is a 1.5 m wide trail above Sungei Pang Sua, located 2 - 6 m from the back mangrove (Figure 2-15) within PUB's drainage reserve. As the trail passes through a patch of secondary forest, further verification of tree species will be carried out at the detailed design stage to determine its actual alignment.

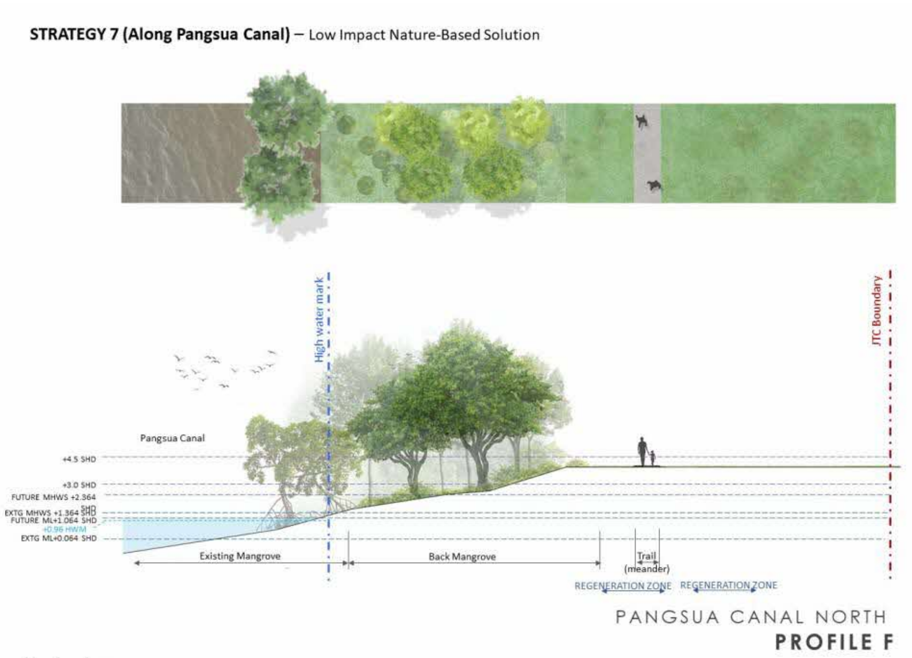


Figure 2-15. Profile F design strategy – trail in the secondary forest along Sungei Pang Sua

Boundary markers
Markers shall be proposed to demarcate the boundary of future Mandai Mangrove and Mudflats Nature Park. Other than floating buoys, these markers could likely be made of Bakau timber and spread out in clusters along the intertidal zone. They can also serve as perching poles for birds.

2.4 Operational Activities Associated with Project

Operational hours for the future Mandai Mangrove and Mudflat Nature Park shall be from 7 am to 7 pm. However, trails along Sungei Pang Sua would be connected with the Railway Corridor and may remain open to the public outside the aforementioned hours (pending confirmation by the authorities).

Operational activities in the area will consist of recreational and educational use of the Nature Park by both the public and researchers. Upon completion, there may also be maintenance works in the area such as pruning of trees and servicing of nearby facilities.

2.5 Project Scope and Implementation Schedule

The project development will be planned in two phases. Phase 1 entails most of the infrastructure development including Kranji Reservoir Park, Sungei Kranji Pavilion, Sungei Pang Sua Pavilion and coastal trails at the public domain. The removal and rebuilding of PCG fence and coastal restoration works will also be carried out during this phase. Phase 2 will be within the Guided Walk domain and lookout deck. All activities are expected to be completed within 24 months from the start of construction. The implementation schedule is provided in Table 2.1. The target physical completion shall be by 2028.

Table 2.1. Implementation schedule of development works for Mandai Mangroves and Mudflat Nature Park

Phase	Description of Works	Months
1	Coastal Trails (Public Trail) + Pavilions + Bridge	18 – 24
2	Coastal Trail (Guided Trail)	8 – 10

2.6 Construction Activities Associated with Project

This section describes the anticipated construction activities during implementation. Considering the sensitive nature of project area and keeping in mind the “low impact development” principle, construction activities will be carried out during daylight hours as far as possible and any heavy construction work close to the mudflat area will avoid the peak migratory bird season (August to April), so as to minimise the disturbance to the migratory shorebirds. Detailed design works/layout plans and detailed construction methodology are not available at this stage. Based on the preliminary information available, proposed construction works and associated work activities are provided. Wherever necessary, the standard construction industry practices applicable to the infrastructure project are taken as references to assess the impacts associated with the proposed project.

Site Features

Site preparation will be carried out and will include some removal of existing vegetation within the construction footprint for the proposed site features at Kranji Reservoir Park, Sungei Kranji Pavilion, Sungei Pang Sua Pavilion as well as the coastal trails in the Public and Guided zones.

Sungei Kranji Pavilion and Sungei Pang Sua Pavilion form the key public nodes and entry points into the proposed Nature Park. At Sungei Kranji Pavilion node, no major site clearance will be required as existing Carpark A will be redeveloped into a 2-storey pavilion that incorporates an entrance promenade, coach drop off, public toilets, information counter and a viewing gallery. No major site clearance will be required at Sungei Pang Sua Pavilion node as the amenities will be built on existing plot of land as well. These amenities include a 7-storey tower, interpretative gallery, experiential boardwalk, vehicular drop off, public toilets and offices. The proposed infrastructures would entail civil engineering works such as minor site clearance (removal of existing trees and vegetation), earthworks cutting/filling within the site to achieve the desired platform levels required for the proposed development; construction of roads, shifting of the Police Coast Guard (PCG) fence, utilities/services laying and other related works. Piling works for the proposed pavilions will require further soil investigation. Overall, it is expected that construction machinery such as excavator, generator, compactor and haul trucks will be utilised.

Coastal trails and other nature trails are to be constructed using options such as porous binded aggregate, binded earth, compacted mill waste or similar. The boardwalk is proposed to be precast / prefabricated construction. Most work will be carried out through using manual/semi-manual labour methods. No heavy machinery will be used. The construction footprint will be kept to a minimum to minimise the site clearance requirements.

For coastal restoration and stabilisation works, some earthworks may be required for cutting back of the slope to achieve a gentle gradient or replacement of existing soft ground materials with approved backfill materials to form a stable profile where gentle slope cannot be achieved (to prevent further erosion of the coastline), in conjunction with various Nature-based Solutions. Also, to avoid unnecessary removal of mangrove trees, different Nature-based Solutions will be applied in response to the type of mangrove species and condition of the slope, subject to further detailed studies. Mangrove trees of conservation significance will be protected. Construction works will be carried out mainly from the terrestrial side and no barges will be used to avoid damage to the mudflat.

Site Clearance

The trail along Sungei Pang Sua is expected to cut through a patch of young secondary forest before joining the Railway Corridor. Site recces with the NParks team will be conducted to confirm the detailed trail alignment. A visual tree assessment has been completed to identify trees suitable for removal based on criteria such as conservation status and public safety. During the submission stage, a vegetation clearance plan will be submitted to and approved by NParks prior to removal of vegetation in the project area.

3 EIA APPROACH

3.1 Singapore's EIA Context

Singapore adopts a systematic framework to determine and mitigate the potential impact of any new development on the environment. In general, development projects are required to undergo a thorough evaluation process that addresses the development's potential impact on traffic, public health, heritage, and the environment. In addition, proposed development projects near sensitive areas, such as Nature Reserves, Nature Areas, marine and coastal areas, forested areas, and other areas of significant biodiversity or with potential trans-boundary impact, are subject to greater scrutiny.

For such projects, relevant Technical Agencies (e.g., the National Parks Board, National Environment Agency, Maritime and Port Authority of Singapore) are consulted more extensively, in which the developer sets out the relevant locational and environmental factors, makes a considered statement on the potential impacts of the project based on these factors, and indicates the measures that will be taken to minimise negative impact on the surrounding environment.

This is intended to help set the grounds (on a reasonable basis) on the potential impacts (whether it will cause substantial pollution or significant and harmful change) and is also consistent with principles of the screening stage in international EIA practices. Government agencies will assess the impact of the project and recommend whether further environmental studies are required.

Due to the potential impacts, it is deemed that a comprehensive study compromising impact analysis, assessment, and mitigation management is required for this proposed development. For this EIA, an Inception Report illustrating the EIA scope was submitted to relevant Technical Agencies in advance of the commencement of the EIA to confirm the scope.

3.2 Scope of EIA

This EIA study is conducted as per the requirements specified by NParks in the Invitation to Tender (ITT), and scoping consultation process with the relevant Technical Agencies. As noted earlier, an Inception Report describing the scope of EIA was submitted to the relevant Technical Agencies prior to the commencement of the EIA study.

The EIA study shall:

- Describe the baseline conditions of the proposed project area and the environmental constraints considering seasonal migratory variations;
- Define and evaluate the acceptable impact levels in a given environmental receptor. The tolerance limits include:
  - Suspended sediment and sedimentation impact;
  - Noise, air, vibration impact;
  - Hydrology, water quality Impact.
- Define, classify and assess potential impacts and determine the significance of impacts on sensitive receptors and biodiversity; including ecological connectivity

to the surrounding greeneries;

- Outline water pollution and construction waste management plans;
- Quantify and assess the magnitude, likelihood of the potential environmental impacts;
- Propose and justify effective mitigation measures (if any) to minimise environmental impacts (e.g. pollution, environmental disturbance and nuisance) during construction of the Project;
- Identify, predict and evaluate the residual environmental impacts (i.e. after practicable mitigation) and the cumulative effects expected to arise during construction of the Infrastructure Project in relation to the sensitive receptors and potential affected uses;
- Identify, assess and specify methods, measures and standards, to be included during construction of the Infrastructure Project which are necessary to mitigate the residual environmental impacts and cumulative effects and reduce them to minimal levels;
- Investigate the extent of the secondary environmental impacts that may arise from the proposed mitigation measures and to identify constraints associated with the mitigation measures (if any) recommended in the EIA, as well as the provision of any necessary modification;
- Tailor mitigation measures to address different type and stages of construction works;
- Propose an Environmental Monitoring and Management Plan (EMMP) to document specific monitoring and environmental impact management procedures for the Infrastructure Project that includes:
  - Flora and Fauna Management Plan
  - Wildlife Management, Protection and Monitoring Plan
  - Earth Control Measures Plan
  - Water Pollution Management Plan
  - Air Pollution Control
  - Noise, Dust, and Vibration Management Plan
  - Waste Management Plan
  - Vector Control Plan

3.3 Relevant Regulatory Framework, Standards, And Guidelines

Table 3.1 lists relevant legislation, regulations and guidelines that govern the various environmental parameters within Singapore. The latest legislations and relevant subsidiary regulations can be accessed from the website of Singapore Statutes Online (SSO) (n.d.) at https://sso.agc.gov.sg/.

Table 3.1. List of applicable Singapore legislations, regulations, and guidelines relating to biodiversity and environmental protection

Parameter	Legislation, Regulations and Guidelines
General	• Environmental Protection and Management Act, 1999 • Environmental Public Health Act, rev. 2020 • Singapore Code of Practice on Pollution Control (SS593: 2013)
Biodiversity	• The Wildlife Act 2020 • The Parks and Trees Act 2005 • The Parks & Trees Regulations 2006 • The Parks & Trees Preservation Order 1998 • Parks & Trees (Composition of Offences Regulations) 2006 • Parks & Trees (Planning Areas) Notifications 2006 • Parks & Trees (Heritage Road Green Buffers) Order 2006 • Singapore Red Data Book, Second Edition, 2008 • Singapore Red Data Book, Third Edition (online), 2023 • IUCN Red List of Threatened Species to assess species vulnerability (2021) • CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora, also known as the Washington Convention) 1983
Noise	• Environmental Protection and Management Act 1999, Part VIII Noise Control • Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2008 • Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations 2008 • NEA Code of Practice on Pollution Control SS 593 (2013) • Code of Practice for Noise Control on Construction and Demolition Sites SS602 (2014)
Marine Water Pollution	• Prevention of Pollution of the Sea (Hazardous & Noxious Substances Pollution Preparedness, Response & Co-operation) Regulations, 2004 • Prevention of Pollution of the Sea (Noxious Liquid Substances in Bulk) Regulations, 2006 • Prevention of Pollution of the Sea (Garbage) Regulations, 2012 • ASEAN Marine Water Quality: Management Guidelines and Monitoring Manual (2008)
Surface and Ground Water Quality	• Sewerage and Drainage Act 2001 • Sewerage and Drainage (Surface Water Drainage) Regulations 2007 • Sewerage and Drainage (Trade Effluent) Regulations revised 2007 • Environmental Protection and Management Act 2002, Part V on water pollution • Environmental Protection and Management Act (Trade Effluent)

Parameter	Legislation, Regulations and Guidelines
	Regulations 2008 • PUB Code of Practice on Surface Water Drainage (2018) • PUB Handbook on Managing Urban Runoff (2013) • NEA Code of Practice on Pollution Control SS 593 (2013) • PUB Guidebook on Erosion and Sediment Control at Construction Sites (2018) • ASEAN Marine Water Quality: Management Guidelines and Monitoring Manual (2008)
Ambient Air Quality	• Environmental Protection and Management Act 2002, Part IV on Air Pollution Control • Environmental Protection and Management (Vehicle Emissions) Regulations 2008 • Environmental Protection and Management (Prohibition on Use of Open Fires) Order 2008 • Environmental Protection and Management (Air Impurities) Regulations 2008 • NEA Singapore Ambient Air Quality Targets (2011) • NEA Code of Practice on Pollution Control SS 593 (2013)
Waste Management	• Environmental Protection and Management Act 2002, Part VII on Hazardous Substances • Environmental Protection and Management (Hazardous Substances) Regulations 2008 • Environmental Public Health (General Waste Collection) Regulations 2000 • Environmental Public Health (Toxic Industrial Waste) Regulations 2000 • NEA Code of Practice on Pollution Control SS 593 (2013)
Vector Control	• NEA Guidelines on Rainwater Collection System and Mosquito Prevention • Control of Vectors and Pesticides Act 2002 • Environmental Public Health Act (EPHA) 2002

3.4 EIA Study Area and Environmental Aspects

The EIA study area denotes the project area where construction of the proposed Nature Park is predicted to have impacts on various environmental aspects within the site.

Figure 1-1 in Chapter 1 shows the extent of the proposed study area of the EIA. It denotes the area where construction of the proposed project area takes place and is predicted to have impacts on various environmental aspects within the site. Both marine and terrestrial baseline surveys will be carried out within this boundary, in respect of the previous baseline studies carried out during the Feasibility studies completed in 2019.

Additionally, the EIA will study potential impacts on sensitive receptors, including ecological connectivity of the surrounding ecologically significant areas.

The project area covers a vegetated area of approximately 60 ha of terrestrial area and 13 ha of intertidal marine areas close to the coast. At the edge of the coast, there is a line of fences managed by the Police Coast Guard (PCG) to prevent trespassers from entering the site and/or coming into Singapore from the nearby Johor Straits.

The environmental aspects that were studied for this project, along with a brief description of each aspect and explanation of its relevance in the study, are presented in the following paragraphs. The identified sensitive receptors are listed down in Table 3.2.

Biodiversity

The biodiversity aspect includes the flora and fauna groups inhabiting the project area that may be impacted by future construction and operation of the Nature Park. The groups studied include mangrove trees, migratory shorebirds and resident birds, mammals, herpetofauna (reptiles and amphibians), odonates (dragonflies and damselflies), butterflies, (intertidal benthic) invertebrate fauna within the mangroves and mudflat, and secondary forest vegetation. These flora and fauna groups dominate the identified potential sensitive receptors.

Surface and marine water quality

Marine and surface water quality in the area is important to support the mangroves and aquatic species inhabiting the site. Marine water quality and all waterways within the site may be impacted during the construction and operation stages of the proposed project. Waterways include Sungei Pang Sua, Sungei Mandai Besar, Sungei Mandai Kechil, the adjacent waters of the West Johor Strait, and the drainages running from nearby industrial areas.

In addition, hydrodynamic modelling was carried out to assess the impact of the proposed Nature Park on parameters such as current velocity, current direction, and waves. Sediment plume modelling was also conducted to identify areas of increased sedimentation or erosion arising from the proposed Nature Park infrastructure.

Soil and topography

Changes in vegetation play an important role in soil stability. Where vegetation clearance has taken place, soil will be left vulnerable to erosion, particularly during rainy periods. This can be further magnified by changes in topography and slope steepness. Erosion may lead to siltation of waterways, and also the runoff of nutrients in topsoil, leading to lowered nutrient levels of the remaining soil on the site and increased nutrient loading in waterways. The development of boardwalks within mangrove areas may affect sediment compaction, pneumatophore densities, and mangrove macrofauna assemblages, in particular crab and bivalve densities in areas immediately adjacent to the boardwalks (Kelaher et al., 1998a; Kelaher et al., 1998b; Skilleter & Warren, 2000). There is also a risk of heavy metal pollution from the use of certain wood-preservatives in the preservation of construction materials used in the construction of the boardwalk (Lebow & Foster, 2005).

Hydrodynamic and sediment modelling for marine EIA

Construction activities along the coastline may lead to impacts on hydrodynamic patterns. Hydrodynamic modelling was carried out to assess the impact of proposed infrastructure development on parameters such as current velocity, current direction and waves etc. Sediment plume modelling was conducted to identify areas of increased sedimentation.

Ambient air quality

Construction activities are known to release dust and other particulate matters that may harm the health of sensitive receptors in surrounding area, in this case flora and fauna species and human receptors within the project area. Vehicular emissions during the operational phase may also cause impact in the same manner but on a less severe scale. Hence, baseline ambient air quality readings were taken to form the basis for the assessment of impacts and recommendations for the mitigation of these impacts.

Noise

Mandai Mangrove and Mudflat holds a diverse community of flora and fauna and is a major feeding ground for migratory and resident birds. Birds have long been known for their sensitivity to noise (Francis, 2015). Since construction activities will likely increase noise levels in future, noise levels were measured at sensitive receptors and analysed to assess baseline conditions. Impacts of noise from construction activities were assessed to recommend mitigation measures.

Light

Increased artificial light during night-time — either from construction activities or after the construction, during park operation — could disrupt circadian cycles of animals and distort the day–night cycle of plants. This may lead to increases in predation pressure by diurnal carnivores on nocturnal animals, exhaustion of insects attracted to artificial light, and alteration of breeding and sleeping cycles of various animals. The distortion of day-night cycles in plants may also lead to altered growth rates and flowering cycles, thus affecting floristic communities. Certain mitigation measures can help to ensure that the lights from the project construction and operation do not adversely affect ecological communities on the site.

Waste management

The main impacts in relation to the storage, handling, transport, and disposal of waste include deterioration of the environment and health & safety risks with regard to hazardous waste, if they are not managed properly.

Vibration

The construction and operation of the new infrastructure will potentially increase vibration levels. Many fauna species, especially marine fauna species, are sensitive to vibration. Vibration levels will be measured at sensitive receptors and analysed to assess baseline condition. Impacts of vibration from construction activities were assessed to recommend mitigation measures.

3.5 Identification of Sensitive Receptors

Table 3.2 provides the overview of the identified sensitive environmental receptors that may be affected during the development of the proposed project.

Table 3.2. Overview of identified biodiversity and environmental sensitive receptors for the development of Mandai Mangroves and Mudflat Nature Park

Environmental Aspects	Sensitive receptors
Biodiversity	• Native flora and fauna of international conservation significance (i.e., classified as Critically Endangered, Endangered, or Vulnerable according to IUCN classification system) in the proposed project area • Native flora and fauna of national conservation significance (i.e., classified as Critically Endangered, Endangered, and/or Vulnerable according to Singapore Red Data Book (Davison et al., 2023) or other relevant local status publications) in the proposed project area • Native flora and fauna endemic to Singapore in the proposed project area • Habitats with high ecological value (i.e., environments that support species of conservation significance)
Surface & Marine Water Quality	• Flora and fauna within the proposed project area • Marine water that supports habitats of hight conservation importance • Surface waterways that support habitats of conservation significance
Hydrodynamics & Sediment & Topography	• Flora and fauna species within the proposed site • Habitats with high ecological value (i.e., environments that support species of conservation significance) • Marine water that supports habitats of high conservation importance • Surface waterways that support habitats of conservation significance
Ambient Air Quality	• Flora and fauna living on the proposed site. • People working on the site (e.g., construction workers, consultants) • People visiting Kranji Recreational Centre • People residing at Kranji Lodge 1
Noise and Vibration	• Species that are susceptible to noise pollution and vibration (e.g., species that require a quiet environment to find prey and species with acute hearing) • People working on the site (e.g., construction workers) • People visiting Kranji Recreational Centre • People residing at Kranji Lodge 1
Light	• Species that are susceptible to light disturbance (e.g., nocturnal fauna)

3.6 Impact Assessment Methodology

3.6.1 Identification of Impacts

The proposed project involves earthworks and infrastructure works within the project area. This will involve clearance of vegetation and earthworks for working spaces (e.g., project footprint, access routes, storage space for construction equipment and materials), which has several potential impacts on the surrounding environment. These impacts include those that are direct in nature, such as loss of species, habitat destruction due to vegetation clearance, and indirect impacts such as fragmentation of habitats, isolation of populations due to reduced connectivity and fauna movement, increased edge effect[5], and noise, light and air pollution during Construction and Operation phases of the project.

Assessment of the impacts of the proposed project will include:

- Elements of the community, man-made environment, and natural environment likely to be affected by the project (including ecological impacts);
- Disturbances to wildlife considering seasonal migratory variations (August to April);
- Suspended sediment and sedimentation impact on stream/aquatic habitats, aquatic plants, animals, or hydrophytes;
- Noise, dust, vibration impact on animals / aquatic habitat, or hydrophytes;
- Impacts on sensitive receptors; including ecological connectivity to the surrounding greenery;
- Water pollution and construction waste management;
- Water discharges, water quality and key hydrological parameters affecting the Projects site and natural or naturalised streams;
- Environmental impacts (e.g., pollution, environmental disturbance and nuisance) during construction of the Infrastructure Project;
- Residual environmental impacts (i.e., after practicable mitigation) expected to arise during construction of the Infrastructure Project in relation to the sensitive receptors and potential affected uses;

3.6.2 Assessment of Impacts

Based on the impact analysis of construction and operation activities of the proposed development, mitigation measures are recommended to lower the magnitude of negative impacts on the environment to within acceptable levels as much as practically possible.

Potential impacts were quantified using the Rapid Impact Assessment Matrix (RIAM) method, a scoring system in which impacts of each project activity are evaluated against environmental receptors (Pastakia & Barber, 1998). The RIAM method attributes values to each condition based on its importance (I), magnitude (M), permanence (P), reversibility (R), and cumulative impact (C).

The parameters are tabulated in Table 3.3

Table 3.3. List of parameters and respective scores assigned in RIAM method

Parameter	Description	Score
Importance	Important to national/international interests	5

[5] i.e., implication of higher temperature, light, noise, and pollution levels on the edges compared to the interior of a forest resulting in retraction or loss of species sensitive to these disturbances.

(I)	Important to regional/national interests	4
	Important to areas immediately outside the local condition	3
	Important to the local condition (within a large direct impact area)	2
	Important only to the local condition (within a small direct impact area)	1
Magnitude (M)	Major Positive benefit or change	+4
	Moderate Positive benefit or change	+3
	Minor Positive benefit or change	+2
	Slight Positive benefit or change	+1
	No change/status quo	0
	Slight Negative disadvantage or change	-1
	Minor Negative disadvantage or change	-2
	Moderate Negative disadvantage or change	-3
	Major Negative disadvantage or change	-4
Permanence (P)	No change/Not applicable	1
	Temporary	2
	Permanent	3
Reversibility (R)	No change/Not applicable	1
	Reversible or controllable through Environmental Management and Monitoring Plan	2
	Irreversible	3
Cumulative Impact (C)	No change / Not applicable	1
	Non-cumulative/single	2
	Cumulative/synergistic	3

To reduce ambiguity in assessing the "magnitude" component, we use the following criteria, tabulated in Table 3.4 to aid the assessment.

Table 3.4. Description of the value of magnitudes in RIAM method

Magnitude	Description
Major Positive benefit or change	Refers to significant improvements in baseline conditions and a significant reduction of stress or improvement in the baseline states of sensitive receptors.
Moderate Positive benefit or change	Refers to significant improvements in local baseline conditions, which may lead to a moderate reduction of stress to sensitive receptors or improvement in their baseline state.
Minor Positive benefit or change	Refers to Minor Positive benefits or changes to baseline conditions that are discernible but local. These changes may lead to local and limited reduction of stress to sensitive receptors.
Slight Positive benefit or change	Refers to Slight Positive benefit or change to baseline conditions that are unlikely to be detectable on site, and thus are unlikely to cause discernible reduction of stress to sensitive receptors.
No change/status	Refers to no expected changes in the baseline conditions, and unlikely

Magnitude	Description
quo	to cause any stress to sensitive receptors.
Slight Negative disadvantage or change	Refers to changes in baseline conditions that are unlikely to be detectable in the field, and thus are unlikely to cause discernible stress to sensitive receptors.
Minor Negative disadvantage or change	Refers to negative changes to baseline conditions that are discernible but local. These may also refer to changes that are approaching thresholds for established standards or guidelines. These changes may lead to a local and limited increase in stress to sensitive receptors.
Moderate Negative disadvantage or change	Refers to significant adverse changes in local baseline conditions. These may also refer to changes that are very close to exceeding established standards or guidelines or causing significant ecological impacts. These changes may lead to a moderate increase of stress to sensitive receptors.
Major Negative disadvantage or change	Refers to significant adverse changes in baseline conditions. These may also refer to changes that exceed established standards or guidelines or causing a complete loss of certain habitats or ecological components. These changes may lead to an unacceptable increase of stress to sensitive receptors.

These values will then contribute to the condition's environmental score, where:

$$Environmental\ Score\ (ES) = I * M * (P + R + C).$$

The ES attained for each condition correlates to a measure of its impact, tabulated in Table 3.5.

Table 3.5. List of ES range along with the degree of impact associated with each range

Range	Impact
116 to 180	Major Positive change/impact
81 to 115	Moderate Positive change/impact
37 to 80	Minor Positive change/impact
7 to 36	Slight Positive impact
-6 to +6	No Impact / Status quo / Not applicable
-7 to -36	Slight Negative change/impact
-37 to -80	Minor Negative change/impact
-81 to -115	Moderate Negative change/impact
-116 to -180	Major Negative change/impact

3.6.3 Mitigation Measures

In general, mitigation measures follow two concepts:

- ALARP : "As Low as Reasonably Practical"
- BATNEEC : "Best Available Technology Not Entailing Excessive Costs"

The first concept is a hierarchy of actions that aims to find anything that can be done to avoid, minimise, or reduce the predicted/ potential adverse (negative) environmental impacts, as practically feasible and reasonable. The second concept applies when discussing whether to adopt certain available technology that could address/reduce environmental impacts.

This EIA utilises both concepts for the development of mitigation measures for this project.

4 DESKTOP STUDY

This Chapter presents the summary findings of the desktop study carried out for project area. This included a thorough review of the previous environmental baseline studies conducted in the project area, publicly available literature on the ecology and biodiversity of the site, as well as other publicly available material that include land use history maps, photographs, and environmental data found on government websites.

The Mandai Mangrove and Mudflat was announced to be conserved as a Nature Park in 2018. The first Environmental Baseline Study was carried out by TAC (TAC, 2020) to understand the existing topography, flora, fauna and hydrology, and guide NParks' development plans.

The current EIA study area (2022) is an extension of that in the previous environmental baseline study, with the current study also encompassing the area along Sungei Pang Sua (south) and Kranji Reservoir Park (west), as depicted in Figure 4-1. Both marine and terrestrial baseline surveys were carried out within EIA boundary, as part of both studies.

Figure 4-1. Map of the Mandai Mangrove and Mudflat project area showing the project boundaries of the current (2022) EIA study and the 2019 EIA study **(TAC, 2020)**

4.1 Mandai Mangrove and Mudflat Site Appreciation

The area studied comprises of four main habitat types which include mangrove forests, mudflats with patches of sandflats, secondary forest, and urban vegetation. The project area is dominated by mudflats and mangrove forests, especially along the eastern coastline. Mudflats with patches of sandflats stretch out from the coast for hundreds of meters (Figure 4-2).

Figure 4-2. Map of the Mandai Mangrove and Mudflat project area, showing distribution of main habitats (adapted from NParks)[6]

The project area is one of the few mangrove areas with an extensive mudflat which provides refuge for a wide variety of flora and fauna with unique adaptations. Mangrove trees, for example, have unique root structures which increase their stability and ensure adequate supplies of oxygen. These include the knee roots of *Bruguiera*, prop roots of *Rhizophora*, and pencil roots of *Avicennia* (Figure 4-3). Some key tree species found in the mangroves include the globally near threatened and locally critically endangered mangrove *Sonneratia ovata*, the globally vulnerable mangrove *Avicennia rumphiana*, and the locally vulnerable palm *Nypa fruticans* (Figure 4-4). Figure 4-4 also shows locally endangered Beccari's seagrass (*Halophila beccarii*).

The combined characteristics of Mandai Mangrove and Mudflat – its connectivity to other local and regional sites, its role as a habitat for rare and threatened fauna, and the unique physical forms and functions of its species – provide a precious opportunity to develop a Nature Park that focuses on biodiversity. Additionally, the mangrove and mudflats

[6]https://data.gov.sg/dataset/coastal-and-marine-habitat-map-of-singapore-2018?resource_id=1f711a24-3851-4bf1-8f4b-c5797b50d950

areas in the vicinity serve as an important site for migratory birds that lies within the East Asian-Australasian Flyway (EAAFP, 2023). It is therefore vital to ensure that the future design of the Nature Park is based on a comprehensive understanding of the site to minimise any impacts and leverage on the unique characteristics of its natural environment.

Figure 4-3. Characteristic prop roots of *Rhizophora* and pencil roots of *Avicennia* in the site

Figure 4-4. *Nypa fruticans* (L) and *Halophila beccarii* (R) found in Mandai Mangrove and Mudflat

Hydrological conditions

The project area is along the catchment areas of Sungei Pang Sua and Sungei Mandai. It is adjacent to but lies outside the Kranji Reservoir catchment area.

There are three natural waterways namely Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil that intersect the project area. Sungei Pang Sua runs for about 3.5 km from mainland Singapore before feeding into the Straits of Johor. It serves as an important waterway and ecological belt supporting rich local biodiversity. Sungei Mandai Besar runs through the mangrove forests and intertidal mudflats before also feeding into the Straits of Johor. Sungei Mandai Kechil flows through a strip of mangrove forest, isolating a patch of mangrove and mudflat at the north-east of the project area. The dynamic of these features – tidal brackish waterways passing through mangrove forests and mudflats before ending in a saltwater strait – encourages interesting ecological communities to thrive in the project area.

4.2 Flora Biodiversity Literature Review

The mangrove and secondary forest habitats were surveyed as part of the previous 2019 baseline study through mangrove health assessment survey and secondary forest rapid assessment survey. The 2019 biodiversity baseline survey contributed to previous knowledge of the biodiversity of the area, along with new records of plant and animal species not previously recorded on the site. The 2019 survey also documented a detailed quantitative analysis of the health of the mangroves, the cover, shoot density and biomass of seagrass, and the density and biomass of benthic fauna inhabiting the intertidal mudflats. **Appendix A** provides the complete list of flora species recorded in 2019 and 2022 baseline studies, together with the historical records.

Mangroves

Based on combined historical records and 2019 survey findings, MMM (excluding Sungei Pang Sua) contains 28 out of the 35 total true mangrove species which can be found in Singapore (Yang et al., 2011), and 27 mangrove associate plant species. Of the 55 true mangrove and associate plant species found on this site, 29 were locally threatened, and five were globally (near-) threatened species (Figure 4-5). These included several individuals of the locally critically endangered *Sonneratia ovata*, and many individuals of the locally endangered *Lumnitzera racemosa a*nd locally vulnerable *Nypa fruticans*. The list also includes the globally vulnerable *Avicennia rumphiana*. There are also several locally threatened back mangrove species found in Mandai Mangrove and Mudflat, including three locally critically endangered species – namely *Finlaysonia obovata, Sonneratia caseolaris* and *Brownlowia tersa* (Sheue et al., 2010; Ang et al., 2010; Yang et al., 2011).

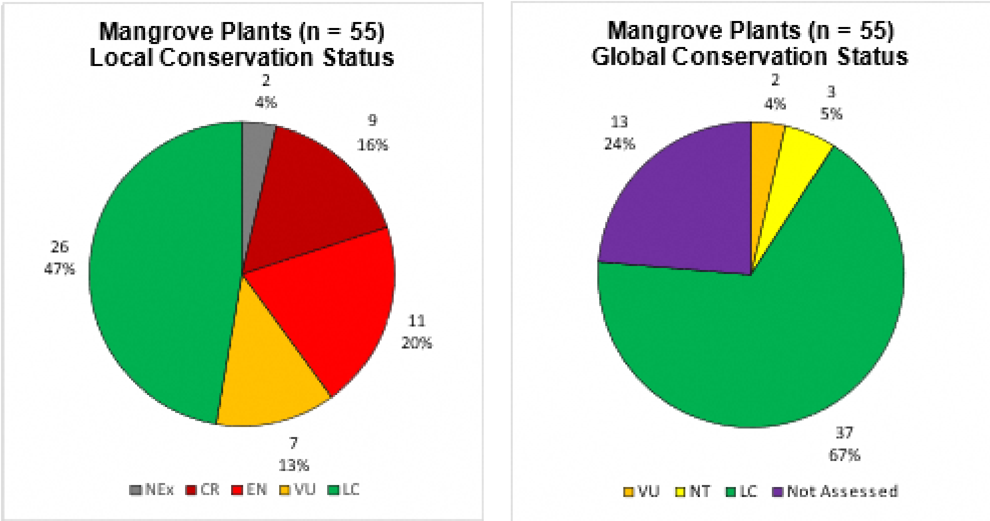


Figure 4-5. Local (left) and global (right) conservation status of mangrove plants in Mandai Mangrove and Mudflat.

At least 18 mangrove species were observed during the 2019 health assessment field survey (TAC, 2020). The six mangrove plots along the two transects surveyed at Mandai were characterised by healthy stands dominated by *Sonneratia alba* (especially abundant in the fringing mangroves), *Avicennia officinalis* (becoming more abundant towards the middle and back mangroves), and *Rhizophora apiculata* (common in the mid-mangroves). Comparison of the findings from the health assessment carried out by TAC in 2022 against the historical records and previous similar survey conducted in 2019 are elaborated in Section 5.4.

Seagrasses

The small, locally endangered seagrass and globally vulnerable species of *Halophila beccarii* were found to be scattered though quite common among pneumatophores and seedlings of *Sonneratia* and *Avicennia* in the fringing mangrove-mudflat transition zone during the 2019 survey. At one of the mangrove health assessment plots (A2) where *Halophila beccarii* was particularly abundant[7], quantitative assessments and sampling were conducted.

Halophila beccarii is one of only seven globally threatened seagrass species, and its numbers are declining (Short et al., 2011). Its population in Singapore, while restricted to the northern coastline and facing threats from coastal developments (Yaakub et al., 2013), is thus important for conservation (McKenzie et al., 2016). The Mandai Mangrove and Mudflat - including the coastal strip all the way up to Kranji Reservoir - along with Sungei Buloh are without doubt some of the Indo-Pacific region's key sites for this globally vulnerable species. Dugongs, which are a seagrass specialist, do feed in muddy areas where there is only *Halophila ovalis* (Marsh et al., 2011) and are also known to eat *Halophila beccarii* (Yaakub et al., 2013). Although the mudflat area in Mandai may be slightly degraded and does not have high seagrass species diversity, it could

[7] The remaining mangrove plots (B1-B3 & A1, A3) did not contain the necessary amount of biomass of *Halophila beccarii.*

potentially be a feeding ground for dugongs which have been recorded around the nearby Merambong Island in Johor (Rajamani, 2013).

Secondary Forest Vegetation

At least 52 plant species were observed in the secondary forest within the 2019 project area (which does not include KRP and Sungei Pang Sua). Along with historical observations (NParks, 2007) this brought the total list of secondary forest plants recorded for this area to 78.

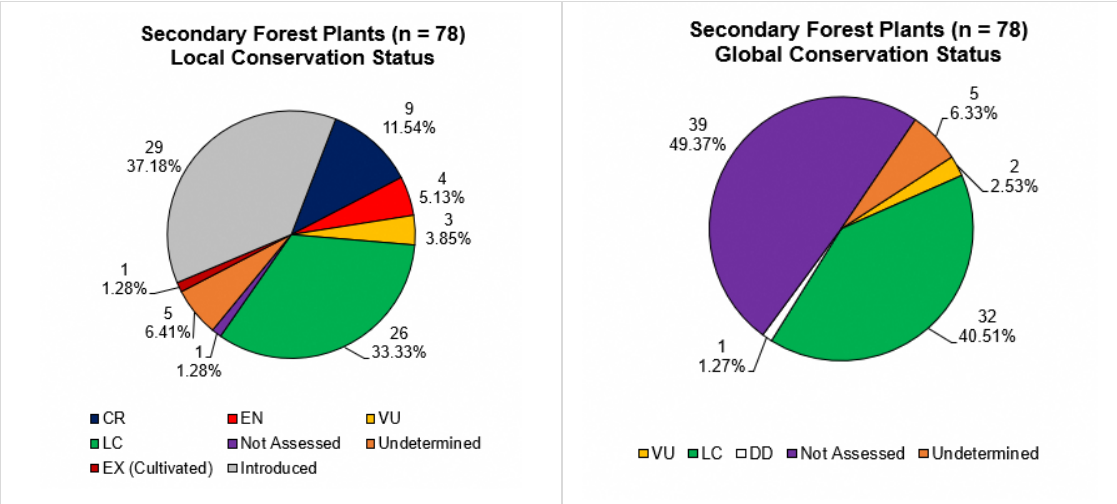


Figure 4-6. Local (left) and global (right) conservation status of secondary forest plants in Mandai Mangrove and Mudflat

At least 54 of the 78 species recorded for this area were native species. Of these, 16 were locally threatened, with three being vulnerable, four endangered, and nine critically endangered, including Penaga Laut (*Calophyllum inophyllum*), of which a few fruit-bearing trees, seedlings and saplings were observed during the field survey. The site reportedly also houses two globally near threatened and vulnerable species, Borneo Teak (*Intsia bijuga*) which is critically endangered in Singapore and Sea Teak (*Podocarpus polystachyus*), which is endangered in Singapore (Singapore Herbarium Online, 2023).

Some native plant species of importance for birds and small mammals included five native fig species (*Ficus* spp.), Fishtail Palm (*Caryota mitis*), and Sea Almond (*Terminalia catappa*). This was evident by the large number of frugivorous birds feeding in mixed flocks, particularly during the bird surveys of September and October 2019.

Mandai Mangrove and Mudflat is considered to have limited geographical and genetic connectivity than other mangrove areas further away, as a result of its small size and isolated location (Friess & Webb, 2014). However, research using “predictive agent-based model for mangrove propagules” developed in 2016 by NParks, suggests that the Mandai Mangrove and Mudflat has been found to be the main “seeding source” for mangrove propagules for many other mangrove areas in the West Johor Straits such as Sungei Buloh, Lim Chu Kang and other downstream mangrove areas (AsiaNewsDay, 2020).

4.3 Fauna Biodiversity Literature Review

A total of 278 species (142 birds, nine mammals, 10 herpetofauna, six fish, 23 terrestrial invertebrates, two horseshoe crabs, 49 molluscs, 19 crustaceans, and 18 benthic worms) are known to occur in the project area. The **Figure 4-7** shows the total number of fauna species and their local and global conservation status documented during the 2019 baseline rapid survey together with the historical sighting's records. The complete list of 2019 and 2022 fauna sightings of observed animals can be found in **Appendix C**.

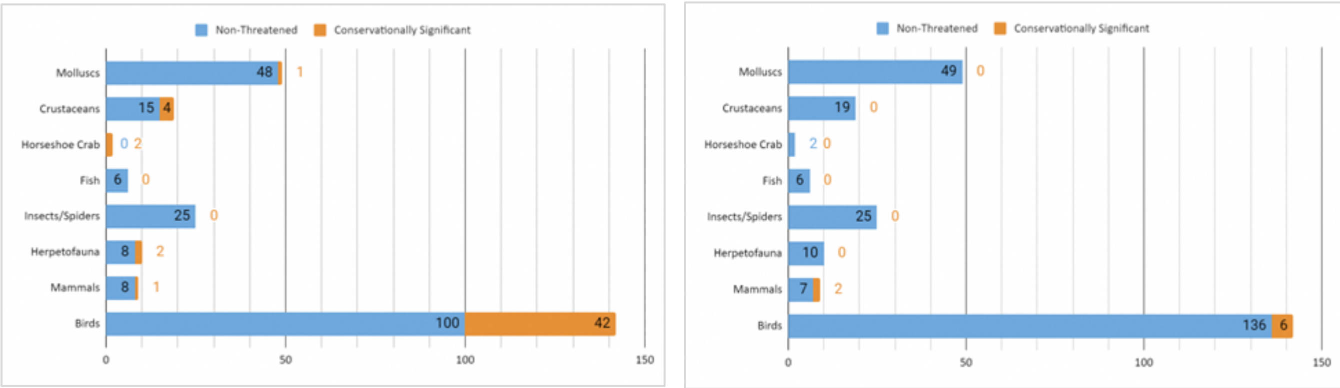


Figure 4-7. Local (left) and global (right) conservation status of fauna sightings recorded in Mandai Mangrove and Mudflat during the 2019 baseline study and historical data records

Birds

A total of 73 bird species were observed during the 2019 surveys (TAC, 2020). Together with historical data (NParks, 2007; Lim & Lim, 2009; Lim et al., 2009; Lim & Chew, 2010), the total number of bird species that have been observed in Mandai Mangrove and Mudflat was at least 142.

42 birds known were locally threatened, with two critically endangered, 17 endangered, and 23 vulnerable. Locally threatened species included the locally endangered black-crowned night heron and the locally vulnerable grey-headed fish eagle, both of which were encountered during 2019 surveys (NParks, 2023). Six species found at the site during the 2019 surveys were globally threatened, with one critically endangered, one endangered, and four vulnerable.

Based on another study conducted at MMM, a total of 118 bird species have been reported (Chew, 2018), 10 of which are listed in the Singapore Red Data Book (NParks, 2023). Threatened species of great significance include the locally and globally endangered great knot (*Calidris tenuirostris*), locally endangered but globally critically endangered straw-headed bulbul (*Pycnonotus zeylanicus*), and the locally endangered and globally vulnerable Chinese egret (*Egretta eulophotes*) (IUCN, 2021; NParks, 2023).

Mammals

A total of nine mammal species were recorded during the 2019 baseline survey. Most species found were common and not of conservation significance. One species, the smooth-coated otter (*Lutrogale perspicillata*), was listed as globally vulnerable under the

IUCN red list with declining populations, and locally endangered as listed by NParks (2023). The most common mammal species found was the plantain squirrel (*Callosciurus notatus*), which was regularly observed throughout the project area on many occasions but not caught in the live traps. Two black rats (*Rattus rattus)* and one common Malayan tree shrew (*Tupaia glis*) were caught in the live traps. Many tracks and footprints, digging marks, and faeces left behind by wild pigs (*Sus scrofa*) were observed, particularly along the inner side of the Police Coast Guard (PCG) fence.

The Malaysian wood rat (*Rattus tiomanicus*), lesser dog-faced fruit bat (*Cynopterus brachyotis*), and long-tailed macaque (*Macaca fascicularis*) are some common species near Sungei Buloh and presumed to be common here since it was first sighted in 2004 (Yong et al., 2010). The Mandai coastal mangrove area and the surrounding secondary forest have also been observed to be home to feral dogs (TAC, 2020).

Figure 4-8. Smooth-coated otter found at the site (source: TAC, 2020)

Herpetofauna

A total of 10 herpetofauna species have been recorded in Mandai Mangrove and Mudflat (excluding Sungei Pang Sua), of which seven were observed during the in 2019 baseline survey (Figure 4-7). Most of these species are common and not threatened in Singapore. There was also a sighting of an estuarine crocodile (*Crocodylus porosus*), which is considered critically endangered in Singapore. Two introduced reptiles, the red-eared slider (*Trachemys scripta scripta*) and the changeable lizard (*Calotes versicolor*) were also observed.

Together with the Malayan water monitor lizard (NParks, pers. comm.), the dog-faced water snake (*Cerberus schneiderii*) is also another commonly observed species in mangroves, including MMM (Wild Singapore, 2016). Other locally threatened homalopsid snake species that can be found in the Sungei Buloh area include the locally endangered yellow-lipped water snake (*Gerarda prevostiana*), crab-eating water snake (*Fordonia leucobalia*), and the Cantor's water snake (*Cantoria violacea*) (Baker & Lim, 2008).

Fish

While fish surveys were not part of the 2019 baseline survey, a total of six species of fish have been historically recorded in Mandai Mangrove and Mudflat. There was a striking absence of mudskippers in both the mudflat and the mangroves, except for a single observation[8] of a giant mudskipper (*Periophthalmodon schlosseri*) at one of the fringing mangrove monitoring plots (plot A1).

Despite lack of specific data on fish in MMM, the fish fauna is presumed to be similar to Sungei Buloh Wetland Reserve, where over 26 fish species are commonly found, including several reportedly abundant fish: square-tailed mullet, halfbeak, gudgeons, green chromite, and archer fish (Wild Singapore, 2014).

Terrestrial Invertebrates

Opportunistic observation of 23 species of insects and spiders were documented during the 2019 baseline survey. Along with historical data, this brought the number of known species from Mandai Mangrove and Mudflat to 25. Most species encountered were common and widespread in Singapore. The mangrove marshal dragonfly (*Pornothemis starrei*), encountered during historical surveys (NParks, 2007), is listed as near-threatened both locally and globally.

The lesser banded hornet (*Vespa affinis*), and the uncommon back mangrove specialist, mangrove marshal (*Pornothemis starrei*), have both been spotted at the Mandai mangroves (Ria Tan, pers. comm., May 2019; Ngiam, 2013).

Tortricid moth (*Lasiognatha leveri*) assaults on Singapore's mangroves, particularly at Mandai, resulted in a significant loss of mangrove saplings, according to Murphy (1985). Due to the compounding effects of current stressors like erosion and pollution, MMM may be particularly susceptible to insect damage. Their isolation and limited size, means that Mandai mangroves are unlikely to get pollen from insect foragers in other mangrove patches, which will have an impact on their genetic diversity and overall resilience (Friess et al., 2012).

Horseshoe Crabs

Both species of horseshoe crabs from Singapore are known to be found at this site. The coastal horseshoe crab (*Tachypleus gigas*) is listed by NParks (2023) as locally endangered and the mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) as locally vulnerable (Figure 4-9).

[8] Ad-hoc observation of giant mudskipper was made during mangrove health assessment survey.

Figure 4-9. Mangrove horseshoe crab found at the site (source: TAC, 2022)

According to Cartwright-Taylor et al. (2011), the Mandai Mangrove and Mudflat hosts the last substantial breeding population of the vulnerable mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) in Singapore.

Molluscs

A total of 49 species of molluscs have been recorded from the project area, 15 of which were recorded during the 2019 baseline field survey. Both locally and globally, most of the mollusc species recorded are data deficient, not assessed or have no status. This diversity of molluscs during the present survey was comparable, although somewhat lower to the 31 species of molluscs reported by NParks (2007). Two live specimens of *Ellobium scheepmakeri* were recorded during the 2019 surveys. This species was thought to be extinct in Singapore and is currently only known from a single population at Mandai (NParks, 2007). Both *Polymesoda expansa* and *Geloina erosa* were particularly abundant in the mangroves with clam densities locally reaching as high as 98 individuals per square metre in mangrove plot B1.

Crustaceans

A total of 12 species of crustaceans were encountered in the mangroves and mudflats of the project area during the 2019 surveys. Together with historical data, the total number of crustacean species recorded from Mandai Mangrove and Mudflat was 19.

Out of the 19 species of crustaceans recorded in the project area, four were locally threatened, with one endangered, and three vulnerable species as listed by NParks (2023). None of the species recorded were assessed under the IUCN red list. The locally endangered mud lobster (*Thalassina* spp.) was also recorded on this site.

Other crustaceans found on the site include fiddler crabs *Uca* spp., caridean shrimp *Potamalpheops johnsoni*, and at least five marine isopod species (Leong et al., 2018; Anker, 2003; Bruce & Wong, 2015).

Previous surveys observed the presence of mud lobsters (*Thalassina* sp.) within the project area. Mud lobsters typically inhabit the back mangrove zone (Davison et al., 2008). Mud lobster mound systems are a common feature in mangrove forests, where they are often found around the high-tide mark (Marshall et al, 1960). They are a keystone species as their activities in digging and burrowing bring fresh mud to the surface which assists in the redistribution of nutrients, organic matter, and trace elements (Aller et al, 1983; De Vaugelas & Buscail, 1990). Mud lobster mounds alter the topography of mangrove soils (Macnae, 1969) which provide habitats for other species. This influences species composition and ecological processes, such as succession and the community structure of mangrove ecosystems (Havanond et al, 1999). According to Ngoc-Ho and de Saint Laurent (Ngoc-Ho & de Saint Laurent, 2009), there are five species of mud lobsters in Singapore. *T. anomala* and *T. gracilis*, which are listed as locally Endangered according to the Singapore Red Data Book (NParks, 2023).

Benthic Macroinvertebrates

The *Eunice grubei*, a common native reef worm species, and at least six benthic nereidid polychaete worms are among the marine worms (*Polychaeta*) that can be found in MMM (Wild Singapore, 2007; Chan, 2009). At least 18 different polychaete groups have been identified on one estuarine mudflat in Singapore's intertidal mudflats, which is located near Mandai in the Johor Strait (Lee & Glasby, 2013)

4.4 Historical Land Use

In 1943, Mandai mangroves together with other mangrove forest represented the significant proportion of the Kranji area, forming rather continuous large patch of mudflat and mangrove forest (Figure 4-10.). Fish and shrimp farming were the main triggers of deforestation and land use change in Kranji area. Major reclamation work took place at Kranji between 1965-1970, and lead to formation of the Kranji Industrial Estate (Teo, 1993).

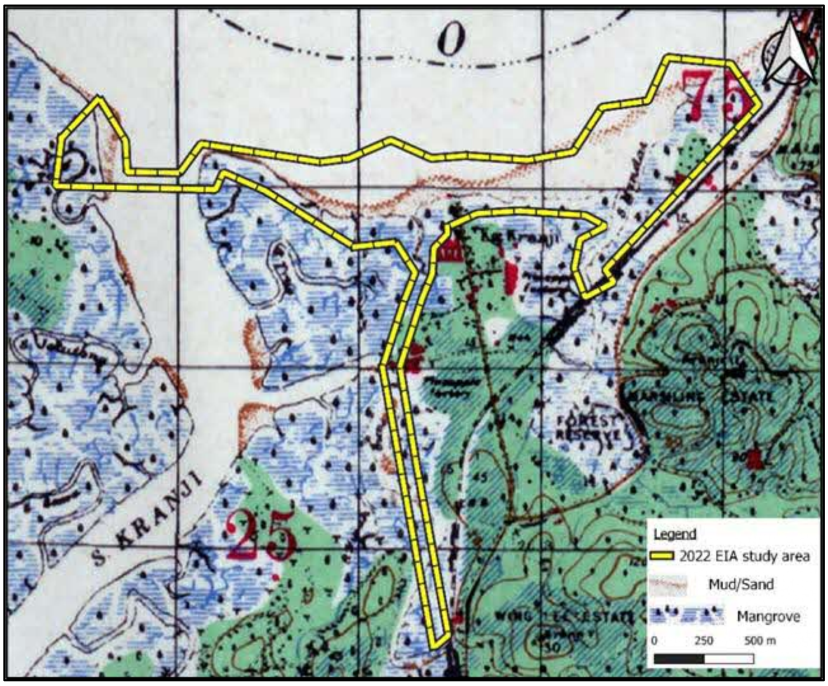


Figure 4-10. Historical map from 1943 of Mandai Mudflat and Mangrove, with the current (2022) EIA project boundary highlighted in yellow [9]

The map from 1966 (Figure 4-11) shows that two pineapple factories were possibly present at the start of the future industrial era in the project area.

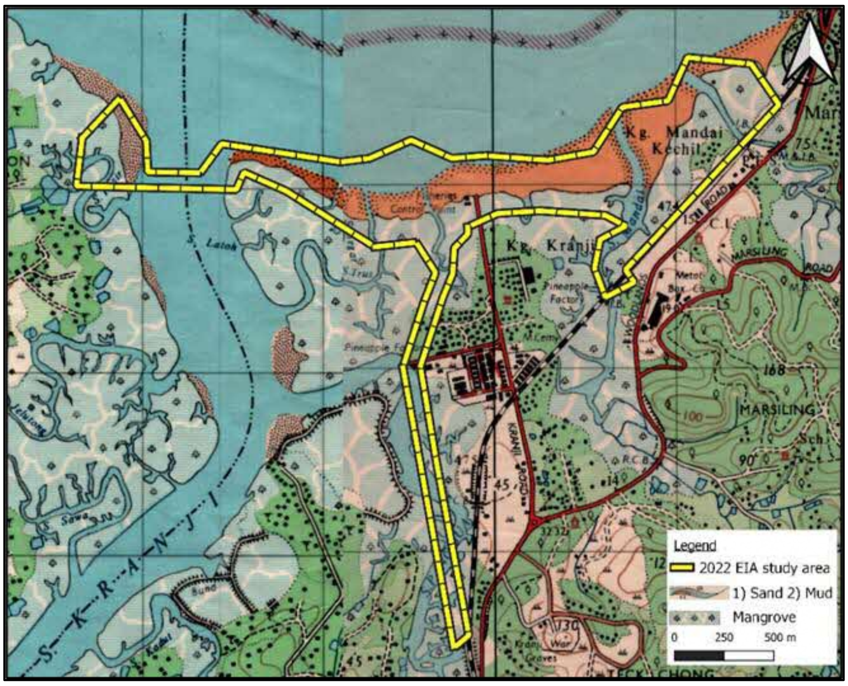


Figure 4-11. Historical map from 1966 of Mandai Mudflat and Mangrove, with the current (2022) EIA project boundary highlighted in yellow [9]

The increase in industrial developments required the progressive reclamation of mangroves. Kranji and Sungei Kadut Industrial Estates became Singapore's manufacturing centre for processing of wood such as saw milling and raw rattan/cane

[9] https://libmaps.nus.edu.sg/

treatment to produce various wood products e.g. wood, rattan and cane furniture (Jansen, 1979). The area held the largest number of such establishments in Singapore at this time. To provide water supply to the newly developed Kranji and Sungei Kadut Industrial estates, a dam was built across the mouth of Sungei Kranji to convert the river into a reservoir (Parliament Singapore, 1978). The map from 1983 shows the establishment of the new Kranji Dam and Kranji Reservoir (Figure 4-12).

Figure 4-12. Historical map from 1983 of Mandai Mudflat and Mangrove, with the current (2022) EIA project boundary highlighted in yellow [9]

Some kampongs were established in the Mandai area e.g., Kampong Mandai Kechil, Kampong Kranji and Kampong Fatimah. The kampongs were still inhabited prior to their abandonment and decommissioning in the late 1970s and 1989 respectively (Thiagarajah et al., 2015).

Pressures from deforestation for shrimp pond development and reclamation for industry and freshwater reservoirs have reduced Mandai mangroves to a patch of 31.2ha today (NParks, 2018). The map from 1983 also shows that a Fisheries Control Point was established at the northern fringe of the case study area. In 1985 PUB opened designated part of the Kranji Reservoir Park to the public for sport fishing (PUB, 1985). The map from 2005 shows the development of the Woodlands New Town (eastwards from the case study area) and further growth of the Kranji industrial estate (Figure 4-13.). In 2018, Mandai Mangrove and Mudflat was designated to be conserved as a Nature Park.

Figure 4-13. Historical map from 2005 of Mandai Mudflat and Mangrove, with the current (2022) EIA project boundary highlighted in yellow [9]

5 BIODIVERSITY

5.1 Introduction

The MMM is one of the few mangrove areas in Singapore with an extensive mudflat which provides refuge for a wide variety of flora and fauna with unique adaptations. The various habitats found within the site host a range of species of conservation significance. Additionally, the mangrove and mudflats areas in the vicinity serve as an important site for migratory birds that lies within the East Asian-Australasian Flyway (EAAFP, 2023). The combined characteristics of MMM – its connectivity to other local and regional sites, its role as a habitat for rare and threatened fauna, and the unique physical forms and functions of its species – provides an opportunity to develop a nature park that focuses on biodiversity.

5.2 Conventions

The local conservation status of faunal species was mainly based on Singapore Red Data Book (NParks, 2023). For flora, a combination of the Flora of Singapore - Checklist and bibliography (Lindsay et al., 2022) and The Checklist of the Total Vascular Plant Flora of Singapore (Chong et al., 2009) were the main references. For butterflies, Singapore does not have conservation statuses, but conservation status is listed according to the species' rarity based on A Field Guide to the Butterflies of Singapore (Khew, 2015). Global conservation statuses were derived from the IUCN Red List of Threatened Species (IUCN, 2021).

Table 5.1 provides a consolidated list of statuses from the various sources. In this report, exotic plant species with no local status were categorised as Not Evaluated. Table 5.2 provides the conservation status definitions for flora species by Lindsay et al. (2022). In this report, flora species with local status of EX, CR, EN, VU, and DD are considered of conservation significance.

Table 5.1. Conservation status for flora & fauna species & respective definitions, adapted from IUCN Red List **(2021)**, Singapore Red Data Book **(2023)**.

Conservation Status	Definition
Global	
Extinct (EX)	There is no reasonable doubt that the last individual has died. Exhaustive surveys in known and/or expected habitat, at appropriate times, throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in the Wild (EW)	Known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. Exhaustive surveys in known and/or expected habitat, at appropriate times, throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered (CR)	Considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	Considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	Considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	Does not qualify as Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Least Concern (LC)	Does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.
Data Deficient (DD)	Inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat.
Not Evaluated (NE)	Not yet been evaluated against the criteria.
Local	
Presumed Nationally Extinct (NE)	This species is extinct in Singapore but still survives outside Singapore. It has not been recorded with the last 30 years (plants) and 50 years (animals).
Critically Endangered (CR)	There are fewer than 50 mature individuals, or if more than 50 mature individuals but less than 250, with some evidence of decline or fragmentation.
Endangered (EN)	There are fewer than 250 mature individuals, and no other evidence of decline or fragmentation.
Vulnerable (VU)	There are fewer than 1000 mature individuals, but more than 250 and there may or may not be any other evidence of decline, small range size, or fragmentation.

Table 5.2. National conservation status definitions for flora species in Singapore adapted from Lindsay, et al. **(2022)**

National Status		**Definition**
Native		Originated or arrived in Singapore without intentional or unintentional involvement of human activities.
	Extinct (EX)	Globally extinct.
	Presumed Nationally Extinct (NEx)	Not recorded in Singapore within the last 30 years. Endemic species that are presumed nationally extinct will consequently also be presumed to be globally extinct.
	Critically Endangered (CR)	Fewer than 50 mature individuals estimated to be in Singapore; or if more than 50 but fewer than 250 mature individuals, with evidence of rapid decline or decline and fragmentation of populations.
	Endangered (EN)	Between 50 and 250 mature individuals estimated to be in Singapore, with no evidence of decline or fragmentation of populations.
	Vulnerable (VU)	Between 250 to 1000 mature individuals estimated in Singapore.
	Least Concern (LC)	More than 1000 mature individuals estimated in Singapore.
	Data Deficient (DD)	Not enough information available to assess the risk of extinction.
Cryptogenic		Uncertain whether presence in Singapore is from natural dispersal or as a result of human activities.
Non-native (=Exotic)		Presence in Singapore is because of intentional or unintentional involvement of human activities.
	Naturalised	Species that have established self-sustaining wild (i.e., non-cultivated) populations such that long-term persistence in Singapore is likely without additional introduction of new individuals or propagules.
	Casual	Species that occur in the wild in Singapore as escapes or relics of cultivation but do not form self-sustaining populations, such that their presence is ephemeral once the original individuals die or are removed without additional introduction of new individuals or propagules. This includes taxa that were formerly considered to be naturalised but have since died out. Those for which we have no record of occurrence in the wild for more than 30 years are still treated as casual but are further highlighted.
	Cultivated Only	Only found in cultivation.
	Not Evaluated (NE)	Not yet assessed for risk of extinction. This includes some species for which there are grounds for rejecting or questioning a previous assessment but for which a new assessment is pending.

5.3 Baseline Survey Methodology

5.3.1 Terrestrial & Mangrove Flora

The baseline survey for all flora habitats was conducted within the EIA case study area (Figure 5-1). Visual Tree Assessment survey methodology and findings are summarized in a separate Visual Tree Assessment Report.

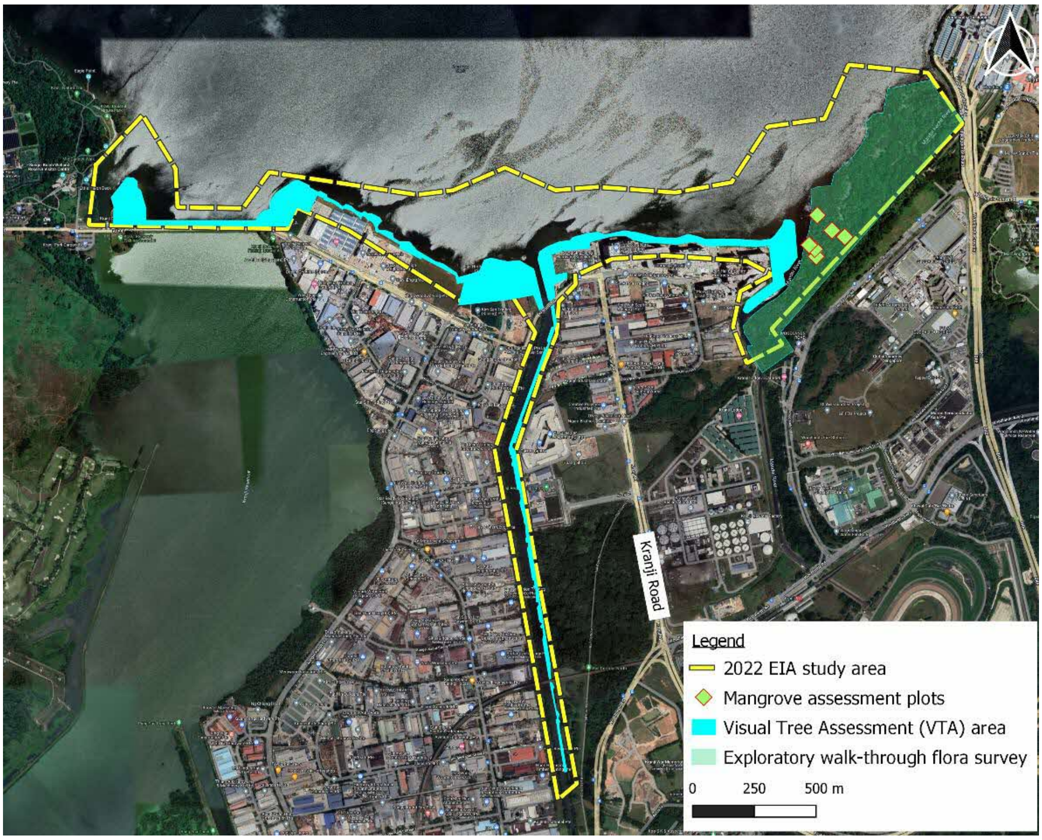


Figure 5-1 Areas for flora baseline surveys

Mangrove Health Survey Methodology

A dedicated field assessment was made of the health of the mangroves, within six 10x10m plots in representative sections of the mangroves covering the main assemblages (Figure 5-2). These plots were permanently marked with four corner posts (and GPS coordinates were carefully recorded) so they can be used for ongoing future monitoring. The assessment included canopy cover (using a densiometer), tree density (by species), stem diameter (to assess biomass), evidence of flowering/fruiting, leaf health and insect damage, leaf litter and propagules (on the forest floor), substrate type and evidence of erosion/accretion), density of seedlings, quantification of pollution (e.g., litter/plastic) and physical damage. Smaller sub-plots within random quadrats were assessed for pneumatophore density (for mangroves such as *Avicennia*, where appropriate) and density of crab holes, snails, and clams (as a measure of benthic activity and soil aeration), using smaller 50 x 50cm frames. Where seagrasses are present, average seagrass percentage cover, leaf morphology and number of leaf blades per cluster were estimated visually within a 50 x 50 cm frame placed randomly within the mangrove health assessment plots (n=6). Seagrass shoot density counts and biomass samples were taken within 25 x 25 cm frames. In the evaluation part, comparisons were made with earlier data (e.g., mangrove stem measurements by TAC in 2019, NUS, and a 2006 survey at Mandai by NParks).

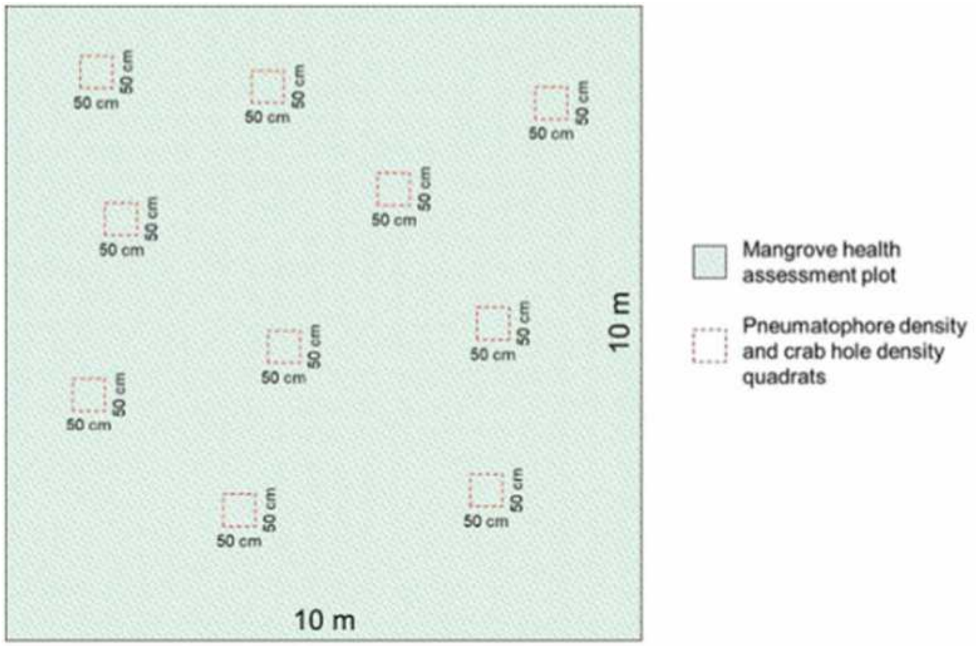


Figure 5-2. Illustration of the mangrove health assessment methodology

5.3.2 Terrestrial & Mangrove Fauna

The fauna field assessment covered various fauna groups: birds, herpetofauna (reptiles and amphibians), mammals, odonates (dragonflies and damselflies), and butterflies. For the natural, free-flowing streams within the site, aquatic surveys covering fish, molluscs, and decapod crustaceans were also conducted. Table 5.3 summarizes the survey methods and appropriate survey timings for each taxonomic group. Fauna species encountered outside their dedicated survey timings are also recorded.

Table 5.3. Survey timings, frequency, and methodology for each fauna group.

Taxonomic Group	Survey Timings	No. of surveys	Survey Methodology
Birds	0700 – 1100	2	Point Counts, Visual encounter survey; call recognition along transects
Mammals (non-volant)	0700 - 1100 2000 - 0000	2 diurnal, 2 nocturnal	Visual encounter survey; call recognition along transects
	24 hrs	2 months	Camera traps attached on tree trunks 30 cm above ground level
Mammals (bats)	1900 – 0700	2	Acoustic recording
Herpetofauna	0700 – 1100 2000 – 0000	2 diurnal, 2 nocturnal	Visual encounter survey; call recognition along transects

Taxonomic Group	Survey Timings	No. of surveys	Survey Methodology
Butterflies	0900 – 1200	2	Visual encounter survey along transects
Odonates	0900 – 1200	2	Visual encounter survey along transects
Aquatic Fauna (fish, molluscs, decapod crustaceans)	Diurnal (0900 – 1500) Nocturnal (2000 – 0000)	1 diurnal, 1 nocturnal, 1 overnight trapping	Sweep sampling with dip/hand nets for diurnal. Visual detection for nocturnal. Baited traps for both, overnight

The terrestrial and aquatic baseline fauna surveys were conducted mainly through visual encounter surveys, camera trapping, and aquatic fauna surveys (visual and trapping), covering habitats of mangroves, coastal forests, secondary forests, and estuarine rivers. Animal sightings were recorded with at least two surveyors walking along each systematic transect for every survey.

Taxonomic groups of focus in the terrestrial baseline surveys included birds, mammals, reptiles, amphibians, butterflies, and odonates. Within three waterways of Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil aquatic surveys covered fish, molluscs, and decapod crustaceans (Figure 5-7).

Any threatened fauna (with reference to the Singapore Red Data Book or other reliable sources) and large animals were identified, with their location and distribution in the project area presented on a map. A species checklist of taxonomic groups of interest, as well as their conservation status in Singapore were compiled.

Visual Encounter Surveys

An updated baseline survey of fauna found in the project area was conducted along systematic transects spread out within the project area (Figure 5-3). A total of one day and one night survey was conducted for Transect 1, and a total of two day and two night surveys were conducted per transect for Transects 2-9. Visual observations were conducted by at least two observers along each transect. These surveys focused on birds, reptiles, amphibians, odonates, and butterflies.

Point count surveys were also conducted for birds (within a 100 m radius buffer around each point). These involved observers staying at a fixed location and recording the number of birds identified by sight and sound over a specific duration. Point count surveys were conducted for 5 minutes per point in non-forested areas and 10 minutes per point in forested areas. In forested areas, an additional 5 minutes was given to allow birds to settle after any initial disturbance from the surveyors before commencing the survey. Only daytime bird surveys were conducted (see Table 5.3 for the survey timings and frequency).

For mammals, herpetofauna, odonates, and butterflies, visual encounter surveys were conducted along the same transects, with observers walking at a slow, steady pace, to record all animals seen and heard along each transect. GPS locations for each species observed as well as the number of individuals detected were also recorded. Both day and night surveys were done, since a large proportion of the target groups, particularly mammals and herpetofauna (reptiles and amphibians), were predominantly nocturnal. (see Table 5.3 for the survey timings and frequency). Locations of fauna species of conservation interest were delimited on maps.

Figure 5-3. Locations of transects for fauna surveys

Camera Trapping

To supplement the visual encounter surveys, camera trapping was also conducted within the project area (Figure 5-4, Figure 5-5). This method is particularly useful for elusive or rare animals that are not often observed during visual encounter surveys. While a variety of animals were captured in the camera traps, these traps mainly target medium to large ground-dwelling mammals. A total of 10 camera traps were deployed over a period of two months (Table 5.4). These cameras were secured on tree trunks at about 30 cm above ground level. The camera traps were programmed to be active 24 hours a day, with the camera capturing three photos and a 10 second video each time it is triggered.

Figure 5-4. Example of a camera trap setup

Figure 5-5. Locations of camera traps

Table 5.4. Coordinates of the camera traps within project area

ID	Latitude (°N)	Longitude (°E)
CAM1	1.438649	103.764377
CAM2	1.436993	103.761039
CAM3	1.438059	103.759847
CAM4	1.437398	103.752888
CAM5	1.437691	103.748148
CAM6	1.439193	103.742861
CAM7	1.439130	103.738200

ID	Latitude (°N)	Longitude (°E)
CAM8	1.434098	103.752805
CAM9	1.429615	103.751946
CAM10	1.422410	103.753054

Acoustic Bat Surveys

Bats belong either to the suborder Megachiroptera (megabats or fruit bats) or Microchiroptera (microbats). Echolocation is only used by microchiropterans who use it to navigate through their environment and locate food (Schnitzler et al., 2003). The echolocation call characteristics of bats (pulses, frequencies, duration, and shape) are fairly unique to each species and can be used to identify bats to species (Fenton & Bell, 1981). Call structure varies depending on habitat type (cluttered vs. uncluttered) and foraging mode (gleaning, trawling, aerial) (Schnitzler et al., 2003). Thus, it is important to note that best practices for using bat calls to identify bats to species level in a certain locality requires capturing several individuals of each species, correctly identifying them, then flying them in a tent and releasing them in different habitat types, and recording their calls under each scenario (Fenton & Bell, 1981; Kingston et al., 2003). With BIA surveys, this is not practical. Given survey locations and trap effort, trapping typically results in capturing species that are more common, fly low, and whose calls are well-known. Bat calls can further be identified by classifying them into one of six call types based on frequency (frequency-modulated [FM], constant frequency [CF], and quasi-constant frequency [QCF], and to a lesser degree, habitat use:

- FM-CF-FM calls used by forest specialists of the family Rhinolophidae.
- CF-FM calls used by forest specialists of the family Hipposideridae.
- QCF Multiharmonic (QCF-MH) calls used by open space foragers of the family Emballonuridae.
- FM Multiharmonic (FM-MH) calls used by forest specialists of the families Megadermatidae and Nycteridae.
- FM Broadband (FM-B) calls used by edge/gap foragers of the family Vespertilionidae.
- FM-QCF calls used by edge/gap foragers of the families Vespertilionidae.

Due to lack of trapping and research, Singapore’s bat assemblage remains ambiguous. According to the most updated mammal species list for Singapore, there are currently 31 species of bats recognised in Singapore, with five being fruit bats and 26 being microbats (NParks, 2023). Additional references for Singapore’s bat species include (Pottie et al., 2005, 2005; Lane, Kingston, & Lee, 2006; Baker & Lim, 2012). The only published resource reporting bat calls from Singapore is Pottie et al. (2005), who used the methods outlined above. Pottie et al. (2005) only reports calls for 13 of Singapore’s 26 microbats. Therefore, bat calls from Singapore must be identified using a call library generated from using Pottie et al. (2005) and published calls from neighbouring countries (e.g., (Heller, 1989; Kingston et al., 2009; Hughes et al.; McArthur & Khan, 2021), and the ChiroVox online bat call database (Görföl et al., 2022).

Acoustic sampling was performed using a handheld Echo Meter Touch 2 Pro (Wildlife Acoustics, Inc.) attached to an iPad (Apple, Inc.) during nocturnal terrestrial transects and mangrove transects. The Echo Meter functions by detecting ultrasonic sounds in real-time and converting them into audible digital signals that can be heard and visualized using the Echo Meter Touch App on the iPad. Each time sounds resembling a bat call was detected, it was automatically recorded and saved onto the iPad as a 16-bit WAV file.

Bat call structure was then analysed using Kaleidoscope v.5.1.9 (Wildlife Acoustics, Inc.). Key call structure parameters include call shape, frequency (kHz) and duration (ms). Each echolocation recording was identified to species level based on call shape, frequency (minimum, maximum, and peak) and call duration (Pottie et al., 2005, 2005). Once these parameters were inspected, the results were compared to those in Pottie et al. (2005) which provided bat echolocation signatures for several species in Singapore (Table 5.14). Conservation significance was taken from the forthcoming third edition of The Singapore Red Data Book (NParks, 2023).

The echolocation calls of bats can be used to identify bats to species as they are unique to each species (Fenton & Bell, 1981). However, call structure varies depending on habitat type and foraging mode (Schnitzler et al., 2003). Microchiropteran bats use echolocation to navigate through their environment and locate food (Schnitzler et al., 2003), whereas megachiropteran bats rely on their vision and do not echolocate. Thus, visual encounter surveys were used to detect megachiropteran bats.

Aquatic Surveys

Surveys were conducted along brackish waterways within the project area (Figure 5-6). One nocturnal survey and one diurnal survey were conducted at all nine points, focusing on fishes, decapod crustaceans, and molluscs such as gastropods and bivalves. 10-minute point count surveys were conducted at points along any streams or ponds. Surveys relied on visual detection as well as hand-netting. In addition, baited cage traps were deployed for fishes and decapod crustaceans.

Baited traps were left on-site for at least 12 hours before retrieval. A portion of the traps remained above the water surface to reduce the risk of drowning of air-breathing species. All aquatic fauna caught by hand-netting or baited traps were sorted, photographed, and identified to species or family level where possible, before being released. The survey locations are indicated in Figure 5-7.

Figure 5-6. Aquatic survey at Sungei Mandai Besar

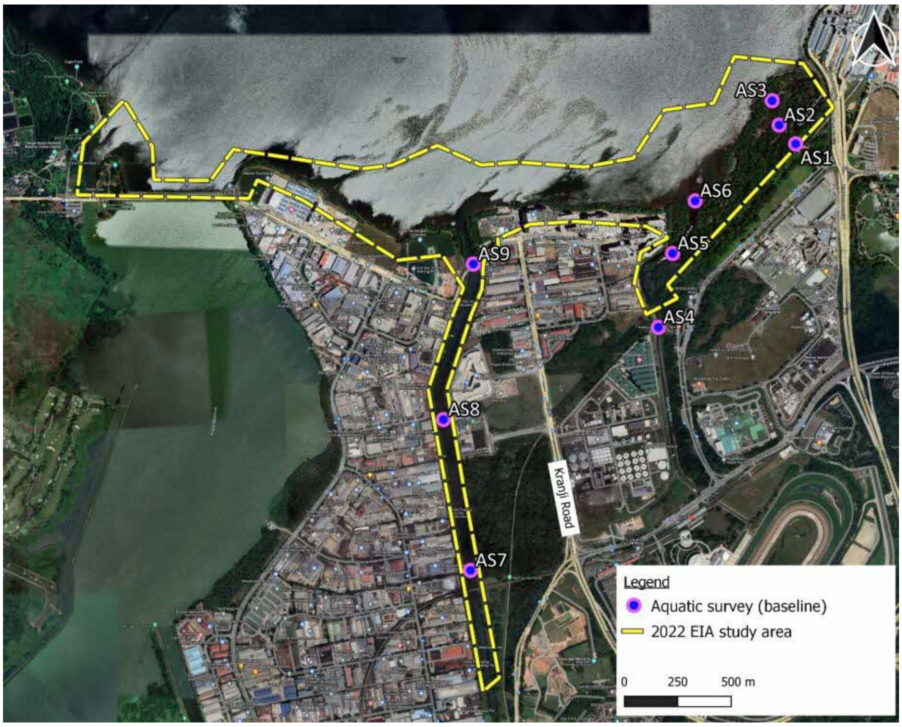


Figure 5-7. Locations of aquatic surveys within project area

5.3.3 Marine Flora

Marine flora (e.g., seagrass, macroalgae) was surveyed along five transects, each 100m long, shown in Figure 5-8. Each round of surveys involved intertidal surveys, carried out once, coinciding with suitable low spring tides.

Transect lines TR1 and TR2 were following the same transect coordinates as two transects in 2019 benthic fauna baseline survey (Figure 5-8). Transect lines TR3 and TR5 followed the coordinates of former NParks survey transects. On a line transect of length L=100m, 11 sampling points were spread in 10-metre intervals along the transect tape (starting from 0m, ending at 100m). At each sampling point, three randomly distributed replicates of 0.25m^2 quadrats were placed, totalling to 33 sampling quadrats per 100m transect. The following data parameters were collected within each quadrat:

- Benthic percentage cover of seagrass, macroalgae
- Biodiversity of major intertidal flora, identified to the lowest taxonomic level possible.

Other species encountered outside of the quadrats were also documented. Coordinates of species of conservation significance were recorded using a hand-held GPS device.

Figure 5-8. Locations of intertidal flora and fauna transects

5.3.4 Marine Fauna

Marine fauna (e.g., shorebirds, benthic invertebrates, molluscs, crustaceans) were surveyed both qualitatively and quantitatively along transects in intertidal, and coastal zones. All individuals were identified to species level where possible.

Invertebrate benthic fauna

Figure 5-11 summarizes the actual locations for intertidal fauna surveys. Transect lines TR1 and TR2 replicate the position of the transects from the 2019 benthic fauna baseline survey. Transect lines TR3 and TR5 were placed at the same positions as two former NParks survey transects.

The intertidal mudflats were sampled for benthic invertebrate fauna using a PVC corer

(9 cm diameter, ~50 cm long) and a sieve (1 mm mesh size). A total of five (5) transects up to 100m across the tidal flats—from mangrove fringe to water edge—were sampled at regular intervals (total of three samples per transect), with each sample consisting of 10 successive cores (taken together and considered as one sample) to a standard depth of approximately 30 cm.

Benthic fauna was sieved over a 1 mm sieve in the field, stored and labelled in zip lock bags, and transported in a cooler box for later sorting, identification, and dry weight determination in the laboratory (Figure 5-9 and Figure 5-10). Biodiversity of major intertidal fauna was identified to the taxonomic level of Family and lower if possible.

Other species encountered outside of the quadrats were also documented. Coordinates of species of conservation significance were recorded using a hand-held GPS device.

Figure 5-9. Coring and sieving of the benthic invertebrates

Figure 5-10. Sorting of benthic invertebrates in the laboratory

Figure 5-11. Locations of benthic fauna surveys within project area

Table 5.5. Summary of survey timings, effort, and methodology for marine fauna

Taxonomic Group	Survey Timings	Survey effort	Survey Methodology
Marine Fauna (molluscs, benthic invertebrates, crustaceans)	Depending on low tide occurrence	5 transects, 3 points per transect	Sampling with PVC corer and sieve along tidal flood transects (from mangroves fringe to water edge).
Shorebirds	Daytime low tide periods	1 point per transect	Visual encounter survey

Any threatened fauna (with reference to the Singapore Red Data Book or other reliable sources) were identified, with their location and distribution in the project area. A species checklist of taxonomic groups of interest, as well as their conservation status in Singapore, was compiled.

5.4 Baseline Survey Results

5.4.1 Terrestrial & Mangrove Flora Survey Results

Flora Survey Results: Overview

Comparison with 2019 and historical flora findings

A total of 212 flora entries were recorded from a combination of historical records, and surveys in 2019 and 2022. Of the 212 entries, 196 were identified to species level and 16 to genus level. The latter were given a national status of NA and omitted from the conservation status summary tables and results. However, entries considered to potentially represent species of conservation significance such as sterile Acanthus sp. with climbing habit (i.e., potentially *Acanthus volubilis*), sterile *Lumnitzera sp.* and *Cerbera sp.* were included in conservation significant flora map where coordinates are available.

Among the 196 flora entries identified to species level, 19 species were recorded only in historical records in which 14 are of conservation significance, 12 species were recorded only in 2019 surveys in which one is of conservation significance. 94 species were recorded only in the 2022 surveys, in which 11 are of conservation significance, and 13 species were recorded in all three instances, in which 3 species are of conservation significance. These 13 species include common mangrove species such as api api putih (*Avicennia alba*), api api ludat (*Avicennia officinalis*), pakau putih (*Bruguiera cylindrica*), mangrove associate or coastal species such as casuarina (*Casuarina equisetifolia*) and sea hibiscus (*Hibiscus tiliaceus*), and rarer mangrove species such as sea holly (*Acanthus ebracteatus*), nipah palm (*Nypa fruticans*) and kalak kambing (*Finlaysonia obovata*). The breakdown of the species recorded in historical records, 2019 and 2022 surveys and the list of conservation significant flora species recorded in combined records are provided in the Table 5.6 and Table 5.7. The complete list of flora species recorded in current and past surveys is provided in **Appendix A**. Photographs of selected flora species are provided in **Appendix B**.

Table 5.6. Breakdown of number of flora species recorded in all studies

	Historical records	2019	2022	Historical & 2019	Historical & 2022	2019 & 2022	All three surveys	Total
Number of flora species	19	12	94	2	20	36	13	196
Number of Conservation Significant flora species	14	1	11	2	8	2	3	41

Table 5.7. Conservation Significant species recorded in historical records, 2019 and 2022 surveys

Scientific Name	Common Name	Growth Form	Origin	National Status	Historical records	2019 surveys	2022 surveys
Acanthus ebracteatus	Sea Holly	Shrub	Native	Vulnerable	X	X	X
Acanthus ilicifolius	Jeruju	Shrub	Native	Endangered	X	-	X
Acanthus volubilis	Jeruju	Shrub, Climber	Native	Endangered	X	-	-
Barringtonia asiatica	Sea Putat	Tree	Native	Critically Endangered	-	X	X
Barringtonia racemosa	Common Putat	Tree	Native	Critically Endangered	-	-	X
Brownlowia tersa	Dungun	Shrub	Native	Critically Endangered	X	-	-
Bruguiera parviflora	Lenggadai	Shrub, Tree	Native	Endangered	X	-	-
Calophyllum inophyllum	Penaga laut	Tree	Native	Endangered	-	X	X
Causonis trifolia	Three-Leaved Wild Vine	Climber	Native	Data Deficient	-	-	X
Ceriops tagal	Tengar	Tree	Native	Vulnerable	X	-	-
Ceriops zippeliana	Tengar merah	Tree	Native	Endangered	X	-	X
Cissus repens	Malayan Wild Vine	Climber	Native	Vulnerable	-	-	X
Crinum asiaticum	Seashore Lily	Herb	Native	Critically Endangered	X	-	-
Cynometra ramiflora	Katong Laut	Tree	Native	Critically Endangered	-	-	X
Diospyros ferrea	Sea Ebony	Tree	Native	Presumed Nationally Extinct	X	-	-
Dolichandrone spathacea	Mangrove Trumpet Tree	Tree	Native	Critically Endangered	X	-	X
Elaeodendron viburnifolium	Barat-barat	Shrub, Tree	Native	Critically Endangered	X	-	-
Fimbristylis complanata	-	Herb	Native	Vulnerable	-	-	X
Finlaysonia obovata	Kalak Kambing	Climber	Native	Critically Endangered	X	X	X
Glochidion cf. obscurum	-	Tree	Native	Critically Endangered	-	-	X
Glochidion littorale	Monkey apple	Shrub	Native	Endangered	X	-	-
Halophila beccarii	Beccari's seagrass	Herb	Native	Endangered	X	X	-
Heptapleurum ellipticum	Ara Bebari	Climber	Native	Endangered	-	-	X
Heritiera littoralis	Dungun	Tree	Native	Endangered	X	-	X
Intsia bijuga	Merbau Ipil	Tree	Native	Critically Endangered	X	-	-
Kirganelia reticulata	-	Shrub	Native	Data Deficient	-	-	X
Lomariopsis lineata	-	Fern	Native	Endangered	-	X	-
Lumnitzera littorea	Teruntum merah	Shrub, Tree	Native	Endangered	X	-	X
Lumnitzera	White teruntum	Shrub, Tree	Native	Endangered	X	-	X

Scientific Name	Common Name	Growth Form	Origin	National Status	Historical records	2019 surveys	2022 surveys
racemosa							
Merope angulata	Mangrove Lime	Shrub, Tree	Native	Critically Endangered	X	-	-
Millettia pinnata	Pongam	Tree	Native	Endangered	X	-	X
Nypa fruticans	Nipah Palm	Palm	Native	Vulnerable	X	X	X
Peltophorum pterocarpum	Yellow Flame Tree	Tree	Native	Critically Endangered	-	-	X
Podocarpus polystachyus	Sea teak	Tree	Native	Endangered	X	-	-
Rhizophora stylosa	Bakau pasir	Tree	Native	Vulnerable	X	-	-
Scyphiphora hydrophylacea	Chengam	Shrub	Native	Endangered	X	-	-
Sonneratia caseolaris	Crabapple Mangrove	Tree	Native	Critically Endangered	X	-	X
Sonneratia ovata	Gedabu	Tree	Native	Critically Endangered	X	X	-
Suregada glomerulata	Limau-Limau	Shrub, Tree	Native	Critically Endangered	-	-	X
Syzygium myrtifolium	Red Lip	Shrub, Tree	Native	Critically Endangered	-	-	X
Tristellateia australasiae	Maiden's Jealousy	Climber	Native	Endangered	X	-	-

Overview of flora survey results in current study

The flora species composition of the project area varies widely depending on habitat types. Along mudflat areas at Pang Sua and Point B to Point J (Figure 1.2), dominant species include trees such as sea hibiscus (*Sea hibiscus*), api api putih (*Avicennia alba*), perepat (*Sonneratia alba*), buta-buta (*Excoecaria agallocha*), and climbers including common Derris (*Derris trifoliata*), squirrel's claws (*Caesalpinia crista*) and seashore tubeflower (*Volkameria inermis*). Along grassland/scrubland habitats at terrestrial areas, dominant species include mission grass (*Cenchrus setosus*), touch-me-not (*Mimosa pudica*), water mimosa (*Neptunia plena*) and beggar's tick (*Bidens pilosa*). Along secondary forests from PCG Point G, Point F to Pang Sua, dominant species include albizia (*Falcataria falcata*), African tulip (*Spathodea campanulata*) and lead tree (*Leucaena leucocephala*), while common understorey species include sea apple (*Syzygium grande*) and wild cinnamon (*Cinnamomum iners*). Regenerations of penaga laut (*Calophyllum inophyllum*) had also been observed along Pang Sua near Carros Centre.

Notable findings in this current study include the addition of several conservation significant mangrove and coastal species such as katong tree (*Cynometra ramiflora)*, *Heptapleurum ellipticum*, sea putat (*Barringtonia asiatica*) and common putat (*Barringtonia racemosa*), and new localities of critically endangered mangrove species such as crabapple mangrove (*Sonneratia caseolaris*), kalak kambing (*Finlaysonia obovata*) and mangrove trumpet Tree (*Dolichandrone spathacea*) (Figure 5-12). While the katong tree (*Cynometra ramiflora*) is commonly planted as a roadside tree, it has been recorded from Kranji in three botanical records from 1895 to 1955 **(Singapore Herbarium Online, 2023)**. Similarly, Pongam (*Millettia pinnata*) had been recorded in Woodland/Kranji from 1890 and 2015 **(Singapore Herbarium Online, 2023)**. Therefore, it is possible that the katong tree (*Cynometra ramiflora*) and Pongam (*Millettia pinnata*) individuals found in the project area might be of native origin.

Figure 5-12. Critically Endangered flora species found in project area: (a) *Sonneratia caseolaris,* (b) *Dolichandrone spathacea,* (c) *Finlaysonia obovata,* (d) *Glochidion cf. obscurum*

Table 5.8. Distribution of flora species by numbers and percentages, which includes combined data from current and validated conservation significant flora species from the previous study (TAC, 2020) and historical data.

Origin	Local Status	Number of Species	Percentage of Species
Native		**124**	**63.3%**
	Least Concern	83	42.3%
	Vulnerable	6	3.1%
	Endangered	16	8.2%
	Critically Endangered	16	8.2%
	Presumed Nationally Extinct	1	0.5%
	Data Deficient	2	1%
Non-native		**64**	**32.7%**
	Cultivated only	7	3.6%
	Casual	16	8.2%
	Naturalised	41	20.9%
Uncertain		**8**	**4.1%**
	Cryptogenic	8	4.1%
Total Number of Species		**196**	**100%**

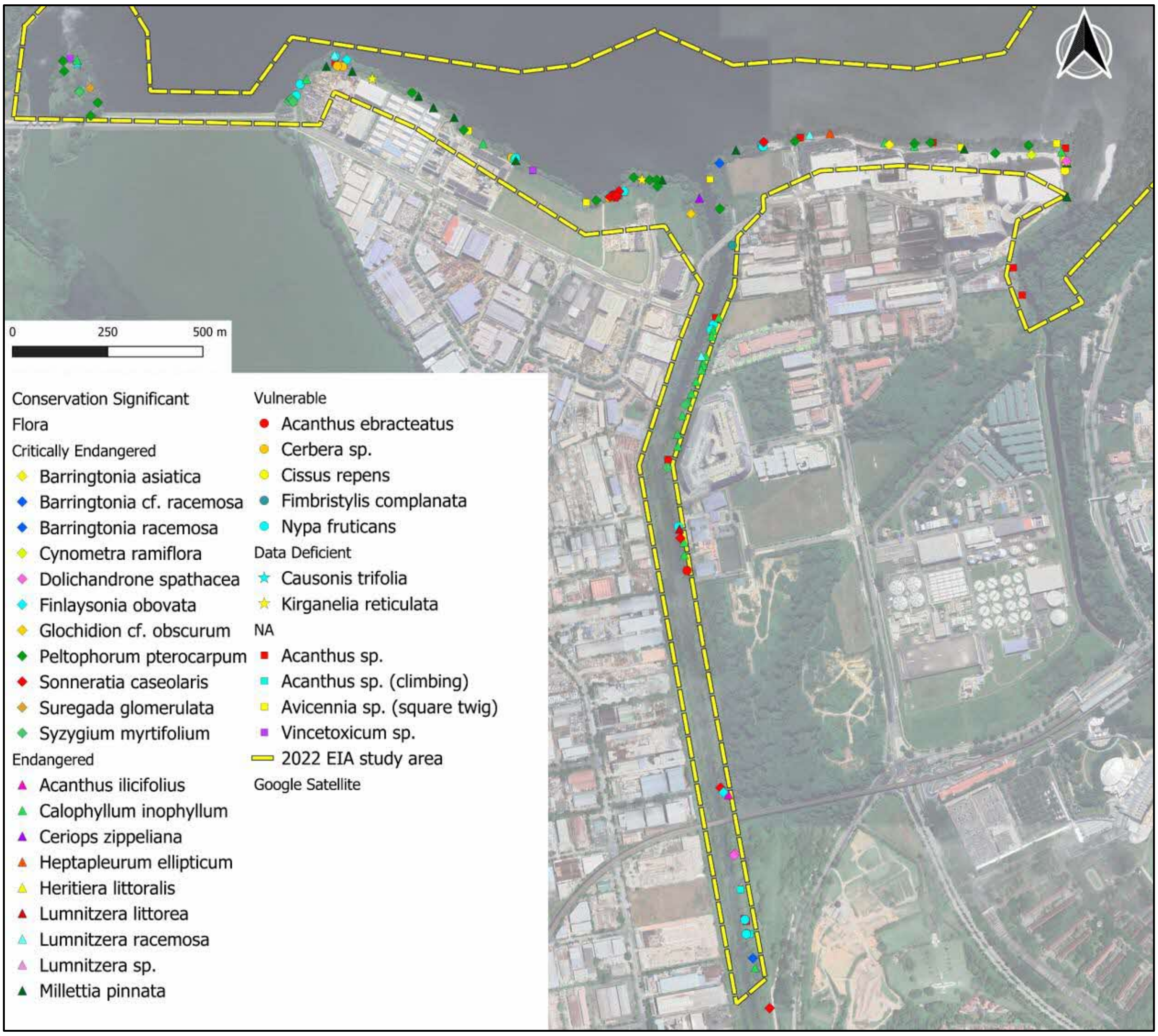


Figure 5-13. Map of all conservation significant flora recorded in current survey

Figure 5-14 Map of critically endangered flora recorded in current survey

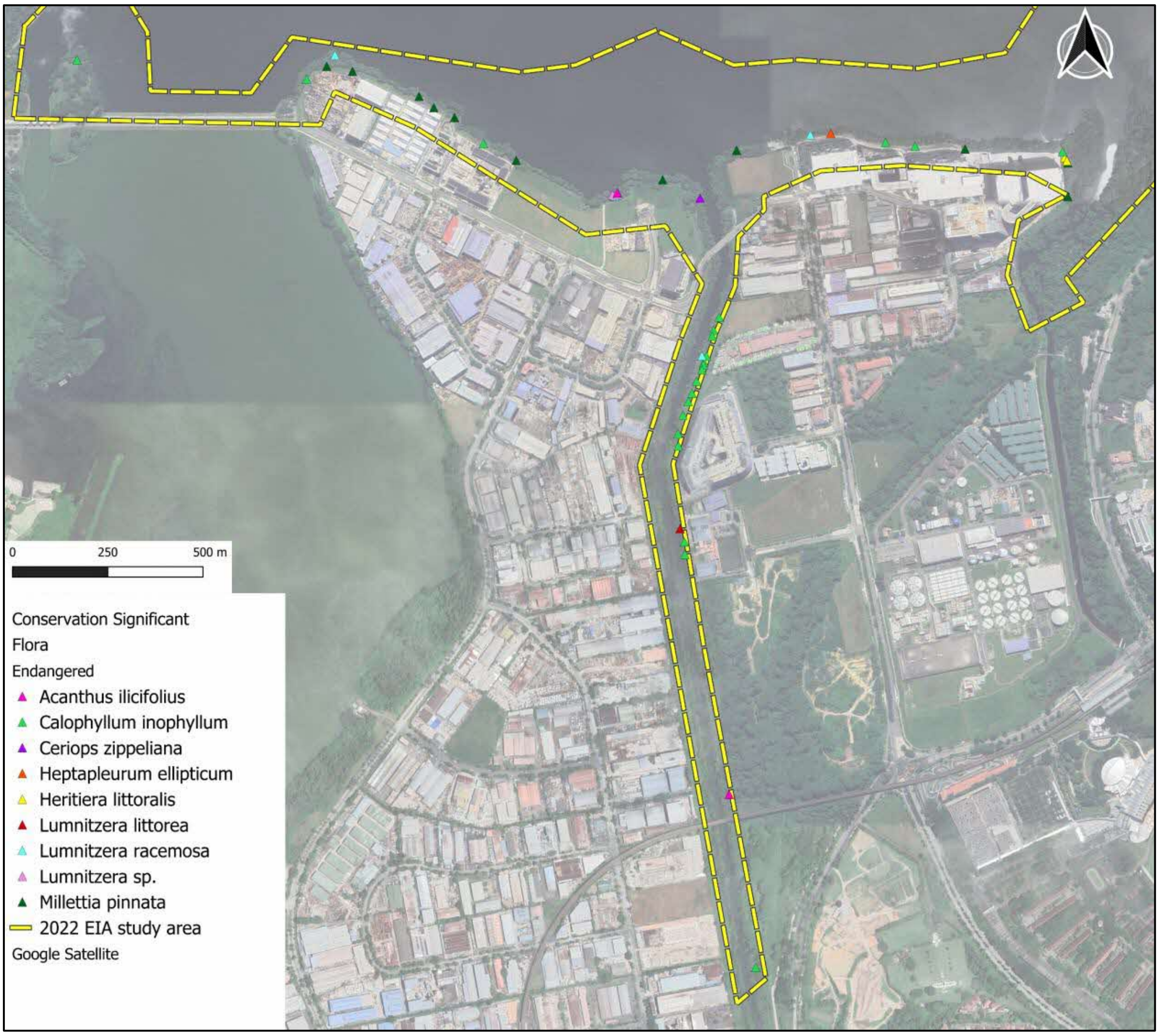


Figure 5-15 Map of endangered flora recorded in current survey

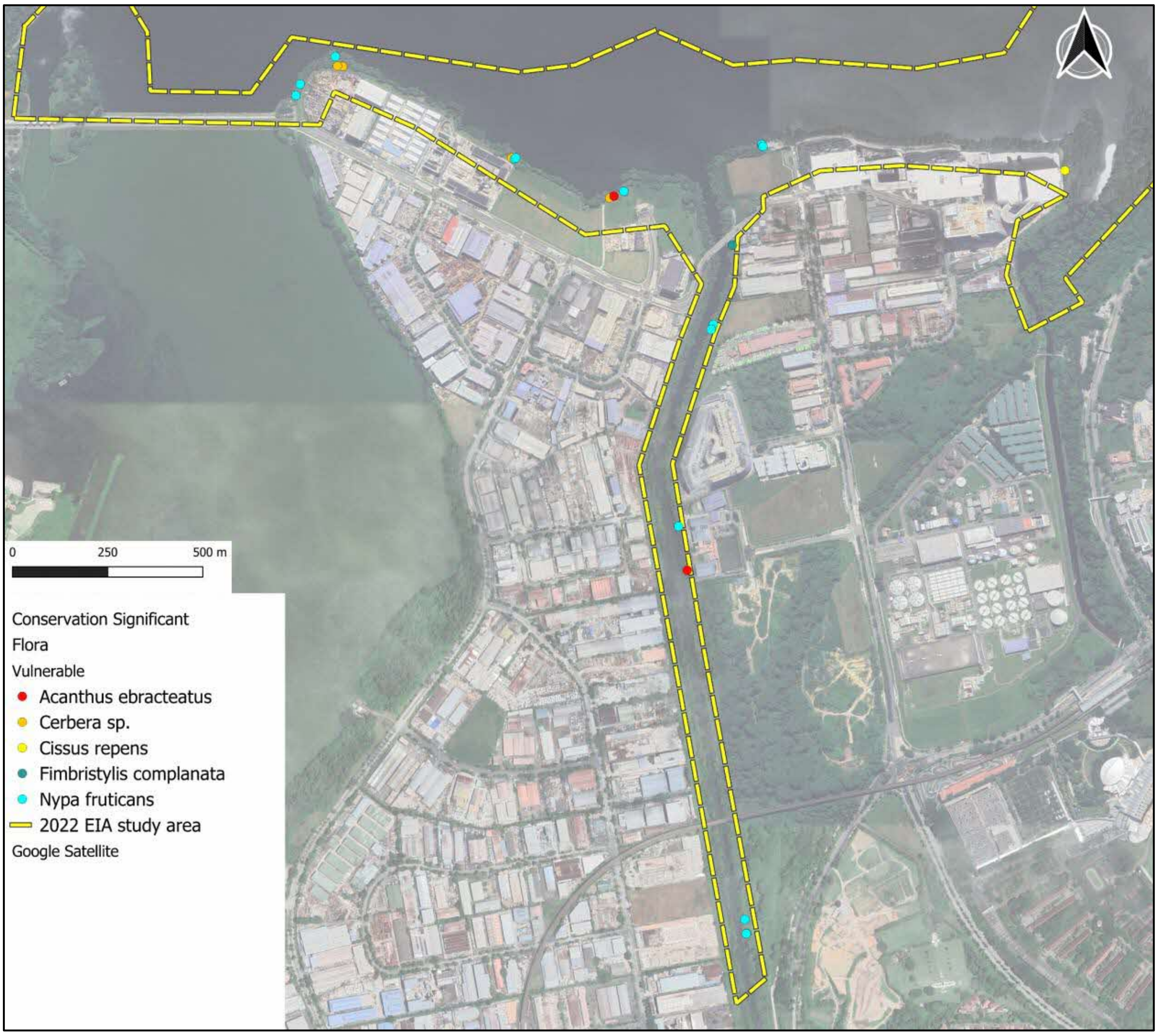


Figure 5-16 Map of vulnerable flora recorded in current survey

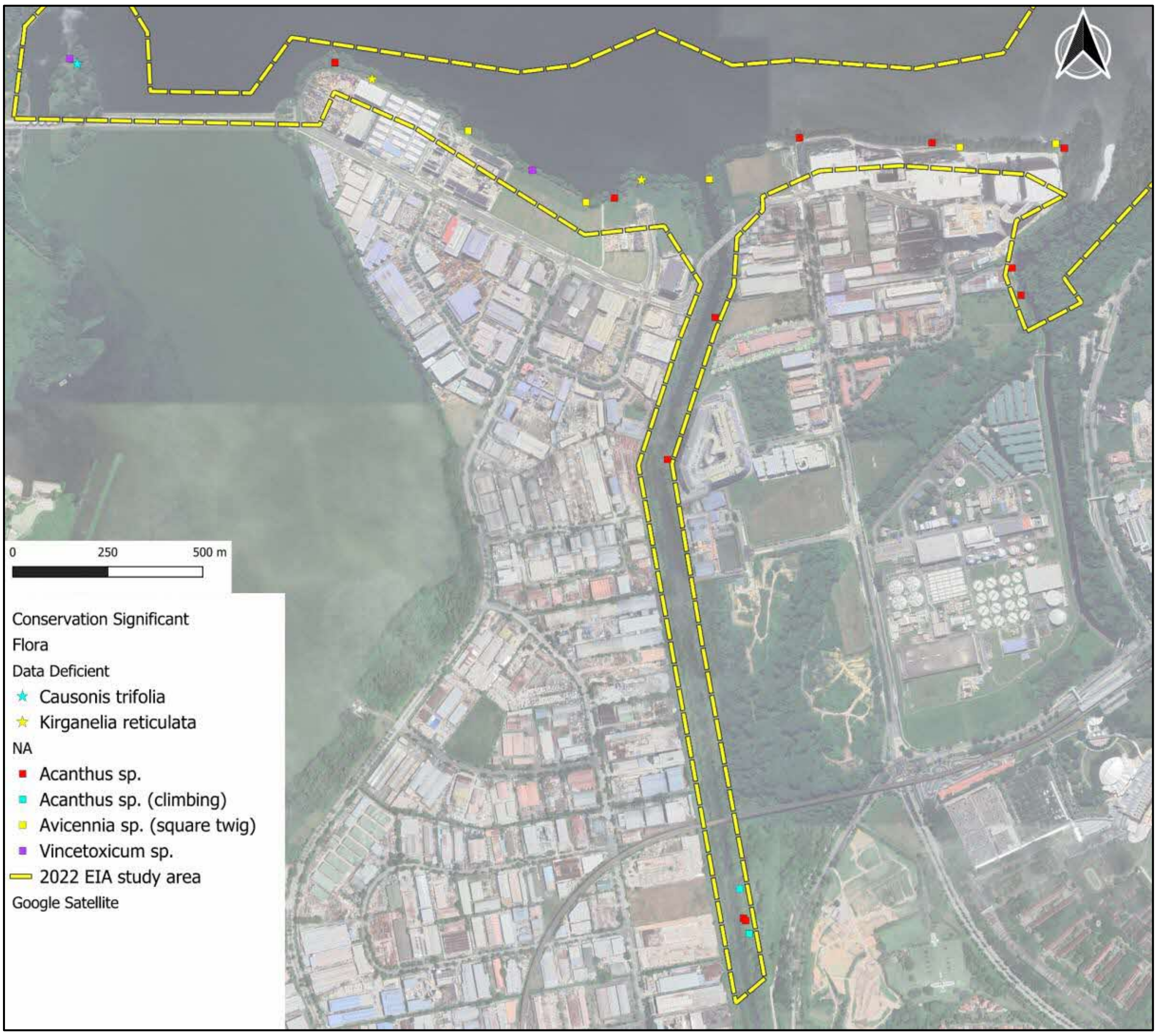


Figure 5-17 Map of data deficient flora and potentially conservation significant flora genera recorded in current survey

Mangrove Health Survey Results

Six mangrove plots located along two transects (transect A1-3 and B1-3) were surveyed in August and September 2022 during periods of low tide. The survey coordinates are presented in Table 5.9 and Table 5.10 below.

The 2022 survey was a replicate of the mangrove health survey conducted in 2019 (refer to Figure 5-1 for locations), located within the same survey plots. Results of the previous study in 2019 (TAC, 2020) and current mangrove health assessment survey in 2022 are presented Table 5.9 and Table 5.10 with values expressed as mean and ± standard error.

The mangrove stands were in both years characterised by healthy stands dominated by *Sonneratia alba* (especially abundant especially in the fringing mangroves), *Avicennia officinalis* (becoming more abundant towards the middle and back mangroves), and *Rhizophora apiculata* (common in the mid-mangroves and back mangroves).

Canopy cover of the forest stands was generally high with a range of 67–96% in 2022. The composition and assemblage of mangroves changed (refer to alterations in dominant species presented in Table 5.9 and Table 5.10), which may be caused by natural mangrove dynamics or possible fluctuations in environmental factors.

Basal area and tree diameter varied between plots and showed no clear zones. Tree stem density varied significantly between plots, ranging from a low density of approximately 0 trees/ha in the mid-mangroves at plot A2 (a few larger, older trees recorded in 2019 were not present at the site anymore) to a higher density of approximately 2,500 trees/ha at plot B3 in the back mangroves (a dense stand of predominantly thin, young trees[10]). There was no evidence of flowering and fruiting during the 2022 surveys.

All sites had some evidence of sexual recruitment, seedlings, and/or saplings, with seedling densities from 500 ha^{-1} (B2) to well over 5,500 ha^{-1}(A2); healthy pneumatophore densities (ranging from 54 to 217 m^{-2}), and an abundant benthic fauna with moderate to high levels of bioturbation (e.g., crab hole densities ranging from 2.40 to 27.52/m^2). Crab hole density was highest in the mid-mangrove and lowest in the back mangrove.

Snail and clam density were consistent in plot A1, A2 and A3 but showed variation across plot B1, B2 and B3. There was a large spike in plot B1 in the fringing mangrove whereas the snail and clam density in plot B3 were comparatively lower. Leaf health, insect damage, and physical damage varied across sites and species but always fell within what would be considered a normal range for healthy mangrove stands (Schmitt & Duke, 2015).

The amount of litter and debris was low in most studied plots, consisting mostly of glass bottles and plastic bags. A lot of litter was however found outside the studied plots, landward, in the back mangrove zone. Further east, near the mouth of Sungei Mandai Kechil, the plastic pollution, styrofoam and glass bottles was particularly abundant. The litter issue may be of concern with regards to the proposed nature park development. Plastic pollution and marine litter accumulation in mangroves are a neglected environmental issue that requires further study to assess the extent and consequences of the problem (Debrot et al., 2013).

A recent study along the Red Sea suggested that marine litter is more abundant where mangrove density is higher (Martin et al., 2019). The aerial root systems of mangroves (especially pneumatophores) act as a sieve retaining large plastic objects, leading to higher quantities of plastic mass in mangroves compared to unvegetated adjacent shorelines (Martin et al., 2019). Given that pneumatophore and tree densities tend to be high in the back mangrove in this study, special consideration should be given to the management of litter and debris in this zone.

[10] Based on the BIA Guidelines (NParks, 2020) trees are defined as >4cm in DBH, saplings are <4cm in DBH and seedlings are <1m in height.

Table 5.9. Results of the 2019 and 2022 mangrove health assessment along Transect A (opposite Gate 3).

	TRANSECT A (opposite Gate 3)					
	2019	**2022**	**2019**	**2022**	**2019**	**2022**
	Plot A1	***Plot A1***	***Plot A2***	***Plot A2***	***Plot A3***	***Plot A3***
Date/Time	3-Jul-2019 8:30 8:30 am	14-Sept-2022 9:00 am	3-Jul-2019 9:57am + 4-Jul-2019 10:40am	14-Sept-2022 10:00 am	4-Jul-2019 10:55 am	14-Sept-2022 11:00 am
Lat/Long	1.43912 N, 103.7627 E		1.43857 N, 103.76323 E		1.43834 N, 103.7637 E	
Description	fringing mangrove (near mudflat)		mid-mangrove		back-mangrove (near secondary forest)	
Mangrove trees						
Tree density (n/ha)	1,200	1,500	300	2,300	1,000	1,200
Shrubs (n/ha)	5,100	-	2,200	-	~100 (saplings)	-
Saplings (n/ha)	0	500	0	3,300	100	200
Tree height (m)	10-15 m	1-17m	15-20 m	1-8 mA	15-25 m	12-15 m
Diameter D_{130} (cm) AVG	4.6	16.7	6.8	2.2	15.2	14.3
Basal area (m^2/ha)	17.4	5.9	36.9	6.22	29.2	13.3
Canopy cover (%)	76.3 ± 2.5 %	86.27 ± 2.4 %	79.9 ± 3.9 %	67.4 ± 3.5 %	93.0 ± 1.2 %	96.3 ± 0.85 %
Dominant species	*Sonneratia alba*	*Sonneratia alba*	*Sonneratia alba* (+ *Avicennia alba*)	*Sonneratia alba*	*Rhizophora apiculata, Avicennia officinalis*	*Rhizophora mucronata, + Avicennia alba*
Flowering	Yes (*S. alba*)	No	No	No	No	No
Fruiting	No	No	No	No	No	No
Pneumatophores						
Density (n/m^2)	48 ± 4	67.2 ± 8.39	122 ± 11	120.8 ± 24.04	157 ± 33	217.2 ± 55.46
Height (cm)	14.5 ± 1.0	25.5 ± 2.76	8.5 ± 0.7	14.7 ± 0.82	14.3 ± 1.8	19.25 ± 3.37
Diameter (mm)	12.8 ± 1.4	43.40 ± 0.63	6.1 ± 0.4	14.90 ± 0.27	6.7 ± 0.6	8.80 ± 0.10
Leaf health						
%green	95%	100%	93%	100%	94%	99%
%yellow	4%	0%	5%	0%	5%	0%
%wilting	0%	0%	0%	0%	0%	0%
%dead/dry	1%	0%	2%	0%	1%	1%
%insect damage	20-50%	none	30-40%	none	30-40% (*A.o*); <5% (*R.a*)	none
new buds/leaves forming?	Yes	Yes	Yes	Yes	Yes (*A.o, R.a*)	Yes
Mortality						
%dead branches	20-30% (*S.a*)	none	10-15% (*A.a*); 20% (*S.a*)	none	5-10% (*R.a*); 10-20% (*A.o*)	none
number of dead trees	7	3	3	1	0	0
dead saplings/seedlings	0	0	0	0	0	0

	TRANSECT A (opposite Gate 3)					
	2019	**2022**	**2019**	**2022**	**2019**	**2022**
	Plot A1	***Plot A1***	***Plot A2***	***Plot A2***	***Plot A3***	***Plot A3***
Seedlings & propagules						
Seedlings (n/ha)	*300 Avicennia* sp.	*1700 Sonneratia* sp.; *1200 Avicennia* sp.*;*	*3000-4000 Sonneratia* sp.*; 300 Avicennia* sp.*; 100 Rhizophora* sp.	*4000 Sonneratia* sp.; *1500 Avicennia* sp.*;*	*700 Avicennia* sp.*; 400 Rhizophora* sp.	*700 Avicennia* sp.*; 200 Rhizophora* sp.
Propagules (n/ha)	200 *Rhizophora* sp.	*<100 Sonneratia & Avicennia* sp.	*<100 Avicennia* sp.	*<100 Sonneratia & Avicennia* sp.	*<100 Rhizophora* sp.	*<100 Rhizophora* sp.
Fauna colonisation						
crab hole density (n/m^2)	66 ± 11	2.40 ± 2	116 ± 15	27.52 ± 5.32	36 ± 4	5.60 ± 3.22
snail/clam density (n/m^2)	18 ± 4 (clams)	8 ± 2.53 (clams)	0	16 ± 4.171 (clams)	0	10.40 ± 2.86 (clams)
Symptoms of disturbances						
litter / debris	minor (plastic bags)	none	none	none	moderate (plastic, bottles, shoes)	minor
tar / oil	none	none	none	none	none	none
physical damage	moderate (storm)	none	low	none	none	none
tracks / footprints	none	none	none	none	none	none

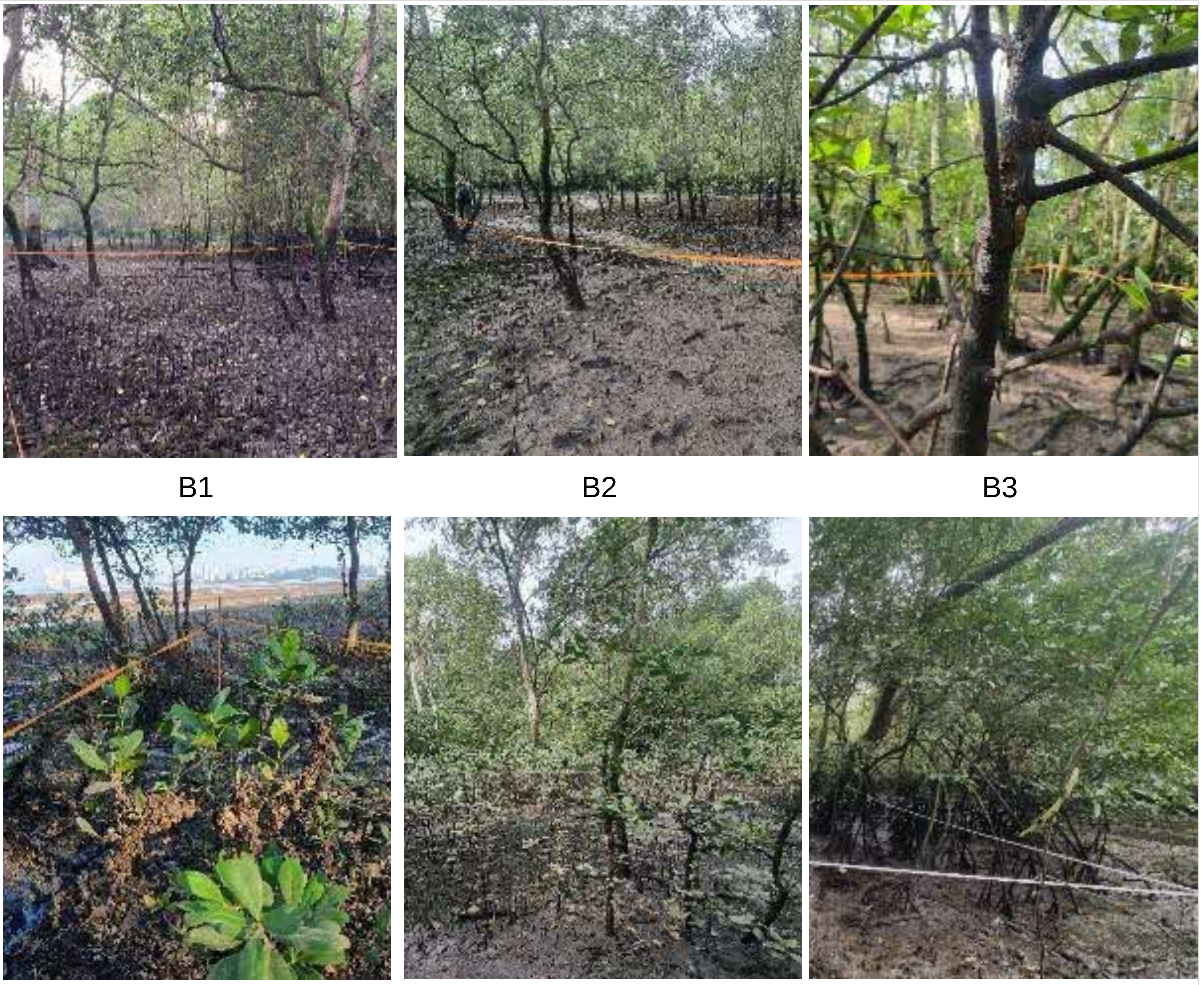
Table 5.10. Results of the mangrove health assessment along Transect B (near Sungei Mandai Besar).

	TRANSECT B (near Sungei Mandai Besar)					
	2019	**2022**	**2019**	**2022**	**2019**	**2022**
	Plot B1	**Plot B1**	**Plot B2**	**Plot B2**	**Plot B3**	**Plot B3**
Date/Time:	4-Jul-2019 8:03 8:30 am	31-Aug-2022 9:00 am	4-Jul-2019 8:45 9:00 am	31-Aug-2022 10:10 am	4-Jul-2019 9:28 am	31-Aug-2022 11:30 am
Lat/Long:	1.43804 N, 103.76241 E		1.43789 N, 103.76261 E		1.43763 N, 103.76266 E	
Description:	fringing mangrove (near mudflat)		mid-mangrove		back-mangrove (near secondary forest)	
Mangrove trees						
Tree density (n/ha)	2,200	1300	1,200	1500	5,100	2500
Shrubs (n/ha)	0	-	0	-	0	-
Saplings (n/ha)	0	0	0	0	200	0
Tree height (m)	8-10 m	2-12 m	10-15 m	5-8 m	10 - 20 m	1.6 - `10 m
Diameter D_{130} (cm) AVG	11.7	11.4	15.3	11.2	5.8	10.5
Basal area (m^2/ha)	27.9	28.4	25.0	16.8	24.5	30.6
Canopy cover (%)	91.4 ± 1.9	87.6 ± 1.6	92.9 ± 1.1	86.5 ± 1.97	88.6 ± 2.6	93.75 ± 1.96
Dominant species	*Sonneratia alba, Avicennia officinalis*	*Avicennia officinalis*	*Sonneratia alba, Rhizophora apiculata*	*Sonneratia alba*	*Avicennia officinalis, Rhizophora apiculata (+ Sonneratia alba)*	*Avicennia officinalis, Rhizophora apiculata*
Flowering	Yes (*S. alba*)	No	Yes (*S. alba*)	No	no	No
Fruiting	Yes (*S. alba*)	No	No	No	Yes (*A. officinalis*)	No
Pneumatophores						
Density (n/m^2)	84 ± 11	70.4 ± 7.57	110 ± 16	54.00 ± 11.63	126 ± 14	111.2 ± 15.85
Height (cm)	17.7 ± 1.9	22.4 ± 2.37	7.9 ± 0.8	16.35 ± 1.97	5.5 ± 0.8	13.80 ± 1.25
Diameter (mm)	9.6 ± 1.2	11.4 ± 0.24	7.2 ± 0.6	9.10 ± 0.10	6.6 ± 0.4	7.40 ± 0.09
Leaf health						
%green	95%	95%	95%	100%	90%	97%
%yellow	4%	4%	1%	0%	5%	0%
%wilting	0%	1%	0%	0%	0%	3%
%dead/dry	1%	0%	4%	0%	5%	0%
%insect damage	<5% (*S.alba*); 15-20% (*A.alba*)	none	5-10% (*S.alba*); 10% (*R.alba*)	none	<5% (*R.apiculata); 5%*(*S.alba*); 30-40% (*A.officinalis*)	none
new buds/leaves forming?	Yes (*S.a; A.alba*)	Yes	Yes (*S.alba, R.alba*)	Yes	Yes (all spp.)	Yes
Mortality						
% dead branches	10% (*A.alba*); 10-20% (*S.alba*)		5% (*R.alba*); 10-20% (*S.alba*)		<5% (*R.apiculata*); 10% (*S. alba*); 15-30% (*A.officinalis*)	
number of dead trees	0	0	0	0	0	1
dead saplings/seedlings	0	0	0	0	0	2
Seedlings & propagules						

	TRANSECT B (near Sungei Mandai Besar)					
	2019	**2022**	**2019**	**2022**	**2019**	**2022**
	Plot B1	**Plot B1**	**Plot B2**	**Plot B2**	**Plot B3**	**Plot B3**
Date/Time:	4-Jul-2019 8:03 8:30 am	31-Aug-2022 9:00 am	4-Jul-2019 8:45 9:00 am	31-Aug-2022 10:10 am	4-Jul-2019 9:28 am	31-Aug-2022 11:30 am
Lat/Long:	1.43804 N, 103.76241 E		1.43789 N, 103.76261 E		1.43763 N, 103.76266 E	
Description:	fringing mangrove (near mudflat)		mid-mangrove		back-mangrove (near secondary forest)	
seedlings (n/ha)	0	*800 Avicennia* sp.	5,200 *Sonneratia* sp.; <100 *Avicennia* sp. 300 *Sonneratia* sp.	*400 Avicennia* sp. *100 Sonneratia* sp.	6,300 *Sonneratia* sp.; 200 *Avicenna* sp.	*800 Avicennia* sp. *400 Sonneratia* sp.
propagules (n/ha)	0	0	0	0	0	*<50 Sonneratia* sp.
Fauna colonisation						
crab hole density (n/m^2)	80 ± 15	3.60 ± 2.02	129 ± 27	15.20 ± 3.31	42 ± 7	12.40 ± 2.95
snail density (n/m^2)	98 ± 6 (clam)	52.80 ± 10.14 (clam)	6 ± 2 (clam)	10.40 ± 2.15 (clam)	21 ± 6 (Red-berry snail)	0.80 ± 0.40 (clam)
Symptoms of disturbances						
litter / debris	minor (plastic)	minor (glass bottles)	minor (plastic)	minor (styro, plate)	minor (plastic bags)	minor (glass bottle, plastic bag)
tar / oil	none	none	none	none	none	none
physical damage	none	none	none	none	minor/moderate (storm?)	none
tracks / footprints	none	none	none	none	none	none

Appendix A and Table 5.11 provides the complete list of flora species recorded in previous 2019 (TAC, 2020) and in the 2022 baseline study while **Appendix B** and Figure 5-18 presents the photos of some of dominant mangrove plant species recorded during 2022 mangrove health assessment survey.

Mangrove Plots



B1 B2 B3

A1 A2 A3

Figure 5-18. Photographs of mangrove plots (A1-3 & B1-3)

Table 5.11. List of true mangrove flora species **(Yang et al., 2011)** of local and global conservation significance encountered within the project area based on historical and current records.

S/N	Species Name	Local Status[1]	Global Status[2]	Historical Observation	2019 Observation	2022 Observation
1	*Acanthus ebracteatus*	VU	LC	✓	✓	✓
2	*Acanthus ilicifolius*	EN	LC	✓	-	✓
3	*Acanthus volubilis*	VU	LC	✓	-	-
4	*Acrostichum aureum*	LC	LC	-	✓	✓
5	*Acrostichum speciosum*	LC	LC	✓	-	-
6	*Avicennia alba*	LC	LC	✓	✓	✓
7	*Avicennia officinalis*	LC	LC	✓	✓	✓
8	*Avicennia rumphiana*	LC	VU	✓	✓	✓
9	*Brownlowia tersa*	CR	NT	✓	-	-
10	*Bruguiera cylindrica*	LC	LC	✓	✓	✓
11	*Bruguiera gymnorhiza*	LC	LC	✓	-	✓
12	*Bruguiera parviflora*	EN	LC	✓	-	-
13	*Ceriops tagal*	VU	LC	✓	-	-
14	*Ceriops zippeliana*	EN	LC	✓	-	✓
15	*Dolichandrone spathacea*	CR	LC	✓	-	✓
16	*Excoecaria agallocha*	LC	LC	✓	-	✓
17	*Heritiera littoralis*	EN	LC	✓	-	✓
18	*Lumnitzera littorea*	EN	LC	✓	-	✓
19	*Lumnitzera racemosa*	EN	LC	✓	-	✓
20	*Nypa fruticans*	VU	LC	✓	✓	✓
21	*Rhizophora apiculata*	LC	LC	✓	✓	✓
22	*Rhizophora mucronata*	LC	LC	✓	✓	✓
23	*Rhizophora stylosa*	VU	LC	✓	-	-
24	*Scyphiphora hydrophylacea*	EN	LC	✓	-	-
25	*Sonneratia alba*	LC	LC	✓	✓	✓
26	*Sonneratia caseolaris*	CR	LC	✓	-	✓
27	*Sonneratia ovata*	CR	NT	✓	✓	-
28	*Xylocarpus granatum*	LC	LC	✓	-	✓

[1] (Davison et al., 2008; Chong et al., 2009; Lindsay, et al., 2022; National Parks Board, 2023)
[2] International Union for Conservation of Nature and Natural Resources (IUCN, 2021)
[3]The information has been corrected and updated as of 30 Aug 2023.

Habitat Mapping

Areas within the project area can be divided into four main habitat types – mangrove forest, intertidal mudflats and sandflats, secondary forest, and urban vegetation:

a) The mangrove forest is mostly found in the east of the site with fringing patches along the coastline of the central and western parts of the site. Pressures from deforestation for shrimp pond development and reclamation for industry and freshwater reservoirs have reduced Mandai mangroves to a patch of Mandai mangroves to a patch of 31.2 ha today (NParks, 2018). Mangrove habitats are highly productive ecosystems which support a wide variety of species with unique adaptations. The organisms which form the foundation of these habitats are mangrove trees with root structures that increase stability in soft estuarine sediments and have the ability to filter saltwater. Root variations include: the knee roots of *Bruguiera*, prop roots of *Rhizophora*, and pencil roots of *Avicennia.* These features create complex structures that function as a nursery to shelter many different juvenile fish species from predators, and offers substrate for invertebrate prey such as decapods, bivalves and gastropods (Laegdsgaard & Johnson, 2001; Blaber, 2007). Some key marine species include the mangrove horseshoe crab (*Carcinoscorpius rotundicauda*), striped-nose halfbeak (*Zenarchopterus buffonis*) and archerfish (*Toxotes sp.*). Other reptile species such as the mangrove pit viper (*Trimeresurus purpureomaculatus*) and Oriental whip snake (*Ahaetulla prasina*) can be found in mangrove forests. The collared kingfisher (*Todiramphus chloris*) is also a common bird species found in mangroves hunting for small/juvenile fish hiding amongst tree roots.

Figure 5-19. Examples of mangrove forest which can be found within the project area.

b) Mudflats with patches of sandflats can be observed along the coastline in the northern and north-eastern side of the project area. The three estuarine waterways: Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil, pass through mangrove forests and mudflats before ending in a saltwater strait. Mudflat ecosystems provide an abundant and diverse food supply for fish as they contain highly digestible microphytobenthos (MacIntyre et al., 1996). During low tides, fish are often forced out of mangroves into surrounding areas, which explains why some mudflats support a higher fish abundance and diversity and may also function as a nursery for juvenile fishes (Marley et al., 2020). In Mandai, the mudflats extend out to more than 200m from the mainland and there have been frequent sightings of the estuarine crocodiles (*Crocodylus porosus*) and the smooth-coated otter *(Lutrogale perspicillata).* This indicates that there is a high abundance of fish and other prey in this habitat to support these top marine predators. The mudflats and sandflats also support shorebird species such as the Eurasian whimbrel (*Numenius phaeopus*) and common sandpiper (*Actitis hypoleucos*) that feed on bivalve and polychaetes prey species.

Figure 5-20. Examples of mudflat habitat which can be found within the project area.

c) The secondary forest is of a relatively low diversity and acts as a natural buffer between the mangrove forest and Woodlands Road. This is a remnant patch of (disturbed) forest that remained following earlier clearance works for the development of the old Keretapi Tanah Melayu (KTM) railway. However, integrating secondary forests into future land use developments are beneficial towards improving biodiversity such as protecting neighbouring core habitat patches from being affected by urban disturbances and providing prospective sites for primary forest species to inhabit (Wu, 2023). Secondary forests also provide important regulating ecosystem services, including microclimate regulation through shade and transpiration; air filtering by particulate matter adhesion to leaves and gaseous absorption; stormwater/ flood regulation via rainfall interception; and carbon sequestration (Wu, 2023). In the Mandai forest patch, tall emergent trees provide refuge and a lookout point for birds of prey, such as Brahminy kite *(Haliastur indus)* and the white-bellied sea-eagle *(Haliaeetus leucogaster),* to hunt targeted marine fish species. This forest is also an important habitat for nocturnal species such as the lesser dog-faced fruit bats (*Cynopterus brachyotis*) and common palm civet (*Paradoxurus musangus*) which are important fruit dispersers that can sustain the forest patch.

Figure 5-21. Examples of secondary forests which can be found within the project area.

d) Urban vegetation habitats are located in various small patches around the site, with the largest patch at Kranji Reservoir Park B. This area is open to public and supports relatively urban park ecology with fauna species such as the Malayan water monitor (*Varanus salvator*), non-native changeable lizard (*Calotes versicolor*), and park bird species such as the black-naped oriole (*Oriolus chinensis*) and pink-necked green pigeon (*Treron vernans*).

Figure 5-22. Examples of urban vegetation which can be found within the project area.

Figure 5-23. Map of the Mandai Mangrove and Mudflat project area, showing distribution of main habitats (adapted from NParks)

5.4.2 Terrestrial & Mangrove Fauna Survey Results

The complete list of fauna sightings and photographs of observed animals can be found respectively in **Appendix C** and **Appendix D**.

Birds

The current surveys yielded 84 species of birds within the project area, of which 19 are locally threatened (NParks, 2023) and three are globally threatened (IUCN, 2021). Figure 5-24 shows the number of threatened bird species recorded at each point count location during the current study. Combining the data from previous studies (NParks, 2007; Lim & Lim, 2009; Lim et al., 2009; Lim & Chew, 2010; TAC, 2020), brings the number of birds observed on the project area to at least 154. Table 5.12 shows the list of all the bird species of conservation value recorded at this site, which comprises 47 locally threatened and six globally threatened species.

Locally threatened species include the critically endangered great-billed heron (*Ardea sumatrana*), endangered purple heron (*Ardea purpurea*), white-winged tern (*Chlidonias leucopterus*), and straw-headed bulbul (*Pycnonotus zeylanicus*). The straw-headed bulbul is also listed as globally critically endangered.

The straw-headed bulbul is a noteworthy species given its globally critically endangered status. While populations of straw-headed bulbuls on Singapore's mainland have been stable over the past few years, this species' numbers in the rest of Southeast Asia have been declining (Yong et al., 2017). Singapore is an important stronghold of this species, and its habitat, secondary forest, needs to be preserved for its continued persistence.

Locally vulnerable species include the grey-headed fish eagle (*Haliaeetus ichthyaetus*), changeable hawk-eagle (*Nisaetus cirrhatus*), large-billed crow (*Corvus macrorhynchos*), Oriental magpie-robin (*Copsychus saularis*), baya weaver (*Ploceus philippinus*), buffy fish owl (*Ketupa ketupu*), and spotted wood owl (*Strix seloputo*). The grey-headed fish eagle is also globally near-threatened.

Other globally threatened species include the vulnerable long-tailed parakeet (*Psittacula longicauda*) and Javan myna (*Acridotheres javanicus*). Javan myna is an introduced species not of significant conservation value in Singapore.

Table 5.12. List of all bird species of conservation value found in the project area

No.	Family	Species name	Common Name	Local Status	Global Status
1	Accipitridae	*Elanus caeruleus*	Black-winged kite	VU	LC
2	Accipitridae	*Haliaeetus ichthyaetus*	Grey-headed fish eagle	VU	NT
3	Accipitridae	*Nisaetus cirrhatus*	Changeable hawk-eagle	VU	LC
4	Acrocephalidae	*Acrocephalus orientalis*	Oriental reed warbler	VU	LC
5	Alcedinidae	*Alcedo atthis*	Common kingfisher	VU	LC
6	Alcedinidae	*Halcyon pileata*	Black-capped kingfisher	VU	VU
7	Apodidae	*Apus nipalensis*	House swift	VU	LC
8	Ardeidae	*Ardea alba*	Great egret	VU	LC
9	Ardeidae	*Ardea purpurea*	Purple heron	EN	LC
10	Ardeidae	*Ardea sumatrana*	Great-billed heron	CR	LC
11	Ardeidae	*Bubulcus coromandus*	Eastern cattle egret	VU	LC
12	Ardeidae	*Egretta eulophotes*	Chinese egret	EN	VU
13	Ardeidae	*Egretta sacra*	Pacific reef heron	EN	LC
14	Ardeidae	*Nycticorax nycticorax*	Black-crowned night heron	EN	LC
15	Charadriidae	*Charadrius dubius*	Little ringed plover	EN	LC
16	Charadriidae	*Pluvialis fulva*	Pacific golden plover	VU	LC
17	Corvidae	*Corvus macrorhynchos*	Large-billed crow	VU	LC
18	Laniidae	*Lanius cristatus*	Brown shrike	VU	LC
19	Laridae	*Chlidonias leucopterus*	White-winged tern	EN	LC
20	Laridae	*Onychoprion aleuticus*	Aleutian tern	VU	VU
21	Laridae	*Sterna sumatrana*	Black-naped tern	EN	LC
22	Laridae	*Sternula albifrons*	Little tern	EN	LC
23	Laridae	*Thalasseus bengalensis*	Lesser crested tern	EN	LC
24	Laridae	*Thalasseus bergii*	Greater crested tern	EN	LC
25	Motacillidae	*Motacilla tschutschensis*	Eastern yellow wagtail	VU	LC
26	Muscicapidae	*Copsychus saularis*	Oriental magpie-robin	VU	LC

No.	Family	Species name	Common Name	Local Status	Global Status
27	Nectariniidae	*Leptocoma calcostetha*	Copper-throated sunbird	VU	LC
28	Pellorneidae	*Pellorneum rostratum*	White-chested babbler	CR	NT
29	Ploceidae	*Ploceus philippinus*	Baya weaver	VU	LC
30	Psittacidae	*Psittacula longicauda*	Long-tailed parakeet	NT	VU
31	Pycnonotidae	*Pycnonotus zeylanicus*	Straw-headed bulbul	EN	CR
32	Scolopacidae	*Actitis hypoleucos*	Common sandpiper	VU	LC
33	Scolopacidae	*Arenaria interpres*	Ruddy turnstone	EN	LC
34	Scolopacidae	*Calidris falcinellus*	Broad-billed sandpiper	VU	LC
35	Scolopacidae	*Calidris ferruginea*	Curlew sandpiper	EN	NT
36	Scolopacidae	*Calidris tenuirostris*	Great knot	EN	EN
37	Scolopacidae	*Limnodromus semipalmatus*	Asian dowitcher	VU	NT
38	Scolopacidae	*Limosa lapponica*	Bar-tailed godwit	VU	NT
39	Scolopacidae	*Limosa limosa*	Black-tailed godwit	CR	NT
40	Scolopacidae	*Numenius arquata*	Eurasian curlew	EN	NT
41	Scolopacidae	*Tringa brevipes*	Grey-tailed tattler	VU	NT
42	Scolopacidae	*Tringa glareola*	Wood sandpiper	EN	LC
43	Scolopacidae	*Tringa nebularia*	Common greenshank	VU	LC
44	Scolopacidae	*Tringa stagnatilis*	Marsh sandpiper	EN	LC
45	Scolopacidae	*Tringa totanus*	Common redshank	VU	LC
46	Scolopacidae	*Xenus cinereus*	Terek sandpiper	EN	LC
47	Strigidae	*Ketupa ketupu*	Buffy fish owl	VU	LC
48	Strigidae	*Strix seloputo*	Spotted wood owl	VU	LC
49	Sturnidae	*Acridotheres javanicus*	Javan myna	NA	VU

Figure 5-24. Distribution of number of threatened bird species in project area

The bird surveys were conducted from September to November 2022, which overlapped with the annual bird migration period. As a result, several migratory birds were recorded within the site. These for instance included the great egret (*Ardea alba*), Pacific golden plover (*Pluvialis fulva*), brown shrike (*Lanius cristatus*), common sandpiper (*Actitis hypoleucos*), bar-tailed godwit (*Limosa lapponica*), and common greenshank (*Tringa nebularia*), all of which are also locally vulnerable (Figure 5-25).

Figure 5-25. Bar-tailed godwit (left) great-billed heron (right) in the project area

The large number of Albizia trees within the project area provides suitable nesting sites for large birds, particularly raptors. The current study recorded raptors such as the grey-headed fish eagle (*Haliaeetus ichthyaetus*), white-bellied sea eagle (*Haliaeetus leucogaster*), changeable hawk-eagle (*Nisaetus cirrhatus*), and Brahminy kite (*Haliastur indus*) (Figure 5-26).

Figure 5-26. Picture of a grey-headed fish eagle in project area

The survey period also coincided with active nesting of a Brahminy kite (*Haliastur indus*), which was spotted on 25 November 2022. The nest was found on an Albizia tree in woodland vegetation. Although a clear view was obscured by some branches, one individual was seen in the nest with motions reminiscent of chick-feeding. There was another individual seen perched nearby (Figure 5-27). The Brahminy kite is a native species to Singapore and can be commonly spotted at coastal areas, estuaries, and mangrove swamps.

Figure 5-27. Picture of two Brahminy kites and a nest in project area

Mammals

There are currently about 74 species of mammals extant in Singapore. A total of nine non-volant and nine volant mammals (i.e., bats) were encountered within the project area in the recent surveys. The current surveys recorded three non-volant and one volant species of conservation significance. These include the critically endangered Sunda pangolin (*Manis javanica*), locally endangered and globally vulnerable smooth-coated otter (*Lutrogale perspicillata*), globally endangered long-tailed macaque (*Macaca fascicularis*), and locally critically endangered long-winged tomb bat (*Taphozous longimanus*) (Table 5.13).

These mammals were detected through bat acoustic surveys, walking transects, and camera trapping. Together with the data from previous surveys (NParks, 2007; TAC, 2020), the total number of mammal species observed on the project area is at least 21.

Table 5.13. List of mammal species of conservation value found in the project area

No.	Species name	Common Name	Local Status	Global Status
1	*Manis javanica*	Sunda Pangolin	CR	CR
2	*Lutrogale perspicillata*	Smooth-coated Otter	EN	VU
3	*Macaca fascicularis*	Long-tailed Macaque	LC	EN
4	*Taphozous longimanus*	Long-winged Tomb Bat	CR	LC

Two rounds of bat acoustic surveys were conducted, split between five nights covering each set of transects consisting of eight terrestrial transects and one mangrove transect (Table 5.15). Acoustic sampling at MMM detected eight bat species (Table 5.15). The call structure and spectrograms for the eight bat species recorded during acoustic sampling are presented in Table 5.15 and Figs. 3.23–3.30. Table 5.15 indicates presence or absence of the species for each transect and survey night. All eight bat species were detected at T2. T2 traverses some of the best habitat for bats in the project area as it passes through riverine habitat consisting of secondary and mangrove forest and runs adjacent to an industrial area. This mixture in habitats increases the chances for a greater diversity of bats to be detected. *Myotis horsfieldii*, which feeds over the water surface of large streams and rivers, was only found at T2 and T1. It is likely that this species is also found along Sungei Pang Sua but was not detected as the transect is situated some distance from the river. *Myotis muricola* also forages over streams and rivers but is more widespread throughout Singapore than *Myotis horsfieldii* and can be found in highly disturbed areas*.* The presence of *Rhinolophus refulgens* at T2, and T3 and Pang Sua, was a bit surprising as this species prefers mature forests. However, as the land area of Singapore's mature forests is small, it could be that this species is now colonising patches of young forest that provide canopy cover and forest connectivity. The remaining bats are generalists and can all be found in forests and in disturbed areas that are brightly lit. However, *Taphozous longimanus* was only first recorded in Singapore 2018 and thought to only reside in Pulau Ubin (Teo, 2018). This species was detected at T2, T3, T5, and Pang Sua (Table 5.15). Thus, either past surveys were not sufficient to detect this species previously on the mainland or *Taphozous longimanus* has since spread across the mainland after establishing itself on Pulau Ubin. Since it was only discovered in Singapore recently and thought to be restricted to Pulau Ubin, *Taphozous longimanus* is recognised as locally critically endangered, and is the only bat species recorded in this project that is of conservation significance (Table 5.16). Only *Scotophilus kuhlii*, the most commonly detected microchiropteran in Singapore, was detected at transects 4 and 6 (Table 5.15). T4 passes through a grassy field that borders the coastline where very few trees are present, and T6 is along Kranji Dam which crosses Kranji Reservoir and provides very little terrestrial habitat for bats. The remaining transects recorded 3–6 bat species (Table 5.15).

Although *Taphozous longimanus* is a generalist in habits, it was only first recorded in Singapore in 2018 when it was found on Pulau Ubin and thought to only reside in Pulau Ubin (Teo, 2018; Yang, 2018) No historic records of this species exist from Singapore, but it was predicted to have previously occurred in Singapore (Lane et al., 2006). Species of Taphozous forage in open-space habitats and have calls that are characterised as multi-harmonic, low frequency QCF call (Yoh et al., 2022). At Mandai Mangrove and Mudflat several QCF calls with a peak frequency at around 31 kHz were recorded. When comparing calls of Singapore's bat species using all available resources, the calls appear to match most closely with *Taphozous longimanus*, which is known to have a peak frequency of 30.35 kHz ± 1.07 (Shah & Srinivasulu, 2020) and a peak frequency of 30.83 kHz ± 1.58 (Hughes et al.). No other species in Singapore has a similar peak frequency (Pottie et al., 2005; Kingston et al., 2009; Hughes et al.). The closest are *Taphozous melanopogon* with a peak frequency of 27.5 kHz ± 0.52 (Shah & Srinivasulu, 2020), 27.9 kHz ± 0.56 (Pottie et al., 2005), and 29.71 kHz ± 2.67 (Hughes et al.), and *Pipistrellus stenopterus* with a peak frequency of 31.0 kHz ± 0.49 for low calls in high altitude, 37.0 kHz ± 0.38 for high calls in high altitude, and 38.6 kHz ± 0.20 for calls in clutter (Kingston et al., 2003). However, *Pipistrellus stenopterus* is an edge/gap forager that possesses calls with a frequency modulated component being either FM-B or FM-QCF calls. Previously, calls with peak frequency at around 31 kHz were also recorded at Lorong Halus and also identified as *Taphozous longimanus* by Nick Baker. Calls resembling *Taphozous longimanus* were detected at T2, T3, T5, and Sungei Pang Sua (Table 5.15). If the calls do belong to *Taphozous longimanus*, then either any past surveys on the mainland were not sufficient to detect this species or *Taphozous longimanus* has since spread across the mainland after establishing itself on Pulau Ubin. Since it was only discovered in Singapore recently and thought to be restricted to Pulau Ubin, *Taphozous longimanus* is recognised as locally critically endangered, and is the only bat species recorded in this project that is of conservation significance (Table 5.16).

Table 5.14. Call structure summary of eight bat species recorded during acoustic sampling at Mandai Mangrove and Mudflat.

Species name	Frequency (kHz) Maximum	Frequency (kHz) Minimum	Peak Frequency (kHz)	Call duration (ms)	Source
Saccolaimus saccolaimus	23.5 ± 1.32	21.8 ± 1.42	22.6 ± 0.42	12.20 ± 0.08	(Pottie et al., 2005)
Taphozous longimanus	--	--	30.4 ± 1.07	--	(Shah & Srinivasulu, 2020)
Taphozous longimanus	--	--	30.8 ± 1.58	--	(Hughes et al., 2011)
Taphozous melanopogon	28.7 ± 1.24	25.2 ± 0.82	27.9 ± 0.56	10.43 ± 0.06	(Pottie et al., 2005)
Rhinolophus refulgens	--	--	97.8 ± 0.07	28.30 ± 1.36	(Pottie et al., 2005)
Myotis horsfieldii	82.5 ± 0.71	30.4 ± 0.36	46.2 ± 0.31	4.68 ± 0.10	(Pottie et al., 2005)
Myotis muricola	79.9 ± 1.02	53.7 ± 0.48	57.2 ± 0.01	4.98 ± 0.07	(Pottie et al., 2005)
Pipistrellus javanicus	88.3 ± 3.50	42.3 ± 2.66	50.3 ± 5.09	4.8 ± 1.06	(Pham et al., 2021)
Scotophilus kuhlii	84.9 ± 2.25	36.6 ± 0.46	43.3 ± 0.16	4.01 ± 0.03	(Pottie et al., 2005)

Table 5.15 Presence or absence of eight bat species recorded during acoustic sampling for each of the four transects at Mandai Mangrove and Mudflat. T = Transect; Mgr = Mangrove.

Species	Transects									
	10/04				10/13		10/17		11/10	11/23
	T2	T3	T4	T6	Mgr	T1	T2	T3	T5	Pang Sua
Saccolaimus saccolaimus	✓	--	--	--	--	✓	--	--	✓	✓
Taphozous longimanus	✓	--	--	--	--	--	--	✓	✓	✓
Taphozous melanopogon	✓	--	--	--	--	--	✓	--	✓	--
Rhinolophus refulgens	✓	--	--	--	--	--	--	✓	--	✓
Myotis horsfieldii	✓	--	--	--	--	✓	✓	--	--	--
Myotis muricola	✓	✓	--	--	✓	✓	--	--	✓	✓
Pipistrellus javanicus	✓	--	--	--	✓	--	--	--	✓	--
Scotophilus kuhlii	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 5.16 List of eight bat species detected via acoustic recordings at Mandai Mangrove and Mudflat and their global and local conservation status**.**

Family	Species name	Common name	Local status	Global IUCN status
Emballonuridae	*Saccolaimus saccolaimus*	Pouched Tomb Bat	LC	LC
Emballonuridae	*Taphozous longimanus*	Long-winged Tomb Bat	CR	LC
Emballonuridae	*Taphozous melanopogon*	Black-bearded Tomb Bat	LC	LC
Rhinolophidae	*Rhinolophus refulgens*	Glossy Horseshoe Bat	LC	-
Vespertilionidae	*Myotis horsfieldii*	Horsfield's Bat	LC	LC
Vespertilionidae	*Myotis muricola*	Whiskered Myotis	LC	LC
Vespertilionidae	*Pipistrellus javanicus*	Javan Pipistrelle	LC	LC
Vespertilionidae	*Scotophilus kuhlii*	Lesser Asian House Bat	LC	LC

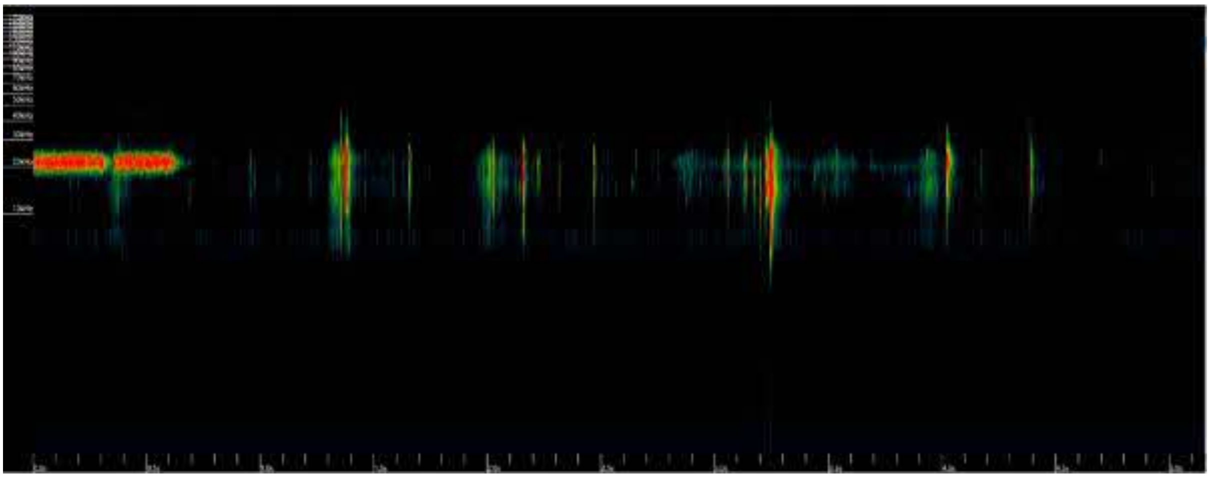


Figure 5-28. Spectrogram showing the acoustic call characteristics of *Saccolaimus saccolaimus*

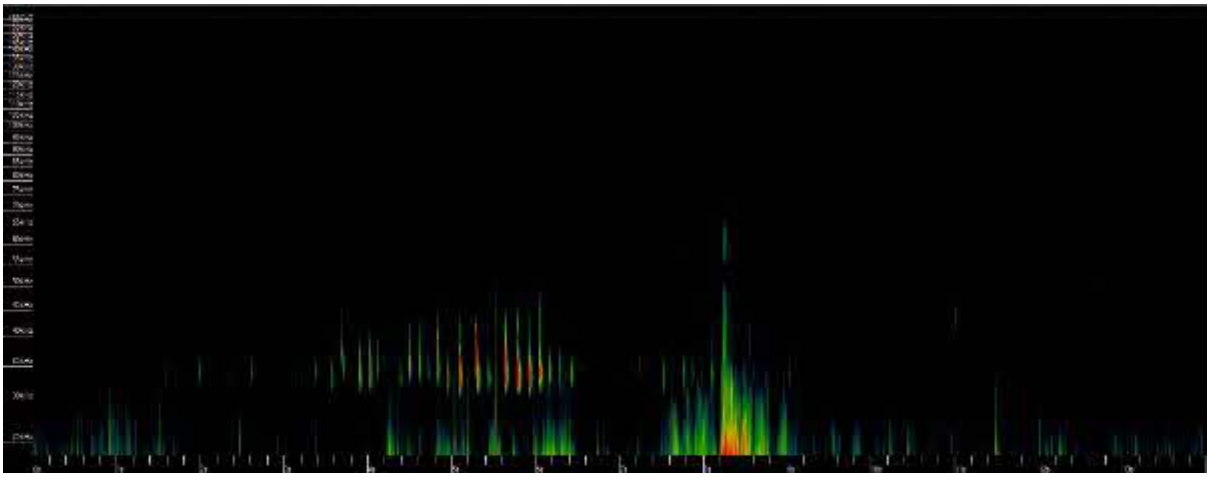


Figure 5-29. Spectrogram showing the acoustic call characteristics of *Taphozous longimanus*

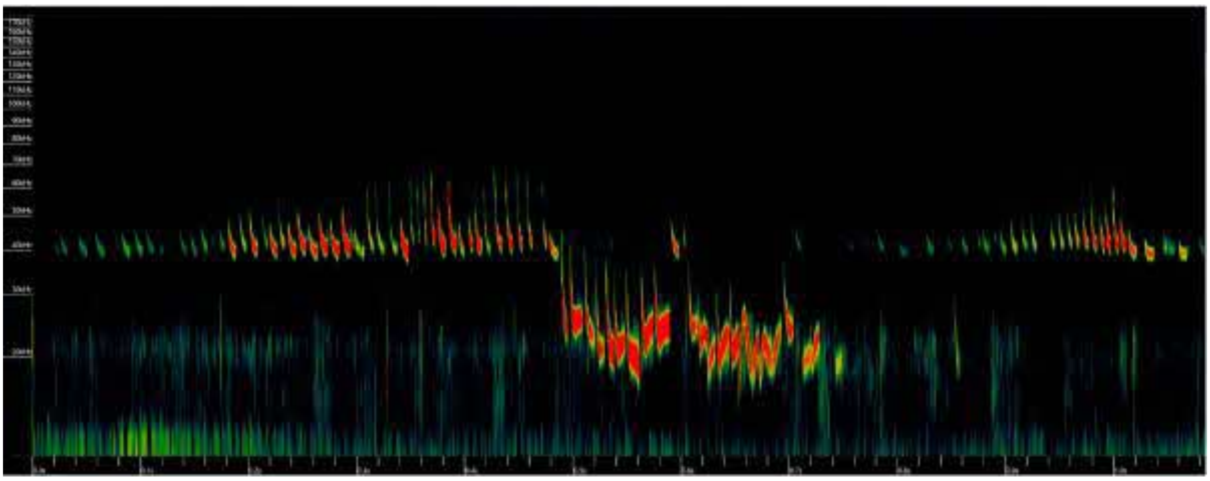


Figure 5-30. Spectrogram showing the acoustic call characteristics of *Taphozous melanopogon*

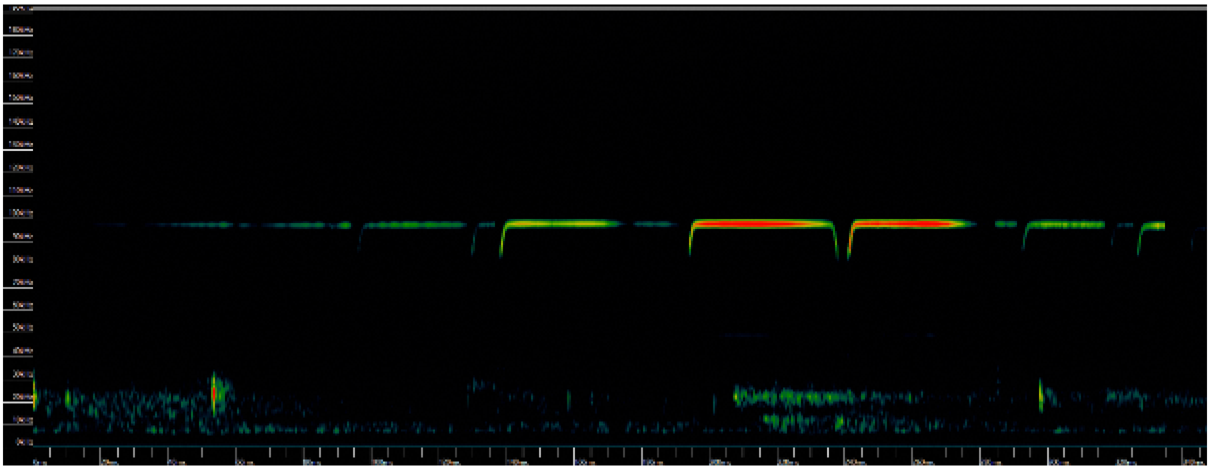


Figure 5-31. Spectrogram showing the acoustic call characteristics of *Rhinolophus refulgens*

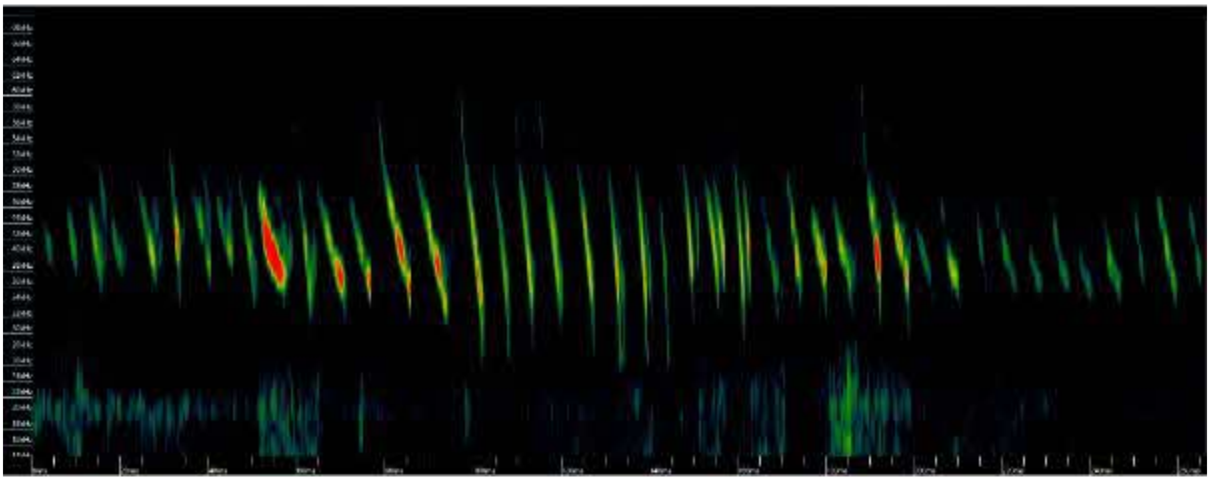


Figure 5-32. Spectrogram showing the acoustic call characteristics of *Myotis horsfieldii*

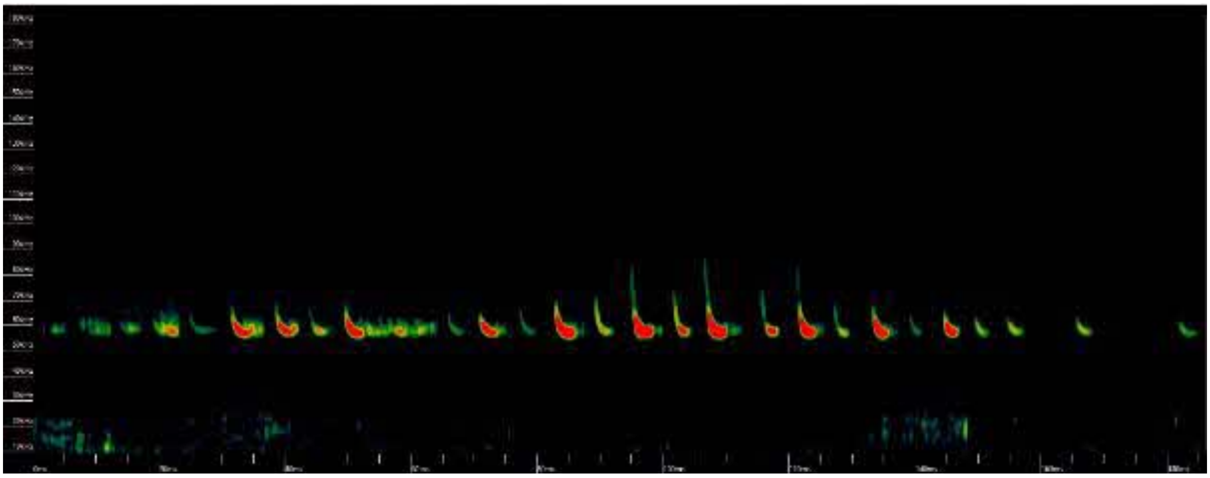


Figure 5-33. Spectrogram showing the acoustic call characteristics of *Myotis muricola*

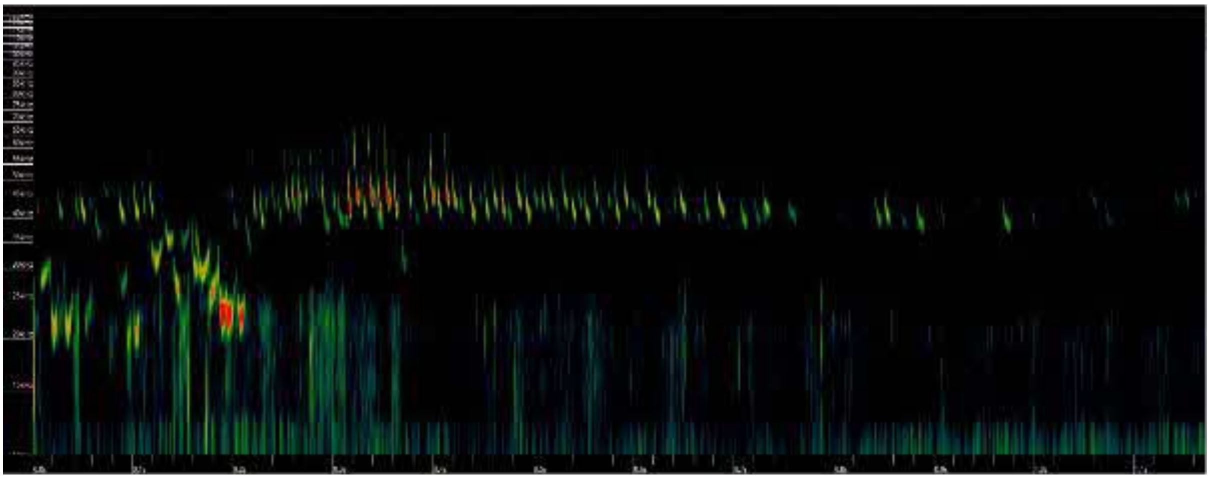


Figure 5-34. Spectrogram showing the acoustic call characteristics of *Pipistrellus javanicus*

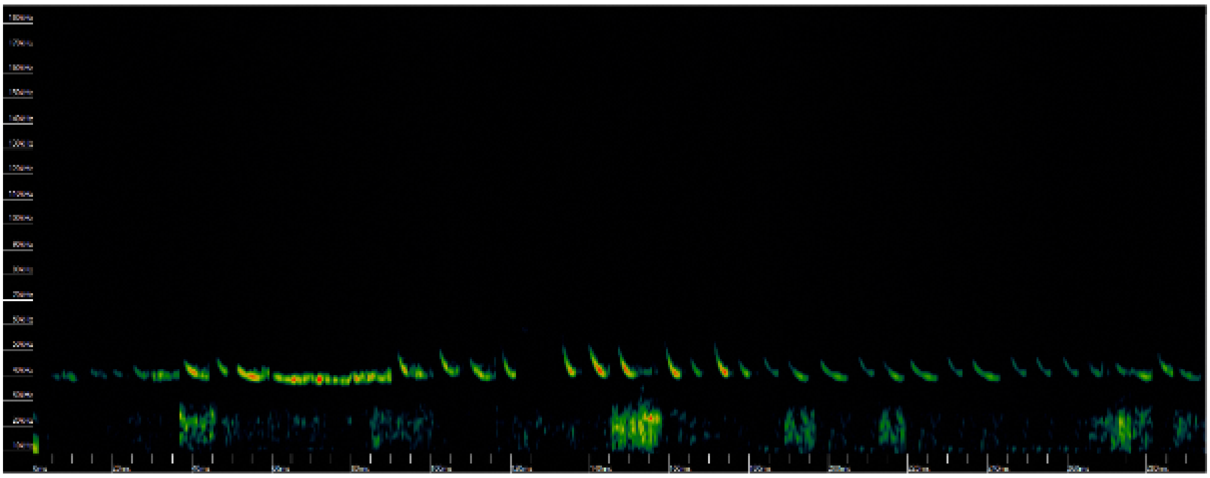


Figure 5-35. Spectrogram showing the acoustic call characteristics of *Scotophilus kuhlii*

Figure 5-36. Location of mammal species of local conservation value within project area

Reptiles

Singapore holds a relatively high diversity of reptiles, with at least 135 species being found in Singapore (Figueroa et al., 2023). A total of 16 reptile species were recorded on the project area during the present surveys. With additional data from previous surveys (NParks, 2007; TAC, 2020), the total number of reptiles observed on the project area is at least 20. The estuarine crocodile (*Crocodylus porosus*) marks the only locally critically endangered species recorded in the current surveys, which had been observed during aquatic surveys (day and night) and terrestrial night surveys. The locally critically endangered mangrove skink (*Emoia atrocostata*) was recorded in previous surveys (NParks, 2007) but not the current survey.

The current surveys also recorded the Indochinese rat snake (*Ptyas korros*) which is a native species and globally near-threatened. Another native species, the green crested lizard (*Bronchocela cristatella*), is widespread but uncommon in Singapore. Introduced species recorded at the project area include the changeable lizard (*Calotes versicolor*), red-eared slider (*Trachemys scripta elegans*), Brooke's house gecko (*Hemidactylus brookii*), and green iguana (*Iguana iguana*).

Figure 5-37. Location of reptile species of conservation value within project area

It is likely that the number of reptile species observed on the site is under-represented due to the elusive nature of most reptile species.

Amphibians

There are currently 31 species of amphibians known from Singapore (Figueroa et al., 2023). However, the diversity of amphibian species present is largely dependent on the quality and variability of habitats, particularly the waterbodies and streams present in the site that provide breeding sites for different species.

During the surveys, 11 frog species were found on the project area. There were no additional species recorded in previous surveys. All the species observed were not listed as locally or globally threatened. Only the Malayan giant frog (*Limnonectes blythii*) is considered near-threatened globally. This species is found commonly throughout Singapore.

Four of the species recorded have been introduced to Singapore: the greenhouse frog (*Eleutherodactylus planirostris*), banded bullfrog (*Kaloula pulchra*), Mukhlesur's narrow-mouthed frog (*Microhyla mukhlesuri*), and Gunther's frog (*Sylvirana guentheri*). Originating from Cuba, the Cayman Islands, and Northern Bahamas, the greenhouse frog is an introduced species that was first detected in Singapore at Sembawang (Groenewoud & Law, 2016). As this species is a direct developer, it does not go through the tadpole stage and hatches into small frogs from eggs laid in moist leaf axils or leaf litter (Kraus & Campbell, 2002). It was likely introduced to Singapore through the horticultural trade.

Terrestrial Invertebrates

Butterflies

Currently, Singapore is home to about 363 species of butterflies (NParks, 2023). At least 44 butterfly species were recorded within the project area during the present surveys. There are three species listed as locally near-threatened. These include the palm king (*Amathusia phidippus phidippus*), tawny palmfly (*Elymnias panthera panthera*), and long brand bush brown (*Mycalesis visala phamis*). All the other species recorded in the current surveys were listed as least concern or had no status. Combining with the data from the previous study (TAC, 2020), this brings the number of butterfly species observed in the project area to at least 46.

Odonates

Currently, at least 126 species of odonates are currently known from Singapore (National Parks Board, 2023). Of these, 15 odonates (dragonflies and damselflies) were found within the project area during the present surveys. The mangrove marshall (*Pornothemis starrei*) is the only species of conservation significance, being of locally and globally near-threatened status. It is also a widespread but uncommon species in Singapore. All the other species are known to be widespread and common, with the conservation status of least concern locally and globally. Together with the data from previous surveys (NParks, 2007; TAC, 2020), the number of odonates observed on the project area is at least 16.

In Singapore, all species of odonates that are no longer found here had faced extirpation due to the loss of key forest habitats they dependent on for their survival (Tang et al., 2010). Much like amphibians, odonates are dependent on waterbodies for survival during their juvenile stage, and their diversity in each site is determined by the quality and variety of waterbodies present.

Aquatic Fauna

Altogether, 22 aquatic fauna species were detected in the project area during the present surveys, covering 15 fish species, four molluscs, one horseshoe crab, and two crustaceans. Four genera, *Oreochromis* sp. (tilapia), *Toxotes* sp. (archerfish), *Elysia* sp. (leaf slug), and *Penaeus* sp. (prawn), were not identified to species level, but were counted as separate species in the analyses. Some species that were not identified to species level were excluded from this analysis as a separate species (i.e., *Pseudogobius* sp.), see Table 5.17. Observations from the marine fauna surveys were also excluded from this analysis.

The mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) is the only species of conservation status found during the current surveys, in or along Sungei Mandai Besar. This locally vulnerable species, though threatened, is still relatively common in intact mangroves and should survive where mangroves habitats are conserved. However, their populations are threatened by increasing urbanisation and redevelopment of mangroves and mudflats.

Figure 5-38. Location of aquatic fauna survey points together with the location of species of conservation value within project area

The locally endangered smooth-coated otter (*Lutrogale perspicillata*) was also sighted along Sungei Mandai Besar. However, the coordinates of this opportunistic sighting were not reported and hence is not shown in the map.

Previous surveys (NParks, 2007; TAC, 2020), recorded locally threatened species including the critically endangered mangrove land snail (*Ellobium scheepmakeri*), endangered mud lobster (*Thalassina* sp.) and coastal horseshoe crab (*Tachypleus gigas*), as well the vulnerable caridean shrimp (*Potamalpheops johnsoni*), mangrove-dwelling hymenosomatid crab (*Neorhynchoplax mangalis*), and grasping dwarf sesarmid (*Haberma nanum*).

Mud lobsters (*Thalassina* sp.) play a key role in maintaining a healthy mangrove ecosystem. There are five species of mud lobsters recorded in Singapore that are *Thalassina anomala*, *T. gracilis*, *T. spinirostris*, *T. kelanang* and *T. krempfi* (Ngoc-Ho & de Saint Laurent, 2009). While rarely seen, the presence of mud lobsters may be indicated by lobster mounds in mangroves. Mud lobsters often form mounds made of mud, which provide habitats for various plants and animals (Hossain et al., 2019). Several associated species include the Blind-Your-Eyes tree (*Excoecaria agallocha*), banded file snake (*Acrochordus granulatus*), mound crab (*Sarmatium germaini*), ant (*Odontomachus malignus*), mud shrimp (*Wolffogebia phuketensis*), and clams (NParks, 2022). Moreover, their digging actions help to aerate the anoxic mangrove mud and recycle nutrients from underground to the surface, which other living organisms can then utilise (Hossain et al., 2019).

Overall, Sungei Pang Sua recorded the highest diversity of aquatic fauna, followed by Sungei Mandai Besar then Sungei Mandai Kechil. All three waterways i.e., Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil were observed to have a continuous flow of water (please see Table 6.19 to Table 6.21); were subjected to tidal action and varied in depth.

Figure 5-39. From left to right: Pictures of a medaka (*Oryzias javanicus*), an archerfish (*Toxotes* sp.) and a golden apple snail (*Pomacea canaliculata*)

Table 5.17. Recorded aquatic fauna composition within the current project area ("Y" indicates the species was observed at the survey point). The survey points AS1-AS3 are from Sungei Mandai Kechil, AS4-AS6 from Sungei Mandai Besar and AS1-AS3 from Sungei Pang Sua waterway (see also Figure 5-38).

No.	Species Name	Common Name	AS1	AS2	AS3	AS4	AS5	AS6	AS7	AS8	AS9
	Fish										
1	*Toxotes* sp.	Archerfish	Y		Y		Y	Y	Y	Y	Y
2	*Butis butis*	Butis									Y
3	*Poecilia sphenops*	Common molly				Y					
4	*Hemigrammus rodwayi*	Gold tetra		Y							
5	*Gobio gobio*	Gudgeon	Y	Y	Y		Y			Y	
6	*Poecilia reticulata*	Guppy				Y					
7	*Pseudogobius javanicus*	Java fat-nose goby				Y	Y	Y	Y	Y	Y
8	*Yarica hyalosoma*	Mangrove cardinalfish								Y	Y
9	*Oryzias javanicus*	Medaka/ Javanese ricefish	Y	Y	Y		Y	Y	Y	Y	Y
10	*Gambusia affinis*	Mosquitofish				Y					
11	*Danionella priapus*	Priapus fish			Y					Y	Y
12	*Scatophagus argus*	Spotted scat							Y		
13	*Zenarchopterus buffonis*	Striped-nose half beak	Y	Y						Y	Y
14	*Trichopsis vittata*	Striped croaking gourami				Y					
15	*Oreochromis* sp.	Tilapia				Y					
-	*Pseudogobius* sp.	Goby	Y	Y	Y	Y	Y	Y	Y	Y	Y
-	Order Siluriformes	Catfish (recorded at T6)									
-	Family Mugilidae	Mullet									Y
-	Family Eleotridae	Sleeper fish								Y	Y
	Molluscs										
1	*Pomacea canaliculata*	Golden apple snail	Y								
2	*Elysia sp.*	Leaf slug			Y						
3	*Melanoides tuberculata*	Malayan trumpet snail				Y					
4	*Tarebia gianifera*	Quilted melania				Y					
	Horseshoe Crab										
1	*Carcinoscorpius rotundicauda*	Mangrove horseshoe crab						Y			
	Crustacean										
1	*Parasesarma eumolpe*	Face-banded sesarmine crab								Y	
2	*Penaeus* sp.	Prawn						Y			

Camera Trapping

Between 11 August 2022 and 4 January 2023, 10 camera traps were deployed for two months each (Figure 5-40). As the camera traps took a sequence of three photos and a 10-second video each time they were triggered, the photos were grouped according to respective sequences. Sequences separated by more than 60 seconds were assumed to be independent sightings.

Figure 5-40. Locations of camera traps

There were a total of 1601 independent sightings from 4398 photos, of which 31 fauna species were identified (Table 5.18). For every camera trap, each independent sighting was categorised into their respective taxonomic groups and summarised in Figure 5-42 below.

Mammal sightings (i.e., wild pig and plantain squirrel) dominated the detections in Camera 1. Of the 76 mammal sightings, there were 32 sightings of plantain squirrels, 43 sightings of wild pigs, and one sighting of a common palm civet. In Cameras 2, 5, and 8, majority of the mammal sightings comprised of plantain squirrels, other rodents, and wild pigs (Figure 5-41). Cameras 1, 5, and 9 were identified to be hotspots for wild pigs, with more than 20 sightings in each camera trap (Table 5.18). It was uncertain whether the wild boar sightings originated from the same individual.

Figure 5-41. Image of wild pig (*Sus scrofa*) captured by Camera Trap 5

In Cameras 3, 4, 5, and 10, majority of the bird sightings were attributed to the white-breasted waterhen. In Camera 4, there was also a high number of red jungle fowl sightings. Of the 209 bird sightings at Camera 4, there were 97 red junglefowl sightings and 105 white-breasted waterhen sightings.

The most frequently recorded species at the site is the white-breasted waterhen (*Amaurornis phoenicurus*). There were 428 independent sightings of white-breasted waterhens across all the camera traps Table 5.18.

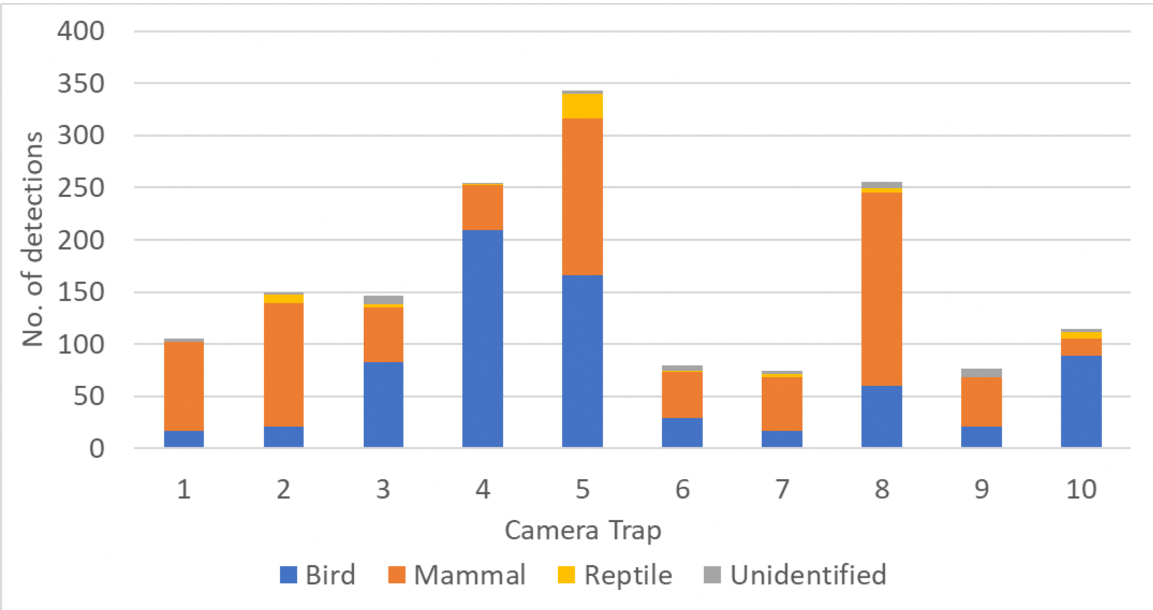


Figure 5-42. Number of detections based on taxonomic groups from each camera

Table 5.18. Number of sightings from each camera by species (*=locally threatened species)

Species	CAM1	CAM2	CAM3	CAM4	CAM5	CAM6	CAM7	CAM8	CAM9	CAM10
Changeable lizard					10					
Clouded monitor			1		1					
Collared kingfisher	3									
Common myna						1			1	
Common palm civet	1	1	3	4	1					
Common sun skink			1		13					4
Common tailorbird							5			
Common treeshrew										1
Feral dog		1	1	11		12		5		
Green iguana										1
House crow						8				
Javan myna						1		3		
Laced woodpecker	1	1						10	1	5
Large-tailed nightjar					4					
Long-tailed macaque				2						
Malayan water monitor		7		1		1	2	3		
Malaysian pied fantail							1			
Oriental magpie-robin*	4	2	10	6	17	2	4	4		1
Pink-necked green pigeon	2	1								
Plantain squirrel	32	18	21	7	99	10	37		2	
Red-legged crake										33
Red junglefowl	5		2	97				3	10	8
Rock dove						5				
Slaty-breasted rail										3
Smooth-coated otter*							2			
Spotted dove			3	1	1	5				

Species	CAM1	CAM2	CAM3	CAM4	CAM5	CAM6	CAM7	CAM8	CAM9	CAM10
Striated heron						2				
Sunda pangolin*										1
White-breasted waterhen	1	17	68	105	144	3	7	40	6	37
Wild pig	43				22			3	35	
Yellow-vented bulbul									1	
Unidentified	3	2	8	1	3	6	1	7	9	4
Unidentified bird	1					2			2	2
Unidentified crab							2			
Unidentified monitor lizard		2	1				1	1		1
Unidentified otter		1					1			
Unidentified rodent	9	97	27	20	28	22	11	177	10	14
Total Number of Detections	**105**	**150**	**146**	**255**	**343**	**80**	**74**	**256**	**77**	**115**
Total Number of Identified Species	**9**	**8**	**9**	**9**	**10**	**11**	**7**	**8**	**7**	**10**

Sightings of interest from the camera traps include the Oriental magpie-robin (*Copsychus saularis*), smooth-coated otter (*Lutrogale perspicillata*), and Sunda pangolin (*Manis javanica*), all of which have conservation significance.

The Oriental magpie-robin (*Copsychus saularis*) is a resident breeder and listed as locally vulnerable (NParks, 2023). This species can be found in terrestrial and mangrove habitats, which supports why it was sighted in all the camera traps except Camera 9 (Figure 5-43).

Figure 5-43. Picture of an Oriental magpie-robin (*Copsychus saularis*) from a camera trap

The smooth coated otter (*Lutrogale perspicillata*) is native to Singapore and is listed as locally endangered and globally vulnerable. It was captured by Camera 7, which was located close to the coast at Kranji Reservoir Park (Figure 5-44).

Figure 5-44. Picture of a smooth-coated otter from a camera trap

Camera 10, located along the Sungei Pang Sua, captured a Sunda pangolin (*Manis javanica*) (Figure 5-45) and green iguana (*Iguana iguana*) (Figure 5-46). The Sunda pangolin is a native species and is listed as critically endangered both locally and globally.

Figure 5-45. Picture of the critically endangered Sunda pangolin (*Manis javanica*)

Figure 5-46. Picture of a green iguana (*Iguana iguana*) at Camera 10

The composition of species listed in Table 5.18 is plotted in Figure 5-47 and Figure 5-48 below.

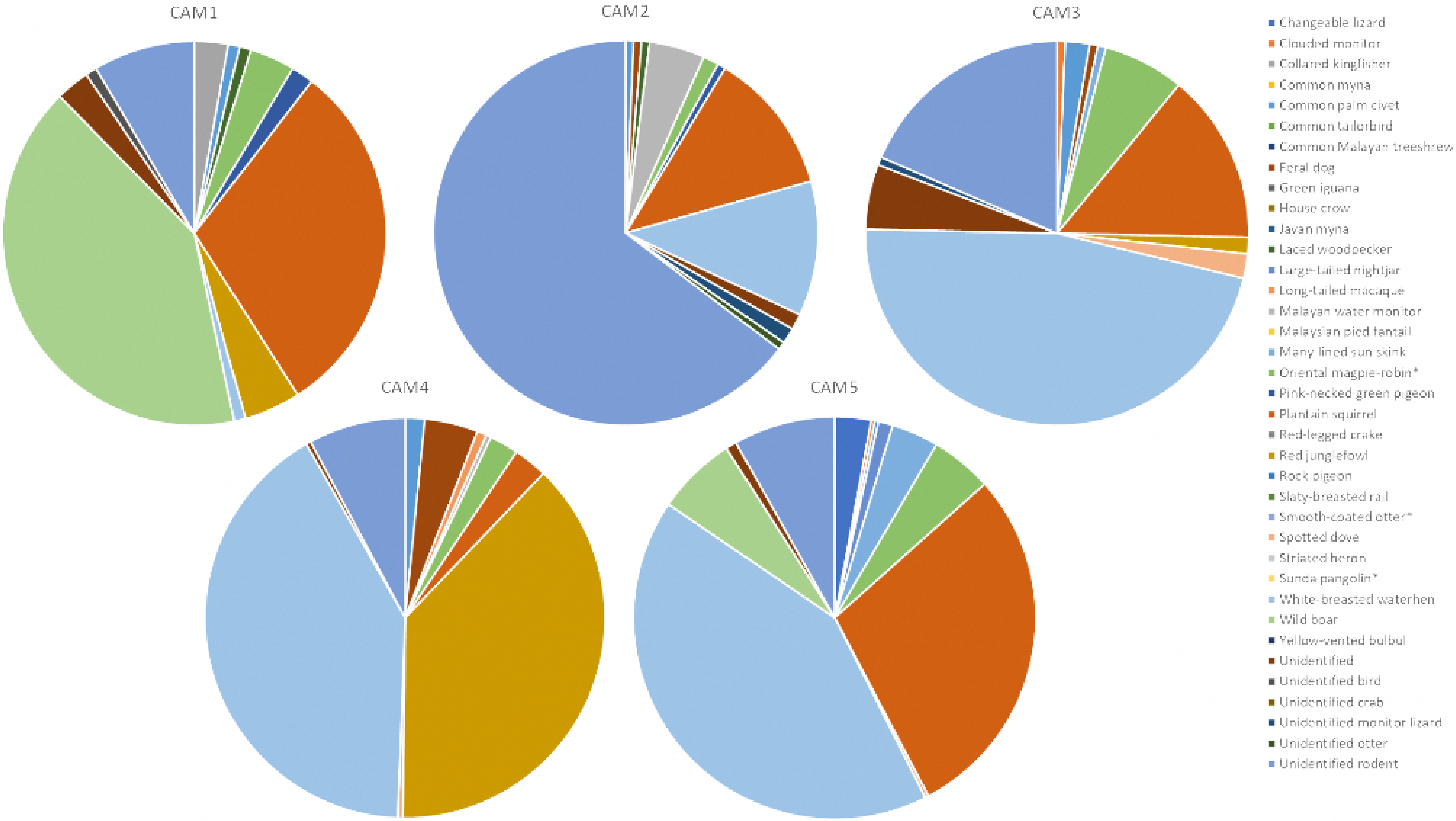


Figure 5-47. Composition of species in Cameras 1 to 5

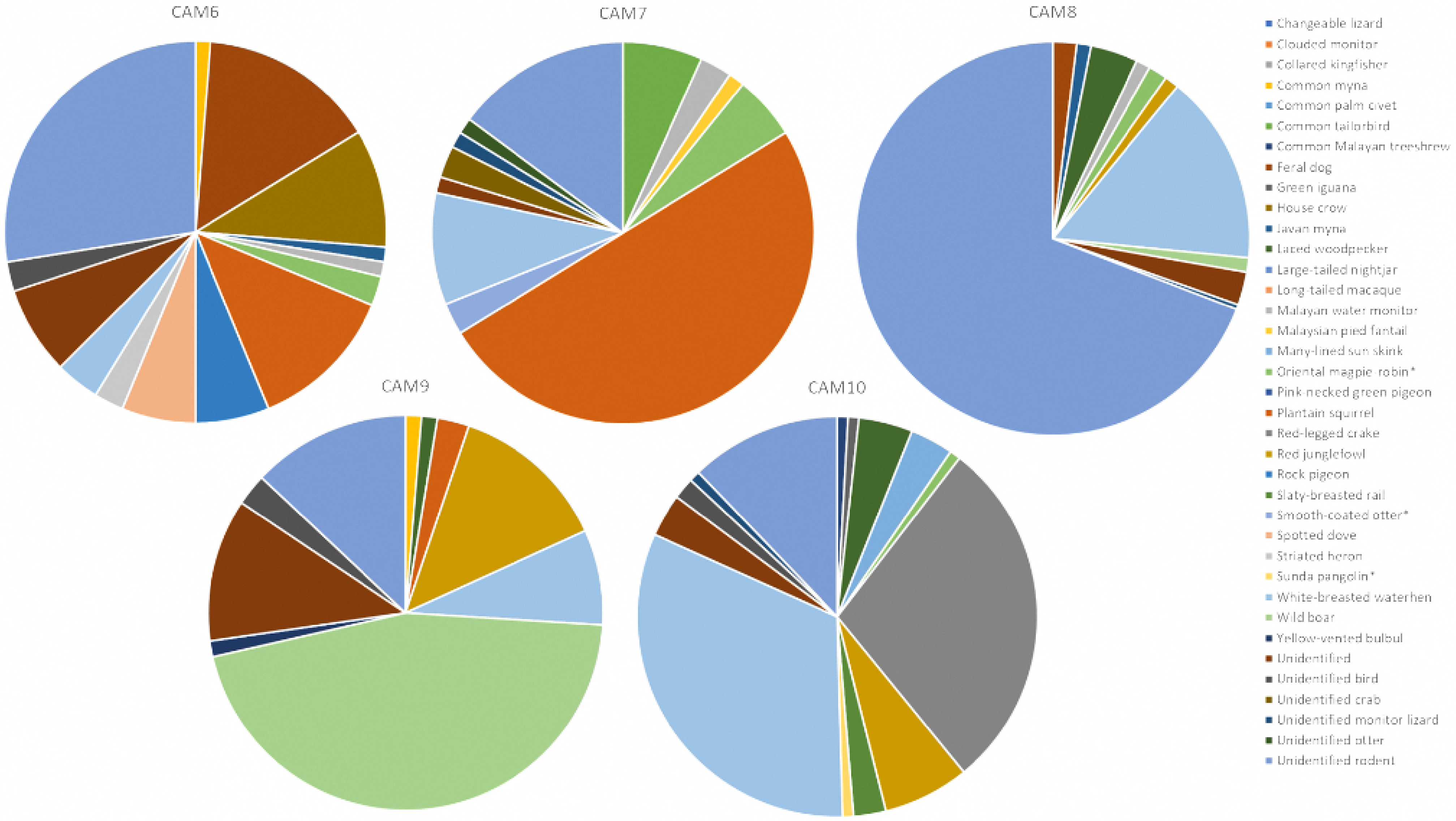


Figure 5-48. Composition of species in Cameras 6 to 10

5.4.3 *Marine Flora Survey Results*

The mudflat area was surveyed in August – October 2022 during periods of low tide. The survey results (Figure 5-49 and Table 5.20) and summary of the locations of the marine flora survey transects are presented in Table 5.19 below.

Table 5.19 Summary of marine flora survey transects

Date	Transect	Start		End	
		Long	Lat	Long	Lat
15 Aug 2022	T2	103.7556	1.4386	103.7555	1.4395
15 Aug 2022	T3	103.7529	1.4382	103.7526	1.4391
16 Aug 2022	T1	103.7608	1.4388	103.7605	1.4397
29 Aug 2022	T4	103.7474	1.4384	103.7477	1.4392
10 Oct 2022	T5	103.7381	1.4406	103.7386	1.4413

The mudflat area comprises mainly of abiotic components such as mud (74.02 ± 23.30%) (mean ± SE) and sand (86.76 ± 19.58%), while biotic components made up only 6.01% of the benthos, out of which the most dominant is macroalgae. Red algae (*Rhodophyta*) and green algae (*Chlorophyta*) were present, with red algae having the highest percentage cover (5.36 ± 9.08). Other biotic components recorded include one species of seagrass, the locally endangered Beccari's seagrass *(Halophila beccarii*) which was observed at the area fronting the mudflat during the survey. The percentage cover of major benthic components is presented in Figure 5-49 below.

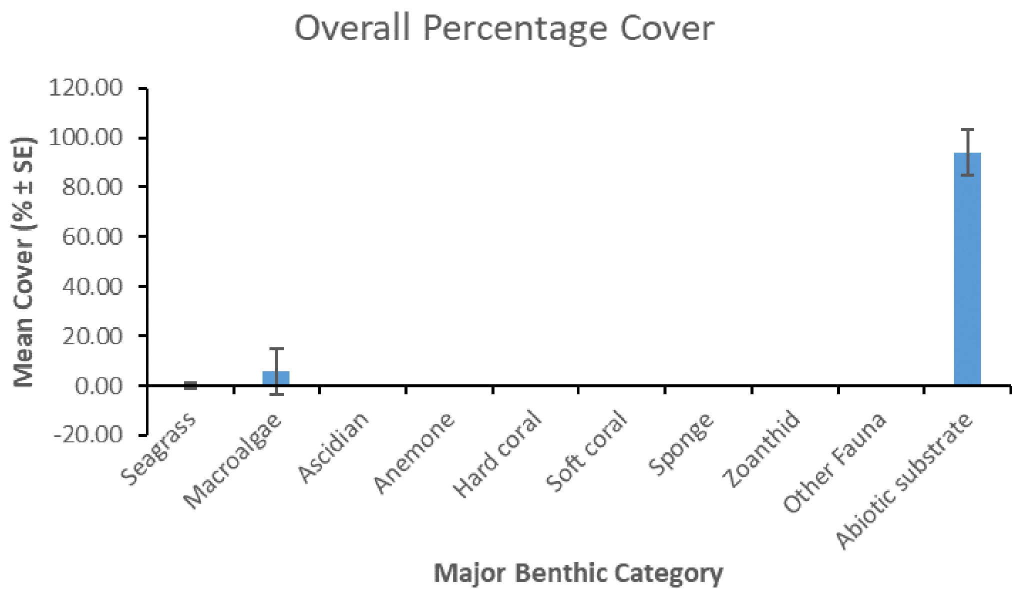


Figure 5-49. Mean percentage cover of major benthic components within the mudflat zone at Kranji.

Table 5.20. Mean percentage cover of the functional groups observed within the mudflats at Kranji

Benthic Category	Species / Type	Mean Percentage Cover (%)	S.E.
Seagrass	*Halophila beccarii*	0.16	1.12
Macroalgae	*Chlorophyta*	0.48	1.71
	Rhodophyta	5.36	9.08
Abiotic	Sand	86.76	19.58
	Mud	74.02	23.30

5.4.4 Marine Fauna Survey Results

Visual Quadrat Transect Survey

Three fauna classes were recorded during the visual quadrat transect survey at the mudflats of Kranji (Table 5.21). Bivalves were the most observed, at 1396.73 ± 1359.44 individuals/m^2. This was followed by gastropods, which was present in lower densities of less than 5 individuals/m^2. It was noted that snail-hitching anemones were found stuck onto shells of marine snails such as creeper snails. A checklist of all fauna species that occurred within the muddy intertidal area fronting Kranji Mudflat is presented in Table 5.21.

These were observed during the survey as well as during a general biodiversity survey of the entire area. A total of 26 species were observed, including the locally vulnerable mangrove horseshoe crab (*Carcinoscorpius rotundicauda*). Representative photos of the survey area are shown Figure 5-51.

Table 5.21. Mean density of individuals per faunal class found within the mudflat zone at Kranji

Functional Group	Density(No./m^2)	StDev	SE
Barnacles	0.00	0.00	0.00
Shrimp	0.00	0.00	0.00
Crab	0.00	0.00	0.00
Spiders	0.00	0.00	0.00
Sea Cucumber	0.00	0.00	0.00
Sea Urchin	0.00	0.00	0.00
Seastar	0.00	0.00	0.00
Brittlestar	0.00	0.00	0.00
Bivalves	1396.73	2354.62	1359.44
Gastropods	4.95	10.95	6.32
Others	0.00	0.00	0.00
Tubeworm	0.00	0.00	0.00
Others	0.00	0.00	0.00
Snail-hitching anemone	3.90	11.72	6.77

Table 5.22. A checklist of the diversity of fauna observed within the mudflat zone at Kranji. VU: Vulnerable. Species marked with N.A. are not listed in the Singapore Red Data Book and have not been accorded a status. *Refers to tentative/ speculative identification

Class	Genus / Species	Common name	Local Status	Global Status
Anthozoa	*Paraiptasia radiata*	Snail-hitching anemone	-	-
	Order Ceriantharia	Common ceranthid	-	-
Cirripedia	*Balanus* sp.	Acorn barnacle	-	-
Bivalvia	*Mytella strigata*	American mussel	-	-
	Diplodonta sp. (Family Ungulinidae)	-	-	-
	Geloina expansa	Lokan clam	-	-
	Arcuatula senhousia	Nest mussel	-	-
	*Austriella corrugata**	-	-	-
	Mytilopsis sallei	Black-striped mussel	-	-
	*Marcia recens**	-	-	-
	Geloina sp.	-	-	-
	*Coecella horsfieldii**	-	-	-
	Anadara sp.	'See-hum'	-	-
	Paphia sp.*	Saltwater clam	-	-
Gastropoda	*Telescopium telescopium*	Rodong snail	-	LC
	Nerita articulata	Lined nerite snail	-	LC
	Cerithium coralium	Mud creeper	-	-
	Littoraria sp.	Mangrove periwinkle snail	-	-
	Thais sp.	Elegant drill	-	-
	Littoraria melanostoma	Black-mouth mangrove periwinkle snail	-	-
	Assiminea sp.	Red berry snail	-	-
	Family Onchidiidae	Onch slug	-	-
	Chicoreus capucinus	Mangrove murex	-	-
Malacostraca	*Selatium brockii*	Mangrove tree-dwelling crab	-	-
	Diogenes sp.	Tidal hermit crab	-	-
Merostomata	*Carcinoscorpius rotundicauda*	Mangrove horseshoe crab	VU	DD

Figure 5-50. Location of marine fauna species of conservation value within the project area

	
Overview	
 Beccarri’s seagrass, *Halophila beccarii*	 Nests of American mussels, *Mytella strigata*
 Mangrove horseshoe crab, *Carcinoscorpius rotundicauda*	 Mangrove tree-dwelling crab, *Selatium brockii*

 Acorn barnacle, *Balanus* sp.	 Rodong snail, *Telescopium telescopium*
 Elegant drill, *Thais* sp.	 Mangrove murex, *Chicoreus capucinus*
 Brown sargassum shell, *Littoraria melanostoma*	 Onch slug, Family *Onchidiidae*

Figure 5-51. Representative photos of the mudflat area at Kranji.

Invertebrate Benthic Fauna Sampling

The surveys were conducted on both the sandy shores bordering SBWR as well as the mudflats of Kranji coastline. The objective of the survey was to establish the baseline condition of the benthic community. The benthic fauna survey consisted of five transects with 3 stations each, namely at the start (0 m), mid (50 m) and end (100 m) of each respective transect (Figure 5-11). Surveys was conducted in September – October 2022 during low tide (Table 5.23). The survey findings are summarised in the following sections.

Table 5.23. Summary of benthic fauna survey station locations

Date	Transect	Point (m)	Coordinates	
			Longitude	Latitude
12 Sep 2022	T5	0	103.7381	1.4406
		50	103.7383	1.4410
		100	103.7386	1.4413
13 Sep 2022	T2	0	103.7556	1.4386
		50	103.7556	1.4391
		100	103.7555	1.4395
13 Sep 2022	T3	0	103.7529	1.4382
		50	103.7527	1.4387
		100	103.7526	1.4391
14 Sep 2022	T1	0	103.7608	1.4388
		50	103.7606	1.4393
		100	103.7605	1.4397
10 Oct 2022	T4	0	103.7474	1.4384
		50	103.7475	1.4388
		100	103.7477	1.4392

<u>Density</u>

A total of 1,487 individual organisms were recorded from the 15 sampling stations in the benthic fauna surveys (Figure 5-11). There was an overall mean density of 389.58 ± 153.55 individuals/m^2, with T4 having the highest mean density of organisms (Table 5.24), at 1,063.68 individuals/m^2. Organism mean densities at other stations within transects ranged from 131.00 to 261.99 individuals/m^2.

A total of four taxonomic classes were recorded: Bivalvia, Polychaeta, Oligochaeta and Gastropoda. The most dominant class of organisms was Bivalvia at all transects, with a mean density of 1,382.27 ± 727.01 individuals/m^2, which consisted of mussels and clams (Table 5.24; Figure 5-52). This was followed by organisms from the class Polychaeta, with a mean density of 155.10 ± 105.59 individuals/m2, which consisted of bristle worms (Table 5.25; Figure 5-52). Organisms from the class Oligochaeta had the lowest density of individuals, with a mean of 19.91 ± 8.18 individuals/m^2.

Table 5.24. Summary of benthic fauna density distribution across the sampling locations

Taxonomic Class	Density (individuals/m²)					Mean	SD	SE
	T1	T2	T3	T4	T5			
Bivalvia	1,006.05	791.21	513.50	4,254.74	345.83	1,382.27	1,625.65	727.01
Polychaeta	5.24	214.83	10.48	-	544.94	155.10	236.10	105.59
Oligochaeta	5.24	-	-	-	-	1.05	2.34	1.05
Gastropoda	31.44	36.68	-	-	31.44	19.91	18.30	8.18
Mean	261.99	260.68	131.00	1,063.68	230.55			
SD	583.08	439.91	247.76	2,483.03	441.64			
SE	168.32	168.32	168.32	168.32	168.32			

Biomass

The overall mean biomass of benthic fauna in the mudflats of the project area is 59,137.31 ± 44,905.29 g DW/m^2, with T4 having the highest mean biomass of organisms (Table 5.25), at 278,479.54 g DW/m^2. Organism mean densities at other stations within transects ranged from 2,241.02 to 6,601.05 g DW/m^2. Representative photos of the taxonomic classes observed are presented in Figure 5-52.

Table 5.25. Summary of benthic fauna biomass distribution across the sampling locations

Taxonomic Class	Density (individuals/m²)					Mean	SD	SE
	T1	T2	T3	T4	T5			
Bivalvia	18,682.51	26,376.65	8,963.22	1,113,918.16	14,542.25	236,496.56	490,534.69	219,373.78
Polychaeta	0.00	0.00	0.86	-	51.03	8.69	23.94	10.71
Oligochaeta	0.74	-	-	-	-	0.15	0.33	0.15
Gastropoda	156.52	35.70	-	-	27.00	43.84	64.98	29.06
Mean	4,709.88	6,601.05	2,241.02	278,479.54	3,655.07			
SD	13,554.55	21,048.64	4,172.21	763,233.83	12,436.34			
SE	3,912.86	3,912.86	3,912.86	3,912.86	3,912.86			

Bivalvia

Polychaeta | **Oligochaeta**

Gastropoda

Figure 5-52. Representative photos from the four groups of fauna recorded

Class Bivalvia could be found in highest abundance across all sampling sites, especially at T4 near the demolished old charcoal jetty which has significantly high abundance of live mussels (Figure 5-53) most of which are the opportunistic nest mussel (*Arcuatula senhousia*) and the invasive American mussel (*Mytella strigata*). The latter is native to Central and South America and was known to have invaded large areas of Johor Strait since 2016 (Lim et al., 2018). Currently, it has established populations and is dominating the intertidal areas of Johor Straits (Lim et al., 2018), including the MMM. The large populations of *Mytella strigata* potentially explain the low numbers of horseshoe crab encountered as the dense mats of the American mussel affect the mobility of horseshoe crabs and prevent them from burrowing.

Class Polychaeta could be found in most transects except T4 (which was dominated by mussels) and was dominant in T5. It was noted that T5 is the only site that has sandy banks, near the coastline of Kranji Coastal Nature Park, while the rest were characterized by soft, muddy sediments. Polychaetes are abundant on Singapore shorelines and act as a food source for many faunal species higher up the food chain, e.g., shorebirds. However, their numbers have been affected by human activities such as land reclamation and pollution (Lu et al., 2002).

The remaining taxonomic groups were found in low numbers (n <10) in various transects.

Figure 5-53. Dense mats of bivalves along T4.

The past study conducted by TAC (2020), noted that T2 had almost no live benthic invertebrate fauna at all except for polychaetes near the mangroves, potentially caused by unusually high pulse loading of organic matter or by sudden changes in redox conditions or pH (e.g., from local discharges). The current study however has recorded three out of the four taxonomic classes observed along the same transect which suggests the habitat conditions may have improved as compared to 2019. Also, the 2019 study had collected crabs and hermit crabs both of which were absent in the benthic samples of the current study. Nonetheless, there were sightings of crabs and hermit crabs along the mudflats.

5.5 Summary of Biodiversity Findings

5.5.1 Fauna Species of Conservation Significance

Combining all the surveys conducted in the current study, there were 24 fauna species of local conservation value (defined as vulnerable and above) recorded. These include 19 bird, three mammal, one reptile, and one horseshoe crab species. All the amphibians, butterflies, odonates, fish, crustaceans, and molluscs found in the current survey were either listed as near threatened or below or had no assessed conservation status. Together with an additional 33 species (28 birds, one reptile, one mollusc, two crustaceans, one horseshoe crab) that were found from previous studies (NParks, 2007; Lim & Lim, 2009; Lim et al., 2009; Lim & Chew, 2010; TAC, 2020), a total of 57 fauna species of local conservation significance are known in the current project area.

Figure 5-54 shows the breakdown of local conservation statuses for each taxonomic group. Species with status as data deficient or not evaluated or not applicable or no status is marked in grey. The group for “Others” includes other benthic macrofauna, insects, and spiders that were not included in any of the specific taxonomic groups.

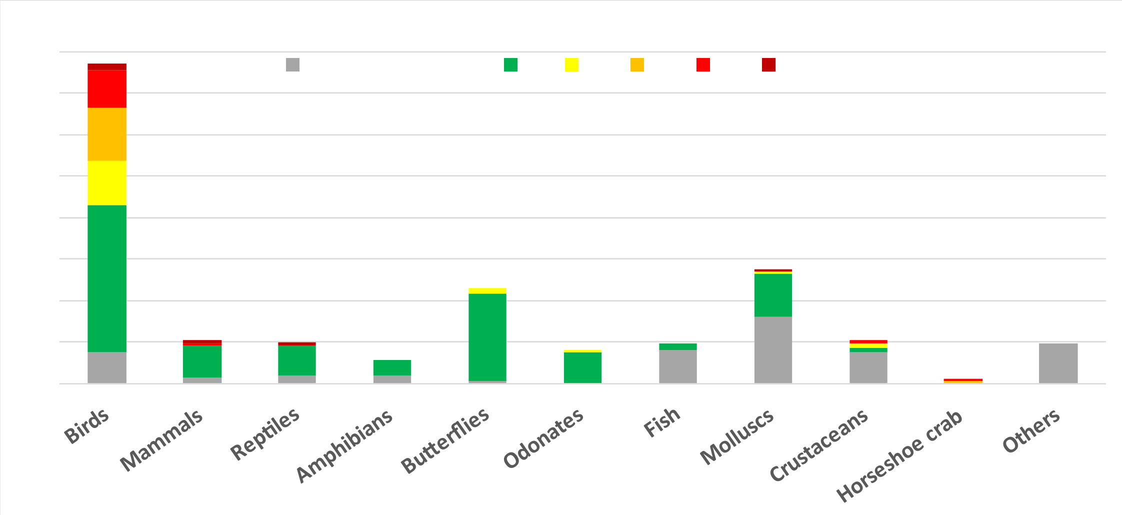


Figure 5-54. Local conservation status overview of all species recorded within the project area

The surveys also recorded nine species of global conservation significance (defined as vulnerable and above) based on the IUCN Red List (IUCN, 2021). These include six bird and three mammal species. All the reptiles, amphibians, butterflies, odonates, and aquatic fauna found in the current survey were either listed as near threatened or below or had no assessed conservation status. With three additional bird species from previous studies (NParks, 2007; Lim & Lim, 2009; Lim et al., 2009; Lim & Chew, 2010; TAC, 2020), a total of nine fauna species of global conservation significance are known in the current project area. Fauna not identified to species level have been excluded from this analysis. The breakdown of global conservation statuses for each taxonomic group can be found in Figure 5-55 below.

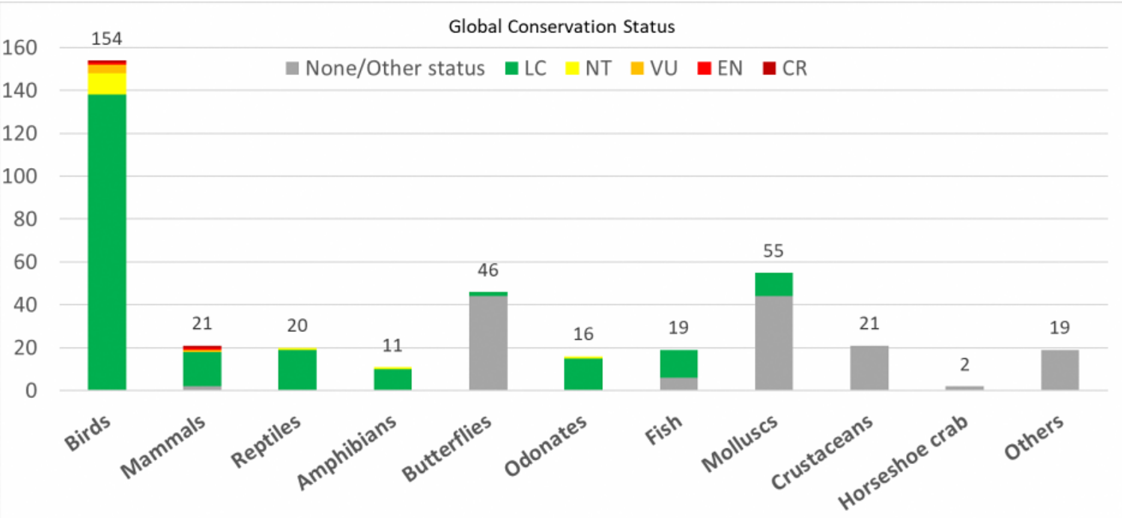


Figure 5-55. Global conservation status overview of all species recorded within the project area

The locations of threatened species found in the project area are overlaid on habitat maps and presented in Figure 5-56. The habitat maps were provided by NParks (2022).

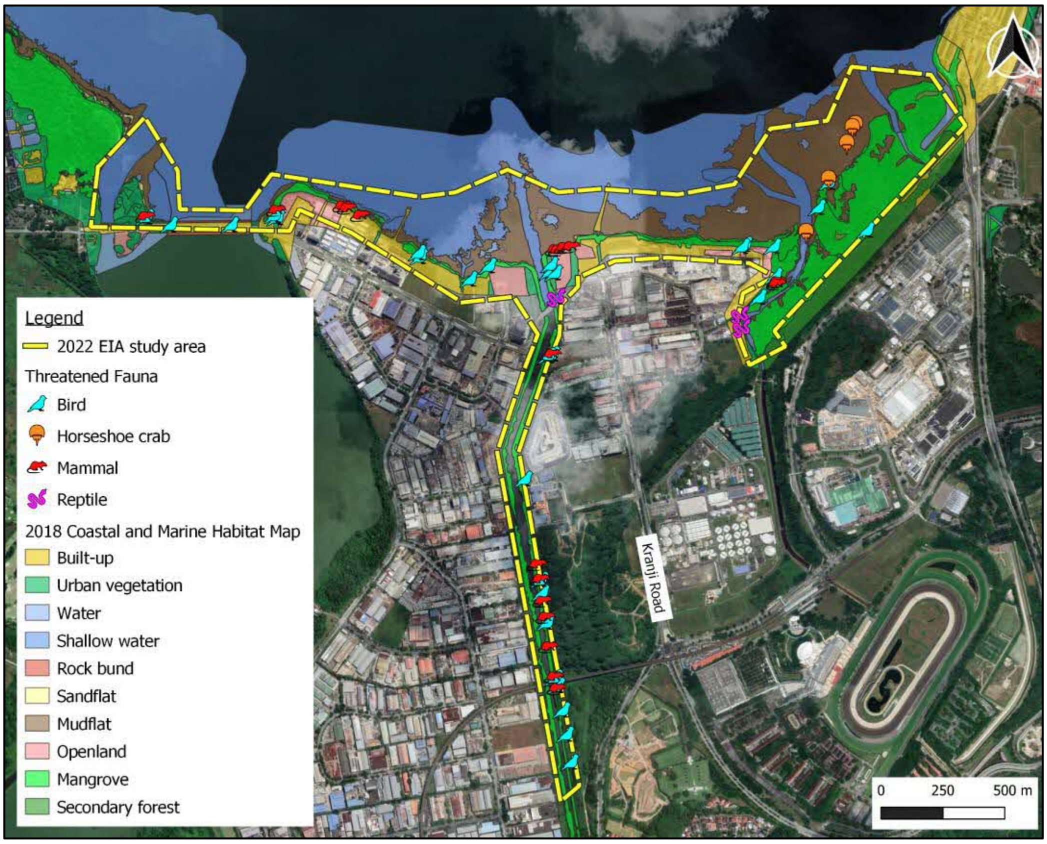


Figure 5-56. Locations of threatened species in project area overlayed on habitat maps (NParks, 2022)

While majority of the threatened species were bird species, there were also threatened species from other taxonomic groups such as mammals, reptiles, molluscs, crustaceans, and horseshoe crabs. As seen in Figure 5-56, many of the threatened species are found within mangrove habitats. This not only shows the diversity of fauna species supported by a mangrove habitat, but also the importance of the mangrove ecosystem.

Many of these conservation significant species (e.g., horseshoe crabs and mud lobsters) depend on brackish water habitats to survive. However, given the extent of coastal development in Singapore, and the threat of sea-level rise causing mangroves to retreat inland (Ellison, 2015), the intertidal habitats are threatened in Singapore.

With this site containing forested and mangrove habitat, as well as being the most extensive mudflat habitat on mainland Singapore, this project area is thus important for the continued protection of rare and threatened species in Singapore.

5.5.2 Summary of Flora and Fauna Baseline

The current study and previous studies (NParks, 2007; Lim & Lim, 2009; Lim et al., 2009; Lim & Chew, 2010; TAC, 2020) observed a total of at least 129 terrestrial and mangrove flora species and 384 terrestrial and aquatic fauna species (birds, mammals, reptiles, amphibians, butterflies, odonates, fish, decapod crustaceans, and molluscs) within the project area. In the marine environment, one seagrass species and at least 2 macroalgae taxons were recorded. The Comprehensive Marine Biodiversity Survey of Singapore was conducted on Mandai's benthic macroinvertebrates and identified hundreds of species, deeming the tidal mudflat to be one of the best of such habitat type in Singapore (NParks, 2010).

The current biodiversity surveys employed different methods, including visual transects, camera trapping, bat acoustic surveys, hand-netting and baited traps, to capture the diversity of flora and fauna species on site. The survey also replicated mangrove health assessments conducted in 2019 to document the health of the mangroves, the cover, shoot density and biomass of seagrass, and the density and biomass of benthic fauna inhabiting the intertidal mudflats. Together with existing literature and data available on the site, it is evident that the project area is one of high conservation significance.

Mandai Mangrove and Mudflat represents one of the last remaining areas in Singapore with significant tracts of healthy mangroves, secondary forest, and intertidal mudflats. The results of the desktop literature review and field survey show that the site has a diverse and unique biodiversity and is significant for the conservation of a variety of locally and internationally rare and threatened flora and fauna species.

Floristically, the site is known to contain individuals of locally threatened mangrove tree species such as locally critically endangered *Sonneratia caseolaris*, and endangered *Lumnitzera littorea;* threatened mangrove and mangrove associates such as *Finlaysonia obovata* and *Barringtonia racemosa* (both locally critically endangered); and other mangrove associates often found in secondary forest such as *Calophyllum inophyllum*, *Ardisia elliptica*, and *Millettia pinnata*, all being locally endangered. The transition between mangroves and mudflats also shows dense and extensive patches of a globally threatened species of seagrass, *Halophila beccarii*.

In terms of fauna, the importance of this site to shorebirds, both migratory and resident, has long been established (Lim & Posa, 2014). This site also contains threatened species of various other taxonomic groups, including mammals and reptiles. As noted by Cartwright-Taylor et al. (2011), Mandai Mangrove and Mudflats hosts the last known breeding populations of *Carcinoscorpius rotundicauda* and *Tachypleus gigas* on the main island of Singapore, making it both locally and regionally important for the conservation of both horseshoe crab species.

Beyond the conservation of individual species, it is important to allow for the continued interactions between species to maintain the ecological integrity of the site. The survival of many species in this site is dependent on that of other species. Several such examples were discussed in TAC (2020), including the role of crustaceans as a link between plant material and animals higher up on the food chain, the importance of polychaetes and other benthic macrofauna as a food source for shorebirds, and the utilisation of mud lobster mounds by many other fauna species as habitats. Impacts on one group of organisms may lead to cascade effects on other groups in the ecosystem.

Previous studies have found that to support a range of different shorebirds, it is important to conserve a variety of habitats with different sediment and elevation characteristics. This will allow for the site to support shorebirds with diverse foraging styles and prey preferences (VanDusen et al., 2012). The Mandai Mangrove and Mudflat is particularly unique in that it offers an intact continuum of secondary forest to back-mangroves to mid-mangroves to fringing mangroves to intertidal mudflat, traversed by several smaller rivers that end in the Johor Straits. It may be one of the few sites in Singapore that has the transition between adjacent habitat types still intact and will be protected as one continuum within a single Nature Park. The heterogenous habitats present in the project area allow for a range of different species to survive in the Nature Park.

5.6 Impact Assessment

The pre-construction, construction, and operation phases of the Mandai Mangrove and Mudflat Nature Park development could have a range of impacts on the ecology of the project area. Based on the proposed spatial layout plan (Figure 2-5), the environmental scoring for the residual impacts for each impact component (after accounting for the recommended mitigation measures) according to the RIAM was Slight Negative, except for habitat enhancement during the operation phase which was scored as Slight Positive.

5.6.1 Predicted Impacts

This section summarises the potential impacts affecting biodiversity receptors that may take place during the pre-construction, construction, and Operation phases. As shown in Table 5.31, all proposed development features are considered according to its location and associated impacts.

RIAM Environmental Scoring for the Predicted Impacts

Table 5.26. Predicted biodiversity impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance • Hoarding installation • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Ecological connectivity loss	1	-2	2	2	2	-12	Slight Negative
				Habitat loss due to vegetation clearance for temporary working areas and hoarding	1	-2	2	2	2	-12	Slight Negative
				Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative
				Species mortality	1	-2	2	2	2	-12	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Changes in soil and topography	3	-2	3	3	3	-54	Minor Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Ecological connectivity loss	2	-2	3	2	3	-32	Slight Negative
				Habitat loss	3	-2	3	2	3	-48	Minor Negative
				Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Roadkill	1	-3	2	2	2	-18	Slight Negative
				Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative
				Species and habitat disturbance	3	-2	2	2	3	-42	Minor Negative
				Species mortality	3	-2	2	2	2	-36	Slight Negative
				Coastal restoration	2	+1	2	2	3	+14	Slight Positive
				Habitat enhancement	2	+2	3	3	3	+36	Slight Positive

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Human-wildlife conflict	2	-3	3	2	1	-36	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Species and habitat disturbance (e.g., light, noise)	2	-2	2	2	2	-24	Slight Negative
				Coastal restoration	2	+1	2	2	3	+14	Slight Positive
				Habitat enhancement	2	+2	3	3	3	+36	Slight Positive
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Impact on mangrove biodiversity due to sediment dispersion	1	-2	2	2	3	-14	Slight Negative
				Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	1	-2	2	2	3	-14	Slight Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	1	-3	2	2	2	-18	Slight Negative
				Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative
				Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Light Pollution	1	0	2	2	2	0	No Impact
				Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance • Hoarding installation • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Impact on mangrove biodiversity due to sediment dispersion	1	-2	2	2	3	-14	Slight Negative
				Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Changes in soil and topography	2	-2	3	2	2	-28	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Human-wildlife conflict	1	-3	2	2	2	-18	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	2	-3	2	2	2	-36	Slight Negative
				Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative
				Species and habitat disturbance	2	-3	2	2	3	-42	Minor Negative
				Species mortality	2	-3	2	2	2	-36	Slight Negative
				Coastal restoration	2	+2	2	2	3	+28	Slight Positive
				Habitat enhancement	2	+2	2	2	3	+28	Slight Positive

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative
				Light Pollution	2	-2	2	2	2	-24	Slight Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Coastal restoration	2	+2	2	2	3	+28	Slight Positive
				Habitat enhancement	2	+2	2	2	3	+28	Slight Positive
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Habitat loss	2	-2	2	2	2	-24	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-30	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	1	-2	2	2	2	-12	Slight Negative
				Soil erosion, runoff and silty discharge	3	-3	2	2	3	-63	Minor Negative
				Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
				Coastal restoration	2	+2	2	2	2	+24	Slight Positive

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Human-wildlife conflict	2	-3	2	2	3	-28	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative
				Roadkill	1	-1	2	2	2	-6	No Impact
				Soil compaction	2	-2	2	2	2	-24	Slight Negative
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Coastal restoration	2	+2	2	2	2	+24	Slight Positive
				Habitat enhancement	2	+2	2	2	2	+24	Slight Positive
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Habitat loss	1	-2	3	2	2	-14	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	1	-2	2	2	2	-12	Slight Negative
				Soil erosion, runoff and silty discharge	3	-3	2	2	3	-63	Minor Negative
				Species and habitat disturbance	2	-3	2	2	3	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Species mortality	2	-3	2	2	2	-36	Slight Negative
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Roadkill	1	-1	2	2	2	-6	No Impact
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Habitat loss (Terrestrial)	2	-2	2	2	2	-24	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Soil erosion, runoff and silty discharge	3	-3	2	2	3	-63	Minor Negative
				Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
				Coastal restoration	2	+1	2	2	3	+14	Slight Positive

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Habitat enhancement (Intertidal)	2	+2	2	2	3	+28	Slight Positive
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative
				Soil compaction	2	-2	2	2	2	-24	Slight Negative
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Habitat loss (Terrestrial)	2	-2	2	2	2	-24	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative
				Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative
				Coastal restoration	2	+2	2	2	3	+28	Slight Positive
				Habitat enhancement (Intertidal)	2	+2	2	2	3	+28	Slight Positive
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship	Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Small vehicle deployment for maintenance works • Enhancement planting	Soil compaction	2	-2	2	2	2	-24	Slight Negative
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Habitat enhancement	2	+1	2	2	3	+14	Slight Positive
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Habitat loss	2	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	1	-3	2	2	2	-18	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative
				Species and habitat disturbance	2	-3	2	2	3	-42	Minor Negative
				Species mortality	2	-3	2	2	2	-36	Slight Negative
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Species and habitat disturbance	2	-3	2	2	2	-24	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Edge effect	1	-1	3	2	2	-7	Slight Negative
				Habitat loss	2	-2	2	2	2	-24	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	4	-2	2	2	3	-56	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	2	-2	2	2	2	-12	Slight Negative
				Soil erosion, runoff and silty discharge	2	-2	2	2	3	-28	Slight Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works	Edge effect	1	-1	3	2	2	-7	Slight Negative
				Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Enhancement planting	Roadkill	1	-1	2	2	2	-6	No Impact
				Soil compaction	1	-1	2	2	2	-6	No Impact
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative
				Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Edge effect	1	-1	3	2	2	-7	Slight Negative
				Habitat loss	2	-3	2	2	2	-36	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	2	-2	2	2	2	-12	Slight Negative
				Soil erosion, runoff and silty discharge	2	-3	2	2	3	-42	Minor Negative
				Species and habitat disturbance	2	-3	2	2	2	-24	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works	Edge effect	1	-1	3	2	2	-7	Slight Negative
				Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Marine litter and plastic pollution	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Enhancement planting	Roadkill	1	-1	2	2	2	-6	No Impact
				Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation • Coastal cleanup	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative
				Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative
				Human-wildlife conflict	1	-1	2	2	2	-6	No Impact
				Roadkill	1	-2	2	2	2	-12	Slight Negative
				Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative
				Species and habitat disturbance	1	-2	2	2	3	-14	Slight Negative
				Habitat enhancement	1	+2	2	2	2	+12	Slight Positive
				Removal of invasive species	1	+1	3	2	3	+8	Slight Positive
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter	Human-wildlife conflict	1	-1	2	2	2	-6	No Impact
				Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Marine litter and plastic pollution	2	-3	2	2	2	-36	Slight Negative
				Roadkill	1	-2	2	2	2	-12	Slight Negative
				Species and habitat disturbance	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Enhancement planting	Habitat enhancement	1	+2	2	2	2	+12	Slight Positive
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation • Coastal cleanup	Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Species mortality	2	-3	2	2	2	-36	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Changes in soil and topography	2	-1	2	2	2	-12	Slight Negative
				Edge effect	1	-1	3	2	2	-7	Slight Negative
				Habitat loss	2	-2	3	2	2	-28	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
				Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative
				Injury cause by tree falls	2	-2	2	2	2	-24	Slight Negative
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Roadkill	1	-2	2	2	2	-12	Slight Negative
				Soil erosion, runoff and silty discharge	2	-3	2	2	3	-42	Minor Negative
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits	Edge effect	1	-1	3	2	2	-7	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Small vehicle deployment for maintenance works • Enhancement planting	Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative
				Marine litter and plastic pollution	2	-3	2	2	2	-36	Slight Negative
				Soil compaction	2	-2	2	2	2	-24	Slight Negative
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative
				Habitat enhancement	2	+2	3	3	2	+32	Slight Positive
Boundary markers	Pre-construction	• Markers made up of rows of Bakau poles	• Vegetation clearance • Boundary marker installation	Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative
				Species mortality	2	-2	2	2	2	-24	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	• Maintenance works	Human-wildlife conflict	1	-1	2	2	2	-6	No Impact
				Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative
				Marine litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative
				Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative

Pre-Construction Phase

Vegetation Clearance
Prior to construction works, limited vegetation clearance will be carried out to facilitate installation of hoardings along project boundary. If necessary, clearance will also be conducted to create site access, storage space and working space.

Construction Phase

The project involves the removal of common coastal species such as Sea hibiscus (*Hibiscus tiliaceus*) and non-native species such as Lead tree (*Leucaena leucocephala*), removal of PCG fencing as well as coastal restoration works, which will result in direct impacts to the species and habitats present within the area. The following section details these impacts:

Species Disturbance, Habitat Disturbance, and Species Mortality
The pre-construction and construction activities may directly impact species mainly through vegetation clearance, and the movement of construction vehicles in the project area, which may inadvertently damage vegetation and crush small animals under its wheels.

For purpose of impact assessment, focus is given to species that are either rare or globally/locally threatened according to the local and international databases. Section 4.2 and Section 5.5 discussed the species composition of flora and fauna on the project area, many of which are threatened or rare in Singapore, as well as globally.

A portion of the infrastructure of the Nature Park will be located in sparsely vegetated areas. The proposed infrastructure i.e., Sungei Kranji Pavilion, Sungei Pang Sua Pavilion and Kranji Reservoir Dam pedestrian connection are to be located on existing land and minimal vegetation clearance is expected.

The largest areas of vegetation clearance predicted for this project are within backfill areas along the coastal trails. However, most of the species to be cleared are common mangrove associate species, including Sea Hibiscus stands (*Hibiscus tiliaceus*) and Sea Almond (*Terminalia catappa*) which dominate much of the coastline in the project area. Guidelines of salvaging mangroves of different sizes are provided in the mitigation measures outlined in section 16.4.1; smaller sized mangroves with less than 4cm DBH that falls within the development footprint can be transplanted if there is suitable transplanting destination.

Clearance of individual trees and shrub stands are expected along the Public Trail and Sungei Pang Sua trail. Some vegetation clearance will also be necessary for the construction of the Guided trail, and species affected will need to be ascertained during the detailed planning stage.

With current development plans, a total of 288 surveyed trees of 0.3m girth and above are expected to be affected by the development which includes trails and nodes. Out of the 288 trees, approximately 126 trees are located in the direct footprint of the infrastructure development and will likely be affected by the construction (Table 5.27);

whereas roughly 162 trees are in a 2 m buffer zone around the development and may be affected by construction (Table 5.28). A map of the affected 288 surveyed trees can found below (Figure 5-57). While critically endangered, Yellow flame (*Peltophorum pterocarpum*) and Kelat oil (*Syzygium myrtifolium*) are likely from cultivated origin as these species are commonly cultivated along roadside and parks and thus are of limited conservation significance.

Table 5.27. Plant species and estimated quantity within direct footprint of the development

Scientific Name	Local Status	Plants Affected
Acacia auriculiformis	Naturalised	1
Acanthus ilicifolius	Endangered	1
Avicennia alba	Least Concern	2
Avicennia rumphiana	Least Concern	1
Avicennia sp. (potentially Avicennia marina)	NA	1
Barringtonia cf. *racemosa*	Critically Endangered	1
Caryota mitis	Least Concern	2
Casuarina equisetifolia	Least Concern	2
Cocos nucifera	Naturalised	1
Dalbergia oliveri	Cultivated Only	5
Finlaysonia obovata	Critically Endangered	1
Hibiscus tiliaceus	Least Concern	19
Kirganelia reticulata	Data Deficient	1
Leucaena leucocephala	Naturalised	45
Millettia pinnata	Endangered	2
Mimusops elengi	Casual	1
Morinda citrifolia	Least Concern	1
Moringa oleifera	Cultivated Only	1
Musa acuminata	Cultivated Only	1
Nypa fruticans	Vulnerable	3
Peltophorum pterocarpum	Critically Endangered	3
Planchonella obovata	Least Concern	3
Pterocarpus indicus	Casual	1
Ptychosperma macarthurii	Naturalised	1
Samanea saman	Casual	10
Sonneratia alba	Least Concern	1
Spathodea campanulata	Naturalised	4
Swietenia macrophylla	Casual	2
Syzygium myrtifolium	Critically Endangered	5
Syzygium zeylanicum	Least Concern	1
Tabebuia rosea	Casual	1
Terminalia catappa	Least Concern	2
Total Plants Affected		126

Table 5.28. Plant species and estimated quantity within footprint of 2m buffer zone around development

Scientific Name	Local Status	Trees Affected
Acacia auriculiformis	Naturalised	3
Acacia mangium	Naturalised	1
Acanthus ilicifolius	Endangered	1
Ardisia elliptica	Least Concern	2
Avicennia alba	Least Concern	8
Avicennia sp. (potentially Avicennia marina)	NA	1
Calophyllum inophyllum	Endangered	2
Caryota mitis	Least Concern	3
Casuarina equisetifolia	Least Concern	1
Causonis trifolia	Data Deficient	1
Cecropia pachystachya	Naturalised	1
Cerbera sp.	NA	1
Cocos nucifera	Naturalised	2
Falcataria falcata	Naturalised	2
Ficus microcarpa	Least Concern	2
Ficus religiosa	Naturalised	1
Hibiscus tiliaceus	Least Concern	24
Kirganelia reticulata	Data Deficient	1
Leucaena leucocephala	Naturalised	58
Mangifera indica	Casual	3
Millettia pinnata	Endangered	1
Morinda citrifolia	Least Concern	1
Muntingia calabura	Naturalised	1
Musa acuminata	Cultivated Only	1
Peltophorum pterocarpum	Critically Endangered	1
Planchonella obovata	Least Concern	1
Pterocarpus indicus	Casual	1
Ptychosperma macarthurii	Naturalised	1
Sonneratia alba	Least Concern	1
Sonneratia caseolaris	Critically Endangered	2
Spathodea campanulata	Naturalised	10
Syzygium myrtifolium	Critically Endangered	1
Terminalia catappa	Least Concern	21
Unidentifiable	NA	1
Total Plants Affected		162

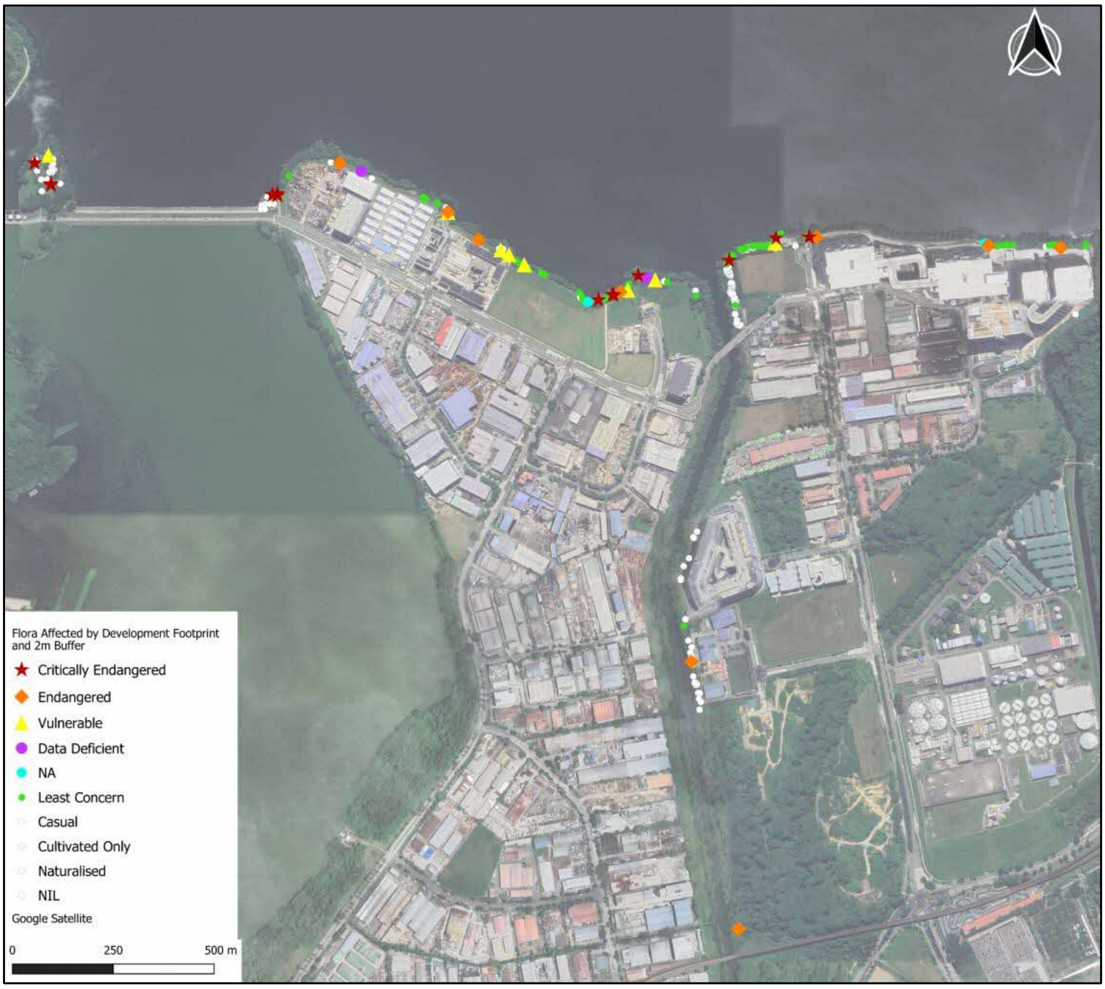


Figure 5-57. Location of plants being affected by the development

In total, 41 flora species of conservation value were found within the project area (Table 5.29). The list is indicative, subject to the final development footprint and ad-hoc site clearance to accommodate various construction needs. Proposed mitigation measures will be provided in Section 15.4.

Table 5.29. List of locally threatened flora species in the project area

S/N	Species Name	Historical Observation	2019 Observation	2022 Observation	Local Status[1]
1	*Acanthus ebracteatus*	✓	✓	✓	VU
2	*Acanthus ilicifolius*	✓	-	✓	EN
3	*Acanthus volubilis*	✓	-	-	EN
4	*Barringtonia asiatica*	-	✓	✓	CR
5	*Barringtonia racemosa*	-	-	✓	CR
6	*Brownlowia tersa*	✓	-	-	CR
7	*Bruguiera parviflora*	✓	-	-	EN
8	*Calophyllum inophyllum*	-	✓	✓	EN
9	*Causonis trifolia*	-	-	✓	DD
10	*Ceriops tagal*	✓	-	-	VU

S/N	Species Name	Historical Observation	2019 Observation	2022 Observation	Local Status[1]
11	*Ceriops zippeliana*	✓	-	✓	EN
12	*Cissus repens*	-	-	✓	VU
13	*Crinum asiaticum*	✓	-	-	CR
14	*Cynometra ramiflora*	-	-	✓	CR
15	*Cyrtococcum accrescens*	-	-	✓	VU
16	*Diospyros ferrea*	✓	-	-	NEx
17	*Dolichandrone spathacea*	✓	-	✓	CR
18	*Elaeodendron viburnifolium*	✓	-	-	CR
19	*Fimbristylis complanata*	-	-	✓	VU
20	*Finlaysonia obovata*	✓	✓	✓	CR
21	*Glochidion littorale*	✓	-	-	EN
22	*Halophila beccarii*	✓	✓	-	EN
23	*Heptapleurum ellipticum*	-	-	✓	EN
24	*Heritiera littoralis*	✓	-	✓	EN
25	*Intsia bijuga*	✓	-	-	CR
26	*Kirganelia reticulata*	-	-	✓	DD
27	*Lomariopsis lineata*	-	✓	-	EN
28	*Lumnitzera littorea*	✓	-	✓	EN
29	*Lumnitzera racemosa*	✓	-	✓	EN
30	*Merope angulata*	✓	-	-	CR
31	*Millettia pinnata*	✓	-	✓	EN
32	*Nypa fruticans*	✓	✓	✓	VU
33	*Peltophorum pterocarpum*	-	-	✓	CR
34	*Podocarpus polystachyus*	✓	-	-	EN
35	*Rhizophora stylosa*	✓	-	-	VU
36	*Scyphiphora hydrophylacea*	✓	-	-	EN
37	*Sonneratia caseolaris*	✓	-	✓	CR
38	*Sonneratia ovata*	✓	✓	-	CR
39	*Suregada glomerulata*	-	-	✓	CR
40	*Syzygium myrtifolium*	-	-	✓	CR
41	*Tristellateia australasiae*	✓	-	-	EN

[1] (Davison et al., 2008; Chong et al., 2009; Lindsay, et al., 2022; National Parks Board, 2023)

With regard to fauna species, there are several rare or threatened bird species that can be found on this site. Most species of conservation value found in the project area are volant (able to fly). These species include several bird species such as the critically endangered great-billed heron, black-tailed godwit or white-chested babbler (Table 5.30). Given these species can fly, they are likely able to use other similar habitats in the area.

Some of the non-volant species of conservation significance include the locally critically endangered nocturnal Sunda pangolin and estuarine crocodile; and the locally endangered smooth-coated otter. Possible nightworks within the area are likely to create species disturbance from artificial light sources, which alter natural cycles of light and dark. Additionally, nocturnal fauna species which rely on their hearing for movement, communication, and foraging, are vulnerable to increased night-time noise levels. If left unchecked, these impacts can negatively affect the ecosystem if not managed properly.

Fauna species, particularly reptiles (including the rare critically endangered mangrove skink) and amphibians, may also become entrapped when navigating through the worksite, especially by getting stuck in ECM blankets or falling into pits.

The project area contains several fauna species of conservation value (see Table 5.30).

Table 5.30. List of locally threatened fauna species in the project area

No.	Species Name	Common Name	Family	Past Observations	2022 Observation	Local Status
1	*Elanus caeruleus*	Black-winged Kite	Accipitridae	✓	-	VU
2	*Haliaeetus ichthyaetus*	Grey-headed Fish Eagle	Accipitridae	✓	✓	VU
3	*Nisaetus cirrhatus*	Changeable Hawk-eagle	Accipitridae	✓	✓	VU
4	*Acrocephalus orientalis*	Oriental Reed Warbler	Acrocephalidae	✓	-	VU
5	*Alcedo atthis*	Common Kingfisher	Alcedinidae	✓	-	VU
6	*Halcyon pileata*	Black-capped Kingfisher	Alcedinidae	✓	-	VU
7	*Apus nipalensis*	House Swift	Apodidae	✓	-	VU
8	*Ardea alba*	Great Egret	Ardeidae	✓	✓	VU
9	*Ardea purpurea*	Purple Heron	Ardeidae	✓	✓	EN
10	*Ardea sumatrana*	Great-billed Heron	Ardeidae	-	✓	CR
11	*Bubulcus coromandus*	Eastern Cattle Egret	Ardeidae	✓	-	VU
12	*Egretta eulophotes*	Chinese Egret	Ardeidae	✓	-	EN
13	*Egretta sacra*	Pacific Reef Heron	Ardeidae	✓	-	EN
14	*Nycticorax nycticorax*	Black-crowned Night Heron	Ardeidae	✓	✓	EN
15	*Charadrius dubius*	Little Ringed Plover	Charadriidae	✓	-	EN
16	*Pluvialis fulva*	Pacific Golden Plover	Charadriidae	✓	✓	VU
17	*Corvus macrorhynchos*	Large-billed Crow	Corvidae	✓	✓	VU
18	*Lanius cristatus*	Brown Shrike	Laniidae	✓	✓	VU
19	*Chlidonias leucopterus*	White-winged Tern	Laridae	✓	✓	EN
20	*Onychoprion aleuticus*	Aleutian Tern	Laridae	✓	-	VU
21	*Sterna sumatrana*	Black-naped Tern	Laridae	✓	-	EN
22	*Sternula albifrons*	Little Tern	Laridae	✓	-	EN
23	*Thalasseus bengalensis*	Lesser Crested Tern	Laridae	✓	-	EN
24	*Thalasseus bergii*	Greater Crested Tern	Laridae	✓	-	EN
25	*Motacilla tschutschensis*	Eastern Yellow Wagtail	Motacillidae	✓	-	VU

No.	Species Name	Common Name	Family	Past Observations	2022 Observation	Local Status
26	*Copsychus saularis*	Oriental Magpie-robin	Muscicapidae	✓	✓	VU
27	*Leptocoma calcostetha*	Copper-throated Sunbird	Nectariniidae	✓	-	VU
28	*Trichastoma rostratum*	White-chested Babbler	Pellorneidae	✓	-	CR
29	*Ploceus philippinus*	Baya Weaver	Ploceidae	-	✓	VU
30	*Pycnonotus zeylanicus*	Straw-headed Bulbul	Pycnonotidae	✓	✓	EN
31	*Actitis hypoleucos*	Common Sandpiper	Scolopacidae	✓	✓	VU
32	*Arenaria interpres*	Ruddy Turnstone	Scolopacidae	✓	-	EN
33	*Calidris falcinellus*	Broad-billed sandpiper	Scolopacidae	✓	-	VU
34	*Calidris ferruginea*	Curlew sandpiper	Scolopacidae	✓	-	EN
35	*Calidris tenuirostris*	Great Knot	Scolopacidae	✓	-	EN
36	*Limnodromus semipalmatus*	Asian Dowitcher	Scolopacidae	✓	-	VU
37	*Limosa lapponica*	Bar-tailed Godwit	Scolopacidae	✓	✓	VU
38	*Limosa limosa*	Black-tailed Godwit	Scolopacidae	✓	-	CR
39	*Numenius arquata*	Eurasian Curlew	Scolopacidae	✓	-	EN
40	*Tringa brevipes*	Grey-tailed Tattler	Scolopacidae	✓	-	VU
41	*Tringa glareola*	Wood Sandpiper	Scolopacidae	✓	-	EN
42	*Tringa nebularia*	Common Greenshank	Scolopacidae	✓	✓	VU
43	*Tringa stagnatilis*	Marsh Sandpiper	Scolopacidae	✓	-	EN
44	*Tringa totanus*	Common Redshank	Scolopacidae	✓	✓	VU
45	*Xenus cinereus*	Terek Sandpiper	Scolopacidae	✓	-	EN
46	*Ketupa ketupu*	Buffy Fish Owl	Strigidae	-	✓	VU
47	*Strix seloputo*	Spotted Wood Owl	Strigidae	-	✓	VU
48	*Taphozous longimanus*	Long-winged Tomb Bat	Emballonuridae	-	✓	CR
49	*Manis javanica*	Sunda Pangolin	Manidae	-	✓	CR
50	*Lutrogale perspicillata*	Smooth-coated Otter	Mustelidae	✓	✓	EN
51	*Crocodylus porosus*	Estuarine Crocodile	Crocodylidae	✓	✓	CR
52	*Emoia atrocostata*	Mangrove Skink	Scincidae	✓	-	CR
53	*Ellobium scheepmakeri*	Mangrove Land Snail	Ellobiidae	✓	-	CR
54	*Potamalpheops johnsoni*	Caridean shrimp	Alpheidae	✓	-	EN
55	*Thalassina sp.*	Mud Lobster	Thalassinidae	✓	-	EN
56	*Carcinoscorpius rotundicauda*	Mangrove Horseshoe Crab	Limulidae	✓	✓	VU
57	*Tachypleus gigas*	Coastal Horseshoe Crab	Limulidae	✓	-	VU

Changes in Soil and Topography

Vegetation plays an important role in soil stability. Where vegetation clearance has taken place, soil will be left vulnerable to erosion, particularly during rainy periods. Erosion leads to physico-chemical degradation of soil properties. Eroded soil may lead to siltation of streams and waterbodies. Runoff of nutrients in topsoil may lead to lowered nutrient levels of the remaining soil on the site. Erosion or siltation, if uncontrolled, may also indirectly impact areas beyond the project footprint.

Where there are planned earthworks within the project footprint, impacts to habitats, including streams and other localized habitats, and species are likely to be felt. For this project, several narrow areas along the trails will be backfilled and widened. The development of boardwalks in mangrove areas have also been shown to affect sediment compaction, pneumatophore densities, and mangrove macrofauna assemblages, in particular crab and bivalve densities in areas immediately adjacent to the boardwalks (Kelaher et al.; Kelaher et al.; Skilleter & Warren, 2000). However, the impact will be localised to a small area within the development (i.e. Sungei Pang Sua Pavilion) during the construction phase and can be mitigated with appropriate measures. Some segments of the proposed Guided trail and Public trail are located in vicinity or in mangrove zone (e.g. construction of concrete rings for slope protection at Profile B-2, Option 1, or boardwalks - Profile C & D, Option 2), which may at places lead to siltation of the pneumatophores. This may in turn lead to the burying of pneumatophores on the roots of mangrove species, thus causing oxygen stress. There is also a risk of heavy metal pollution from the use of certain wood-preservatives in the preservation of construction materials used in the construction of the boardwalks (Lebow & Foster, 2005).

Impacts on the biodiversity may go beyond the actual footprint of working boundaries due to indirect impacts caused by these works, and other associated earthworks including compaction and soil excavation.

Concretisation and sealing of surfaces (at the location of the two proposed pavilions etc.) could increase surface runoff which may result in increased soil erosion while facilitating the transport of any chemicals and nutrients from the concretised surface to the surrounding soil. The surface runoff may also contribute to increased nutrient, chemical levels or change in pH levels in the surrounding soils due to other substances on the concrete the surface runoff may collect. Additionally, sealing of surfaces could reduce groundwater recharge, thus affecting stream flow in adjacent streams.

Ecological Connectivity Loss and Habitat Loss

Vegetation clearance leads to the loss of habitat for fauna species. This will lead to a reduction of foraging habitat, food sources, roosting, breeding and nesting sites, and other resources needed for the continued survival of a species. This may also lead to the fragmentation of populations of the species living at the site. Ultimately, these impacts may lead to the reduced resilience and survivability of some of the species present in the project area.

Some vegetation clearance will be necessary along the proposed trails and in the direct project footprint of the pavilions. The Nature Park project however comprises also the component of habitat enhancement, especially around the Kranji Reservoir Park and pavilions, where the quality of the existing vegetation will be enhanced by mangrove, coastal forest species and urban vegetation at appropriate locations (Table 5.34).

Further for this project, it is important to address connectivity not just of terrestrial habitats, but also coastal and marine habitats. Disruption of connectivity may lead to reduced movement between populations. Such fragmentation of populations can in turn lead to reduced gene flow and local extinctions of species. There is currently a belt of mangrove habitats along the edge of the project area which connects the site to mangrove habitats east and west of the site. Also important is connectivity between habitats, including mudflat habitats to mangrove habitats, which in turn connect to secondary forest habitat on the landward edge of the project area. It is therefore important to preserve and restore the connectivity as much as possible in the landscape design.

For this project, coastal works are expected to be localised and short term and the site is a low-impact development with minimal clearance of vegetation. The trail is placed on predominantly sparsely vegetated areas, and a large majority of the trees being affected due to the development are not of conservation significance (see Figure 5-57). Furthermore, with its status as a Nature Park, priority will be placed on the preservation of sensitive habitats. With proper mitigation in place, impacts to habitats are expected to be minor and temporary.

Edge Effect

Besides the loss of habitat, vegetation clearance may also lead to indirect impacts such as the creation of edge effects, where forest edges are exposed to abiotic and biotic changes. These changes include increased light intensity and temperature, increased soil nutrient content, and changes in air and soil moisture levels. Edge effects may lead to changes in microclimate, forest structure, ecological interactions, and eventually gradual deterioration of habitats and changes in ecological communities in the areas adjacent to the proposed development.

However, current edge effects on the existing habitats in the project area have been high since industrial development and human activity became prevalent in the area for many decades. With minimal additional vegetation clearance in the current development, it is expected that additional edge effects will be negligible.

Human–Wildlife Conflict

The project area is also home to estuarine crocodiles, snakes and wild pigs, all of which may result in human-wildlife conflict during the construction phase. If measures are not taken to ensure that fauna species are not able to enter the working area, and that construction personnel are not trained on actions to take when occurring wildlife, injury to construction personnel or these fauna species is possible during the construction phase.

Impact on Mangrove Biodiversity due to Sediment Dispersion

Fringing mangroves and mangrove forest can be found within and bordering the coastlines of Mandai Mangrove and Mudflat. During construction phase, land-based developments (i.e., buildings, pavilions, and boardwalks) and intertidal works (i.e., revetment, terracing etc) could have sedimentation impacts on mangroves such as root smothering which can adversely affect mangrove health. If uncontrolled the tidal movement could potentially cause sediment to spread and affect a large area of mangrove habitat.

Injury caused by Tree Falls

The project area is fringed with mangroves and coastal vegetation and is densely vegetated along the banks of Sungei Pang Sua and Sungei Mandai Besar. During construction phase, impact by heavy machineries and encroachment of construction equipment into the Tree Protection Zones (TPZ) will affect tree health and cause impacted trees to become susceptible to tree falls. Furthermore, there is risk of tree injury due to inclement weather. People in the vicinity are prone to injuries should there be events of tree falls.

Introduction of Invasive Species

Invasive species have many impacts on biodiversity, including the displacement of native species (Peh, 2010), hybridisation of distinct populations (Vuillaume, 2015; Peh, 2010), and degradation of ecosystem services (Çinar, 2014).

In the case of construction activities, invasive plants are sometimes introduced through seeds embedded in construction equipment and the boots of construction personnel such as Lead Tree (*Leucaena leucocephala*), which forms persistent soil bank that aids in species dispersal with soil (Nghiem, Tan, & Corlett, 2015; Zhang, Shu, Lan, & Wong, 2001). Invasive plants and animals are also sometimes found in soil that is used for construction activities.

Roadkill

The project area is bounded by Kranji Road which is a source of heavy traffic. During the construction phase, traffic volume is also likely to increase from construction vehicles accessing the site. If mitigation measures are not taken, animals are likely to run out of the forest, particularly during periods of high disturbance such as tree-felling. This may lead to an increased incidence of roadkill, which has negative impacts on both the wildlife present on the site as well as drivers along the road.

Soil Erosion, Runoff, and Silty Discharge

Construction works such as demolition, backfilling and slope stabilisation etc are likely to cause soil erosion which may lead to run-offs and discharge of silty waters to nearby waterbodies (i.e., Sungei Pang Sua, Sungei Mandai Besar) and drains.

Operation Phase

Edge Effect/ Light Pollution

The likely sources of environmental impacts during operation phase of the Nature Park are increased human presence due to Nature Park visitorship and generation of light pollution from night-time lighting.

Increases in noise levels from park visitors could also be a disturbance to sensitive fauna present on the site. The presence of lights may increase light pollution into some areas, thus affecting sensitive flora and fauna species.

Species and Habitat Disturbance/ Introduction of Invasive Species
In addition to increased noise and light levels as described above, there might also be regular deployment of vessels to conduct maintenance works offshore (e.g., maintenance of the boundary markers (Bakau poles). The vessels and equipment used may carry non-native species into the mudflat. Moreover, if the machinery is not well-maintained, there may be risk of fuel leakage or oil spill, causing species and habitat disturbance.

Human-Wildlife Conflict
There is also the risk of human-wildlife conflict due to the close proximity of humans to animals currently present on the site including snakes, wild boar, and long-tailed macaques. During maintenance works, there is a risk of encounters with estuarine crocodiles and smooth-coated otters.

Litter and Plastic Pollution/ Soil Compaction
With increased visitorship once the park opens, constant treading on the ground and as well as movement of small vehicles including buggies driven by NParks officers during the operational phase could compress soil and damage root systems, thus potentially compromising tree health. The increase in human traffic is also likely to increase the amount of litter and plastic pollution in the area. Use of non-biodegradable materials with plastic content may increase the level of microplastic accumulation along the coast.

Roadkill
During the operation phase, there is likely to be more traffic due to the increased visitorship. If mitigation measures are not taken, animals may run out of the forest, which may injure both the wildlife and passengers in the vehicles.

Overall Impact

Based on the assessment above, some of the potential impacts on site's biodiversity are deemed to be permanent in nature while the others are short-term and reversible. However, given NParks' intention to develop a low-impact Nature Park, the scope of construction activities in this site is relatively small, and impacts are expected to be controlled. Appropriate measures are to be proposed to mitigate these impacts to an acceptable level.

Overall, the predicted impacts are expected to be mainly Slight Negative across all locations, except for locations with heavy construction and/or are adjacent to sensitive ecological receptors.

During pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc) are expected. The predicted impacts from these works would mostly be species and habitat disturbances due to the noise pollution and increase in human and vehicular traffic flow, and the impacts on aquatic environments especially mangrove biodiversity due to sediment dispersion and soil erosion. Since the area of impact will be restricted to the boundary of the project footprint, as such there will be limited to no changes in baseline conditions and the predicated impacts are Slight Negative.

During the construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas along the coastline (i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion). The main ecological concerns arising from these works are the sedimentation effects due to changes in soil and topography and impacts on the coastal and intertidal environments due to sediment dispersion and runoffs to adjacent habitats, thereby resulting in cumulative outcomes. Given that Mandai Mangrove and Mudflats is one of the few remaining mangrove habitats in Singapore and houses threatened species of seagrass and horseshoe crabs, the site is deemed as ecologically sensitive leading to predicted impacts assessed to be mostly Minor Negative. Likewise, for the planned trails (i.e. Profile A to F) the predicted impacts are of Minor Negative impacts in sections adjacent to mangroves. Other predicted impacts such as edge effect and risk of roadkill are expected to be of relatively lower importance (i.e. within small direct impact area compared to sedimentation effects), temporary and non-cumulative, and hence their environment scores are assessed to be within Slight Negative range.

During operation phase, maintenance and horticultural works will be carried out following completion of construction works. The occurrence of human-wildlife conflicts is expected to increase due to the increased opportunities of wildlife encounters following increased visitor ship to the proposed nature park. Also, litter and plastic pollution is expected to be higher than during baseline conditions given that the area will be accessible to public. Since there will be limited impacts towards biodiversity, the assessment is generally in the Slight Negative range.

Additionally, critical impacts of other physical parameters are discussed in the relevant chapters. Impacts of hydrology and surface water quality and hydrology on biodiversity are addressed in Chapter 5, impacts of noise are discussed in Chapter 9, impacts of air quality on biodiversity are discussed in Chapter 10, impacts of light on biodiversity are discussed in Chapter 12, and impacts of waste management are discussed in Chapter 13.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

5.6.2 Mitigation Measures

Mitigation measures are to be implemented wherever negative impacts are predicted; the measures are proposed with the goal to limit the predicted negative impact to smaller direct impact area (i.e. lower importance), reduce score of magnitude of predicted impact, and/or alter the permanence, recoverability and cumulativeness of predicted impact, hereby reducing the environment score of a predicted negative impact.

Most of the biodiversity mitigation measures are covered in this Chapter. Additionally, mitigation measures related to other environmental aspects are covered in relevant chapters as well.

Table 5.31. Biodiversity impact components and their respective mitigation measures across all locations

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Ecological connectivity loss	• Ensure project footprint avoids targeted sensitive receptors where possible. • Erect temporary hoarding to limit vegetation clearance • Identify flora specimens to be transplanted (if any) • Establish Tree Protection Zones (TPZ) for trees to be retained • Visually inspect trees and holes for nesting birds prior to felling • Reinstate habitats and conduct enhancement planting where possible upon completion of works
	Habitat loss due to vegetation clearance for temporary working areas and hoarding	
	Impact on mangrove biodiversity due to sediment dispersion	• Implement proper Earth Control Measures (ECMs) approved by Qualified Erosion Control Professional (QECP) • Pre-construction activities to be limited to the smallest footprint areas possible. • Storage and stockpiles areas to be identified and approved by NParks. • Pre-construction to be carried out during low tide period as far as possible. • All machinery and equipment to be located on dry land as far as possible. • No heavy construction machinery should be located on intertidal areas. • Ensure soil exposed areas are stabilized and replanted to prevent further erosion
	Soil erosion, runoff, and silty discharge	• Implement Earth Control Measures (ECMs) that are approved by PUB • Ensure soil exposed areas are stabilized and replanted to prevent further erosion • Ensure exposed surfaces are covered with earth control blankets (ECB)
	Species and habitat disturbance	• Ensure project footprint avoids more densely vegetated areas, and those with species of conservation significance when planning trail/boardwalk paths to reduce overall vegetation clearance. • Select only low-impact design strategies in the vicinity of trees with conservation significance • Re-routing of trails inland where possible • Choosing design strategies which least affect the mangrove trees in the vicinity • Avoid heavy construction during the bird migratory season during late August to early May • Prefabricate the boardwalk materials off site • Avoid works at areas with breeding or nesting activities • Limit trail/boardwalk path construction to periods of low tide and daytime hours only
	Species mortality	
Construction	Changes in soil and topography	• Implementation of ECM. • Construction activities to be limited to the smallest footprint areas possible. • Storage and stockpiles areas to be identified and approved by NParks. • Construction to be carried out during low tide period and daytime hours as far as possible. • All machinery and equipment to be located on dry land as far as possible.

Phase	Impact Component	Recommended Mitigation Measures
		• No heavy construction machinery should be located on intertidal areas.
	Ecological connectivity loss	• Ensure infrastructure layout avoids targeted sensitive receptors where possible. • Erect temporary hoarding to limit vegetation clearance • Identify flora specimens to be transplanted (if any) • Establish Tree Protection Zones (TPZ) for trees to be retained • Visually inspect trees and holes for nesting birds prior to felling • Reinstate habitats and conduct enhancement planting where possible upon completion of works
	Edge effect	• Avoid night works (i.e., limit construction activities to 8 am – 6 pm) • Construction lights (if any) should face inwards and away from the sensitive areas (forest, mudflat, mangroves etc.)
	Habitat loss	• Erect temporary hoarding • Establish Tree Protection Zones (TPZ) for trees to be retained • Identify flora specimens to be salvaged or transplanted • Reinstate land and conduct enhancement planting after construction • Visually inspect trees for nesting birds prior to felling • Adjust the project footprint to avoid sensitive receptors (e.g., species of conservation significance)
	Human-wildlife conflict	• Establish designated areas for food and waste disposal • Install monkey-proof bins • Conduct information sessions on what to do upon encountering wildlife • Implement proper use of Personal Protective Equipment (PPE) • Erect hoarding to prevent entry of animals (e.g., wild pig) into the project area • Wild pig management (e.g., trapping) prior to the commencement of tree felling • Regular training and briefing of proper behaviour for workers • Activate Wildlife Response Protocol upon wildlife encounters
	Impact on mangrove biodiversity due to sediment dispersion	• Implement proper Earth Control Measures (ECMs) approved by Qualified Erosion Control Professional (QECP) • Construction activities to be limited to the smallest footprint areas possible. • Storage and stockpiles areas to be identified and approved by NParks. • Construction to be carried out during low tide period as far as possible. • All machinery and equipment to be located on dry land as far as possible. • No heavy construction machinery should be located on intertidal areas. • Ensure soil exposed areas are stabilized and replanted to prevent further erosion
	Injury caused by tree falls	• Incorporate signs prohibiting entrance into densely vegetated areas • Erect fences to prevent illegal entry

Phase	Impact Component	Recommended Mitigation Measures
	Introduction of invasive species	• Ensure equipment, vehicles, and footwear used are clean prior to commencing works.
	Roadkill	• Erect physical barriers to direct fauna movement into unaffected forested areas and prevent fauna from crossing the road • Erect speed bumps or signages to alert drivers about potential animal crossings • Enforce speed limit on the roads
	Soil erosion, runoff, and silty discharge	• Implement Earth Control Measures (ECMs) that are approved by PUB • Ensure soil exposed areas are stabilized and replanted to prevent further erosion • Ensure exposed surfaces are covered with earth control blankets (ECB)
	Species and habitat disturbance	• Erect noise barriers or acoustic enclosures to reduce noise levels • Avoiding more densely vegetated areas, and those with species of conservation value when building trail/boardwalk paths to reduce overall vegetation clearance • Choosing only low-impact design strategies in the vicinity of trees with conservation value • Regular training and briefing of proper behaviour for workers • Erect physical barriers to prevent illegal entry where applicable • Implement dust control measures e.g., dust screens, water suppression systems
	Species mortality	• Visually inspect trees and burrows for nesting birds and other fauna prior to felling • Conduct bat emergence surveys at bamboo clusters to detect bamboo bats. If found, to conduct translocation for bamboo bats to location approved by NParks • Establish Tree Protection Zone (TPZ) where required • Daily inspection of earth control blanket (ECB) and pits for entrapped fauna • Utilize only non-plastic biodegradable ECB throughout the site • Conduct phased, directional clearance along Profile F. Temporary hoarding is to be erected after each phase of clearance. • Conduct fauna translocation where required by a NParks certified Animal Management Specialist • Erect temporary hoarding to limit clearance to within project footprint • Avoiding more densely vegetated areas, and those with species of conservation value when building trail/boardwalk paths to reduce overall vegetation clearance • Choosing only low-impact design strategies in the vicinity of trees with conservation value • Re-routing of trails inland where possible • Choosing design strategies which least affect the mangrove trees in the vicinity • Avoid heavy construction during the bird migratory season late August and early May • Prefabricate the boardwalk materials off the site • Avoid/stop works at areas of breeding or nesting activities • Limit trail/boardwalk path construction to periods of low tide and daytime hours only

Phase	Impact Component	Recommended Mitigation Measures
	Coastal restoration	• Integrate nature-based solutions to facilitate mangrove restoration and slope stabilization enhancements, using biodegradable materials • To design and implement suitable placement of interlocking concrete rings, geobags and/or biodegradable coir fibre logs along public trails to aid in coastal restoration • Planting of mangroves species along the coastline where possible upon completion of works
	Habitat enhancement	• Reinstate habitats using native species where possible upon completion of works • Planting of mangroves species along the coastline where possible upon completion of works
	Removal of invasive species	• Care should be taken to ensure invasive plants are not introduced through seeds embedded in construction equipment and the boots of construction personnel
Operation	Edge effect	• Avoid nighttime lighting except for safety exigencies. • Night lightings (if any) should face inwards and away from the sensitive areas (forest, mudflat, mangroves etc.)
	Human-wildlife conflict	• Erect physical barriers to prevent large animals from entering trails • Erect educational signs to inform visitors on proper conduct in a Nature Park • Conduct informative sessions on the do's and don'ts upon wildlife encounters • Implementation and enforcement of NParks visitors' rules & regulations
	Introduction of invasive species	• Erect educational signs to prohibit visitors on illegal release of animals
	Light pollution	• Lights shall be directed downwards and inwards, toward project area (i.e., directly away from forested areas) • Light usage shall be kept only for emergency events
	Litter and plastic pollution	• Use of biodegradable materials for coastal restoration works • Incorporate signs including guidelines of proper park behaviour. • Set up proper bin system • Implement regular clean-ups especially in the intertidal and marine areas to minimize risk of plastic breakdown to microplastics
	Roadkill	• Erect speed bumps or signages to alert drivers about potential animal crossings • Enforce speed limit on the roads
	Soil compaction	• Erect educational signs to inform visitors on proper conduct in a Nature Park • Physical barriers (e.g., rope handrails) to deter visitors from veering off the designated pathways
	Species and habitat disturbance (e.g., light, noise)	• Incorporate signs including guidelines of proper park behaviour • Rinsing of machinery to remove any potential invasive species • Maintenance of machinery to avoid oil spills
	Coastal restoration	• To maintain interlocking concrete rings, geobags and/or biodegradable coir fibre logs along public trails

Phase	Impact Component	Recommended Mitigation Measures
		• Where mangroves species were planted along the coastline, regular monitoring should be conducted
	Habitat enhancement	• Where necessary, the planting palette should include native species of various plant forms (eg., tree, shrub, herbaceous plants) to mimic the structure of a healthy forested area. • Where mangroves species were planted along the coastline, regular monitoring should be conducted

Pre-Construction Phase

Impacts to Connectivity Loss

Given the importance of the site for migratory waterbirds along the East Asian – Australasian Flyway and has linkages to the Sungei Buloh Nature Park Network, the project footprint should be limited to avoid ecological habitats in the project area with proper implementation of different design strategies. These strategies include but are not limited to trail design, trail layout, coastal protection works, and construction works.

To ensure there is a flow of connectivity between habitats, vegetation clearance should be limited, and trees of ecological importance should be retained. Where possible, habitats are to be reinstated.

Impacts to Habitats of Importance

The pre-construction footprint should consider avoiding important habitats such as the mangroves and intertidal zones, as well as the densely vegetated areas. Design strategies which least affect the mangrove habitats should be chosen, and trails to access the worksite should be re-routed inland where possible.

Impacts related to Species Mortality

Tree Protection Zones (TPZs) should be set up prior to the installation of hoarding. The hoarding line should be demarcated clearly and inspected by an Arborist for any impact to the trees.

If any trees are required to be felled for the installation of the hoarding, pre-felling fauna inspection must be carried out by an Ecologist to determine if there are any nesting fauna.

Construction Phase

Impacts to Habitats of Importance

Direct impacts on important habitats including the mangrove and mudflat habitats were avoided as far as possible by the current layout of the Nature Park, by for instance, designing the trails away from the back mangrove zone and avoiding species of conservation significance. Given that the proposed Nature Park is envisioned as a conservation-focused, low-impact development, impacts to ecology from the project footprint were intentionally limited through appropriate spatial layout and building design.

During the construction phase, care should be taken to also reduce the impacts from all working boundaries. The design of assess routes, storage areas, site offices, and all working areas should aim to minimise the amount of vegetated land area cleared and used. All working areas should also be hoarded up to prevent any inadvertent damage to existing habitats.

Indirect impacts on important habitats should also be avoided. Care must be taken to ensure that soil erosion or sediment runoff does not affect adjacent habitats, particularly water streams and mangrove habitats (rapid sedimentation may cause the burying of pneumatophores on the roots of mangrove species, thus causing oxygen stress). As such, proper Earth Control Measures (ECMs) should be in place, the details of which are further discussed in Section 15.7. As far as possible, the project should utilise construction materials that are inert so as not to release chemicals into surrounding habitats.

Given the importance of the site for migratory shorebirds, disturbance to shorebirds should be minimised as far as possible. Heavy construction activities (such as piling) should be avoided during the migratory season, from August to April each year. Construction activities in intertidal areas should also take place during the low tide period as far as possible. No heavy machinery should be allowed on the intertidal area.

Impacts related to Species Mortality

Trees identified for retention should be demarcated by Tree Protection Zones (TPZs) determined by an ISA-certified arborist (see Figure 5-58.). Special consideration is to be given to TPZs for mangrove trees as they have extensive underground root systems. TPZs in mangrove areas can be established such that the radius is 2m in addition to the distance of visible pencil, conical, or prop roots furthest away from the main tree trunk. For example, if a mangrove tree's furthest pencil root is 5m away from the main tree trunk, the tree should have at least TPZ area of 7m in radius. For mangrove clusters, the TPZ can be established such that the radius is 2m in addition to the distance of visible pencil, conical or prop root furthest away from the centre of mangrove cluster. Preventing trees on site from suffering damage also reduces the risk of tree falls, which may pose a human health and safety concern. These trees should be monitored throughout the construction phase and at the start of the operation phase to ensure that they have not been adversely impacted by developmental works.

Mortality of fauna species, especially those of conservation value should be avoided. In general, the fauna of conservation value recorded includes birds and mammals that are highly mobile, hence the temporary impacts and disturbances from the construction works should not greatly affect their survivability. However, specific measures can be put in place to minimise such impacts to levels that are as low as reasonably practical (ALARP). Where tree felling works are required, they should avoid the main breeding season of the residential bird species (February to July) where possible. Prior to any tree felling, the project area should be inspected for active bird nests or holes, and chicks should be allowed to fledge prior to tree felling. Establish appropriate response protocols to be followed within work site for encounters with large wildlife species (e.g., wild pig, crocodile, smooth-coated otter) such as ceasing works in affected areas to prevent wildlife injury or mortality.

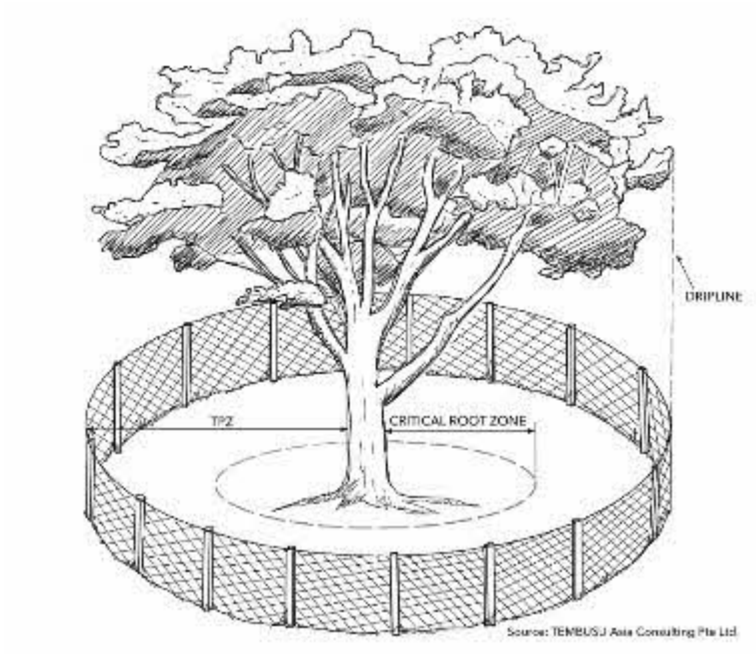


Figure 5-58. Diagram of a hoarding demarking a Tree Protection Zone **(2022)**

Impacts related to Design Strategies and Mangrove Habitats

Impacts on the mangrove habitats in the project area should be minimized with proper implementation of different design strategies. These strategies include but are not limited to trail design, trail layout, coastal protection works, and construction work.

Actively breeding populations of horseshoe crabs are known to be found on the eastern shores of Mandai Mangrove and Mudflat, around Sungei Mandai Besar. Utmost care should therefore be taken for the adoption of design strategies in the area to curtail impacts on the mudflat habitats which may support the horseshoe crab populations. Where possible, this includes the re-routing of trails further inland, the refrainment of choosing boardwalk options near Sungei Mandai Besar (as these may require foundation works in the mudflats), and avoidance of coastal protection works.

Another design consideration involves the impacts on mangrove trees. Each genus of mangrove tree has a distinct morphological and physiological adaptation to the environment in which it thrives. Design strategies can be selected which have the lowest impact on the surrounding trees, depending on nearby tree species, or the presence of species with conservation significance in the area. For example, trees in the *Avicennia* or *Sonneratia* genus have widely branched cable root systems 25-50 cm underground, while *Rhizophora* trees have prop roots branching above the ground. For human safety as well (cutting of major roots may affect the stability of the trees), the finalized design plans must account for the genera of nearby tree species and circumvent these root systems. Additionally, only low-impact design strategies should be chosen in the vicinity of trees with conservation value to reduce the likelihood of impacting their health.

Avoiding Impacts on Sensitive Habitats

Direct impacts on important habitats should be avoided and direct impacts on other habitats should be minimised where possible. Placement of working shafts, trenchwork, and all other working spaces should avoid mangrove areas. Should any threatened native, mature tree species be affected by the working area, a slight shift of placement could help to prevent impacts on these species. The full working area should be hoarded to prevent encroachment into sensitive habitats beyond working area boundary to prevent damage.

Species may also be affected by increased noise, light, and vibration disturbance. Noise barriers / sound proofing should surround all working areas to decrease the impact of noise to the surrounding fauna. Nightworks should be minimized. To reduce vibration impacts to fauna located in proximity to construction areas, machinery causing vibration may be placed on isolators. The details of these impacts are further elaborated upon in their respective chapters.

Indirect impacts to the important habitats should be avoided. These habitats include the core mangrove sites. Care must be taken to prevent soil erosion or sediment run-off into mangroves. Construction activities may lead to soil erosion which in turn can result in sediment transport to a sensitive mangrove area. Rapid sedimentation may cause the burying of pneumatophores on the roots of mangrove species, thus causing oxygen stress. As such, a proper Earth Control Measures (ECM) Plan approved by PUB should be in place prior to start of pre-construction activities and effectively implemented throughout the duration of construction activities. The ECM tanks utilised for the project must have surplus capacities to avoid overflow and silty discharge. All hazardous / flammable chemicals to be used during construction shall be properly labelled, stored within bund containment, and under shelter.

Specific mitigation measures for Public Trail and Guided Trail and Sungei Pang Sua Trail

The construction of the Public and Guided trails near mangrove habitat may pose particular concern, hence the following measures are recommended:

- The layout of this boardwalk should avoid trees of conservation value, very large trees, and where possible, multi-stemmed trees.
- A preliminary layout avoiding such trees has already been planned; this should be finetuned during the detailed implementation stage.
- The boardwalk should be constructed with pre-cast and prefabricated material as far as possible.
- Most of work should be carried out through manual/semi-manual labour methods.
- Trees close to construction works should be demarcated with a TPZ if required.
- Proper Earth Control Measures (ECMs) must be applied to ensure that soil erosion or sediment runoff does not affect adjacent mangrove habitats and water streams.

Impacts related to Human-wildlife Conflict

The occurrence of feral dogs, venomous snakes, wild pigs and estuarine crocodiles on site might pose a human health issue due to the risk of bites and attacks. Construction personnel working on site should be briefed on what to do should they encounter specific wild animals. Besides the potential human-wildlife conflict issue, feral dogs also pose a threat to native wildlife due to predation. Multiple recordings of feral dogs were recorded on the camera traps (Table 5.18). Long term management of feral dogs should be considered. Such measures could include the removal of dogs from the Nature Park as well as trap-neuter-release programmes.

Plant Salvaging and Planting of Native Species

The project area includes several flora species of conservation significance. Given the nature of the project, the clearance of threatened plant species within the area is unavoidable, and several Conservation Significant flora species will be affected.

To remedy the adverse impact to biodiversity, it is recommended salvaging saplings and small individuals of plants of conservation value (especially mangrove species) in areas where vegetation clearance is unavoidable. However, prior to salvaging the tree species, it is important to consider the amendment of the infrastructure design, to avoid the direct removal of species of conservation value.

Native species can be incorporated as far as reasonably practical as a nature-based component for replanting requirements such as for reinstatement, slope stabilising, or fauna connectivity purposes. Compared to conventional method of planting solely ornamental trees in residential estate with planting stocks ordered from local or overseas nurseries, the moving of small plants salvaged in-situ at least partially for reinstatement works brings ecological and biodiversity benefits, as this demonstrates an effort to preserve and disperse native flora germplasm rather than introducing foreign species which might affect conservation of native flora germplasm. This will help to mitigate biodiversity loss and conserve a certain degree of biodiversity. Should there be additional flora saplings of conservation significance, these could also be used to enhance the mangrove habitats in the planned development (e.g. in the Nature-based Solutions demonstrative zone). However, as the design plans and locations have not yet been confirmed, an exact list of flora specimens to be transplanted is not provided at this time.

Flora Management Plan
The detailed plant salvaging and tree protection guidelines are provided in Section 15.4.1 as part of the overall EMMP framework, including the requirements of personnel qualification, specifications of nursery, transplanting, tree assessment, tree felling and so on. A summary of the flora management plan is provided below.

Prior to any site clearance and plant salvaging processes, the Contractor is to liaise with NParks on plants they plan to salvage.

A tree assessment report recording tree information such as site condition and tree photos, species, height, girth, crown spread, tree health, form, structure and possible impacts to the trees affected by proposed development footprint is to be prepared. The report should also include mitigation measures to reduce construction impact on trees. This tree assessment report will then serve as a record of pre-development tree conditions and be utilised when performing monthly monitoring for trees.

Any necessary slope levelling work should also consider any flora immediately upslope of the planned work area, especially trees, as their root zones would likely be affected by any excavation works that are carried out and therefore affecting their structural integrity. Any waste material should be properly disposed of to prevent leaching of contaminants into soil and surface run off into adjacent waterbodies like Kranji Reservoir, Sungei Pang Sua, Sungei Mandai Besar, and the Johor Strait.

Trees identified for retention at the boundaries of the construction footprint of the working area should be demarcated by Tree Protection Zones (TPZs) determined by a certified Arborist (see Figure 13.11). TPZ should be installed prior to construction zone, and monthly monitoring should be conducted by the Arborist to maintain records of tree health and TPZ integrity. If the tree needs to be pruned due to machinery and work access, the pruning shall be carried out by landscape contractors with relevant qualifications under supervision of the Arborist.

Restricted Work Timings for Heavy Construction
Due to the sensitive nature of animals in the EIA case project area, particularly nocturnal animals, heavy construction works (including tree clearance, piling, and pipejacking) are to be limited to daylight hours (8 am – 6 pm). Should there be a need for construction activities to continue at night due to work exigencies, the authorities' approval should be obtained. For such works, a detailed Light management plan (LMP) shall be developed as part of the Construction EMMP.

Pre-felling Fauna Inspections
Mortality of fauna species of conservation value should be avoided. In general, most of

the fauna of conservation value recorded include birds that are highly mobile, hence the works should not greatly affect their survivability. However, several measures can be put in place to further decrease species mortality. Prior to any tree felling, the project area should be inspected for active bird nests or holes, and chicks should be allowed to fledge prior to tree felling. Where possible, tree hollows and burrows should also be inspected for mammal and bird species, and such species should be translocated prior to tree felling.

Operation Phase

The impacts on the natural environment for this project are largely due to increased visitorship to the Nature Park. Impacts to flora and fauna due to trampling on soil should be avoided through the designation of dedicated trails, and the provision of markers to prevent visitors from straying away from marked trails.

Educational signboards should be in place throughout the Nature Park site. These include informing against interacting with (e.g., chasing, catching, feeding) wildlife on site and advising on the importance of not making excessive noise. Educational boards should also highlight the ecological sensitivity and high nature conservation value of the Mandai Mangrove and Mudflat.

To minimise the chances of animal attacks on visitors, signboards should also advise people against going off the trails and include information on what to do should a wild animal be encountered.

In cases where ships need to be deployed to maintain the Nature Park (e.g., bakau poles), the machinery should be rinsed to wash off any potential invasive species. All machinery should also be well-maintained to avoid the occurrence of oil spills.

Proposed Habitat Enhancement Plan

Given the importance of the site for biodiversity, enhancement planting is envisioned as part of the developmental works. These can partially help to compensate for other impacts of development, particularly in areas where unavoidable vegetation clearance is to take place. Enhancement planting would also increase the gene pool of mangrove plants in Mandai Mangrove and Mudflat, which is partly affected by the lack of connectivity to other mangrove populations in eastern Singapore and Peninsula Malaysia due to the presence of the causeway, which block gene flow.

The transplanting of enhancement plant species which do not currently occur in the area such as *Avicennia marina*, *Kandelia candel* is also possible. However, transplanting of these species needs to be done in larger numbers, as small populations are not likely to be robust enough to establish in the area and reproduce successfully. Furthermore, studies or trials need to be performed before transplanting to assess the viability of these species in the wider ecological community and environment. Therefore, priority should be given to transplanting species of conservation significance already present in the area to bolster their populations and increase their likelihood of reproductive success.

Habitat enhancement could also involve translocation of propagules from mangroves in the eastern part of Singapore or offshore islands to the project area. Propagation of rare or threatened plant species on site could also be done by collection of propagules and planting in one of NParks' mangrove nurseries. These can then be planted in strategic locations either for conservation purposes, or close to areas open to visitors for educational purposes. Beyond the mangrove areas, threatened plant species in the secondary forest such as Penaga Laut (*Calophyllum inophyllum*) and Seashore Ardisia (*Ardisia elliptica*), can be planted to increase the species' resilience in that forested patch.

The main trail to be created for Mandai Mangrove and Mudflat is the coastal (Public and Guided) trail at the boundary of the mudflats. Coastal trail works will be integrated with coastal restoration and protection works to address the eroded conditions on site. Nature-based Solutions will be applied for coastal restoration works to facilitate mangrove restoration and slope stabilization enhancements (placement of interlocking concrete rings, geobags and coir fibre logs, planting of mangroves species etc.). Access for trail and coastal restoration works will be carried out from the landward side to avoid damaging the mudflats.

Areas within the project area can be divided into various habitat types, and enhancement can be done targeting these respective habitat types. The vegetation types selected are mangroves, coastal trees and shrubs and grass. Table 5.34 lays out the habitat enhancement plans within the project area. Table 5.32 shows a layout of infrastructure plan for the project area and the total area of enhancement activity carried out within each profile (please refer to Figure 2-5 and Section 2.3.3 for description of each profile).

Table 5.32. Total area of the enhancement activity per each profile

	Width (m)	Length (m)	Area (m2)
Profile A	7.5	1,020	7,650
Profile B	8	425	3,400
Profile C	4	160	640
Profile D	9.5	1,250	11,875
Profile F	4	2,000	8,000
TOTAL			**31,565**

Plants for habitat enhancement serve various purposes, including:

- Their ability to establish in proposed enhancement site, thus forming the habitat for other species to establish;
- As a conservation tool to increased numbers of nationally or globally threatened plant species; and
- To provide resources for targeted animal species to use (e.g., host or nectar plants for butterfly species).

The sources of the species mentioned are subjected to authorities' approval. These chosen plants and their faunal interactions are tabulated in Figure 5-38.

Table 5.33. Plants and their fauna species interactions

Plant Species	Local Status	Associated fauna
Ardisia elliptica	Least Concern	Visited by bees. Host plant for Malayan plum judy and Harlequin.
Calophyllum inophyllum	Endangered	Fruits eaten by lesser dog-faced fruit bat.
Millettia pinnata	Endangered	Its flowers are insect-pollinated. Its fruits and seeds are probably eaten and dispersed by small mammals, bats and birds. The lowest pairs of leaflets, that are stipule-like, are usually inhabited by ants. Host plant for dark caerulean, Malayan sunbeam and common banded awl. It is eaten by the leaf-footed bug *Homoeocerus bipustulatus.*
Ficus consociata	Critically Endangered	Bird-attracting, caterpillar moth food plant, fruits eaten by long-tailed macaque.
Melastoma malabathricum	Least Concern	Host plants for butterflies including Horsefield's baron. Visited by bees. Fruits eaten by mammals, birds, and butterflies, including long-tailed macaque, scarlet-backed flowerpecker, Oriental white-eye and short banded sailor.
Barringtonia racemosa	Critically Endangered	It is the food plant for caterpillars of the moths *Attacus atlas* (atlas moth), *Gnathmocerodes tonsoria*, and *Thosea andamanica*. Its flowers are pollinated by bats and moths.
Terminalia catappa	Least Concern	Fruits eaten by Long-tailed macaque, lesser dog-faced fruit bat, Tanimbar corella and plantain squirrel. Host for nesting to Oriental white-eye. Host plant for long banded silverline, centaur oakblue

Plant Species	Local Status	Associated fauna
		and plain plushblue.
Hibiscus tiliaceus	Least Concern	Bee-attracting plant, caterpillar-food plant, host plant for suffused flash, short banded sailor, copper flash, chestnut angle and common tit.
Knema corticosa (globularia)	Vulnerable	Its fruits are eaten by the Oriental pied hornbill.
Acanthus ebracteatus	Vulnerable	Provides shelter for small vertebrates. Its flowers are bird and insect pollinated. Visited by bees.
Barringtonia asiatica	Critically Endangered	It is the food plant for moth larvae of *Dasychira* spp. and *Thyas honesta*. Host plant for the *Attacus atlas*. Fruit bats and night-flying moths are attracted to its flowers and act as pollinators. Fruits eaten by the Tanimbar corella.
Sonneratia caseolaris	Critically Endangered	Host plant for *Pteroptyx tener* beetle (Malaysian firefly). Its flowers are visited by fruit bats and large night-moths. It is the preferred local food plant for caterpillars of the moths *Indarbela quadrinotata*, *Lymantria lepcha*, *Suana concolor, Trabala irrorata*, and *Trabala vishnou*.
Avicennia marina	Critically Endangered	Host plant for moths, including the Tide-watching mangrove moth (*Aucha velans*)
Avicennia alba	Least Concern	Eaten by *Episesarma versicolor* crab, host plant for moths, host for nesting to copper-throated sunbird.
Lumnitzera racemosa	Endangered	Its flowers are insect-pollinated. It is also the preferred local food plant for caterpillars of the Common Tit butterfly (Hypolycaena erylus teatus), and the moth

Plant Species	Local Status	Associated fauna
		Trabala vishnou. The adults of the common tit butterfly lay eggs singly on leaves, stems or young shoots of the plant.
Podocarpus polystachyus	Endangered	Its fruits are bird-attracting.
Sophora tomentosa	Critically Endangered	Butterfly food plant, moth caterpillar food plant
Myrsine capitellata	Endangered	Bird-attracting, with its fruits associated with species such as the yellow-vented bulbul (*Pycnonotus goiavier*).

Table 5.34. Enhancement objectives of target plant species (Credit: Tinderbox Softscape Presentation)

Habitat	Plant Species	Enhancement Objectives
Mangrove		• Planting plan involves progressively rehabilitating and keeping the mangrove edge along the coast intact to maintain and improve **ecological connectivity**. • Common mangrove species include *Avicennia alba, Avicennia officinalis, Sonneratia alba*, *Bruguiera gymnorhiza*, *Rhizophora apiculata, Rhizophora mucronata e*tc. • Threatened species including *Lumnitzera littorea* (EN), *Lumnitzera racemosa* (EN), *Sonneratia caseolaris* (CR), *Avicennia marina* (CR), and *Kandelia candel* (CR) etc.

Habitat	Plant Species	Enhancement Objectives
Coastal Trees	 *Hibiscus tiliaceus*  *Cocoloba uvifera*  *Guettarda speciosa*  *Barringtonia racemosa*  *Ardisia elliptica*  *Terminalia catappa*	• This will include a mix of **common native plants** such as *Ardisia elliptica, Dendrolobium umbellatum, Guioa pleuropteris, Hibiscus tiliaceus, Ilex cymosa, Syzygium cerasiforme, Syzygium zeylanicum, Terminalia catappa* and **threatened native plants** such as *Barringtonia asiatica* (CR), *Barringtonia racemosa* (CR), *Calophyllum inophyllum* (EN), *Cordia subcordata* (CR), *Cynometra ramiflora* (CR), *Fagraea auriculata* (CR), *Garcinia celebica* (EN), *Guettarda speciosa* (EN), *Ficus consociata* (CR), *Intsia bijuga* (CR), *Melaleuca cajuputi* (Nex), *Memecylon edule* (EN), *Millettia pinnata* (EN), *Podocarpus polystachyus* (EN), *Syzygium pycnanthum* (CR), *Tristaniopsis obovata* (CR), *Tristaniopsis whiteana* (EN) and palm *Cycas edentata* (CR) etc. • Plants in this list also act as **wildlife attracting plants** or food plants

Habitat	Plant Species	Enhancement Objectives
Coastal Shrubs and Grasses	 *Ipomoea pes-caprae*  *Calotropis gigantea*  *Volkameria inermis*  *Rhodomyrtus tomentosa*  *Sophora tomentosa*  *Vitex trifolia*	• The enhancement will be supported with **native shrubs** mostly. Common native species are *Acrostichum speciosum, Canavalia rosea, Hoya verticillata, Ipomoea pes-caprae, Ixora congesta, Leea indica, Melastoma malabathricum, Pluchea indica, Volkameria inermis etc.* • **Threatened coastal shrubs** and **plants** will include *Acanthus ebracteatus* (VU), *Barringtonia racemosa* (CR), *Crinum asiaticum* (CR), *Dipteris conjugata* (CR), *Flemingia strobilifera* (CR), *Hoya diversifolia* (VU), *Myrsine capitellata* (EN), *Ormocarpum cochinchinense* (CR), *Rhodomyrtus tomentosa* (VU), *Sophora tomentosa* (CR), *Vitex trifolia* (CR) etc.
Sungei Pang Sua Pavilion and Experiential trail	 *Heritiera littoralis*  *Barringtonia racemosa*  *Calophyllum inophyllum*  *Thespesia populnea*  *Guettarda speciosa*  *Sophora tomentosa*	• **Experiential walk trail** around Sungei Pang Sua Pavilion will comprise of threatened native species *Heritiera littoralis* (EN), *Barringtonia racemosa* (CR), *Ficus consociata* (CR) and common species *Buchanania arborescens, Ilex cymosa* together with the coastal native trees *Calophyllum inophyllum* (EN), *Guettarda speciosa* (EN). Some common mangrove species will include *Bruguiera gymnorhiza* and threatened species include *Lumnitzera littorea* (EN), *Rhizophora stylosa* (VU), *Sonneratia ovata* (CR) etc. • **Pavilion** planting will comprise of common trees such as *Planchonella obovate, Thespesia populnea* and threatened trees *Podocarpus*

Habitat	Plant Species	Enhancement Objectives
		polystachyus (EN) as well as shrubs e.g. *Sophora tomentosa* (CR) and *Acanthus ebracteatus* (VU) etc..
Kranji Reservoir Park	 Peltophorum pterocarpum  Cordia subcordata  Cynometra ramiflora  Flemingia strobilifera  Planchonella obovata  Crinum asiaticum	• Common **native trees** and **shrubs**: *Acrostichum aureum, Bruguiera gymnorhiza, Dendrolobium umbellatum, Ixora congesta, Planchonella obovata, Terminalia catappa, Volkameria inermis* • **Threatened trees**: *Peltophorum pterocarpum* (CR), *Cynometra ramiflora* (CR), *Flemingia strobilifera* (CR), *Lumnitzera littorea* (EN), *Cordia subcordata* (CR), • **Threatened shrubs**: *Sophora tomentosa* (CR), *Vitex trifolia* (CR) and **plants** *Crinum asiaticum* (CR)
Sungei Kranji Pavilion	 Microsorum scolopendria  Acrostichum aureum  Premna serratifolia  Labisia pumila  Licuala spinosa  Tristaniopsis obovata	• **Common native trees** and **shrubs** in roundabout and carpark: *Licuala spinosa, Microsorum scolopendria, Acrostichum aureum*, *Premna serratifolia, Microsorum scolopendria, Ixora congesta, Pluchea indica* • **Threatened trees, shrubs** & **plants:** *Tristaniopsis obovata* (CR), *Labisia pumila* (VU), *Crinum asiaticum* (CR)

In summary, the recommended measures above, when implemented effectively, could to a large extent help mitigate the potential impacts on the site's biodiversity to acceptable levels.

Further mitigation measures involving the impacts of noise, water quality, air quality, and light to biodiversity are addressed in their respective chapters.

5.6.3 Residual Impacts

The residual impacts were evaluated using the RIAM method (Section 3.6) with due consideration that the recommended mitigation measures are implemented by Contractor. Given proper implementation of mitigation measures, the overall residual impacts across all locations are expected to be in the range of No Impact to Slight Negative.

During pre-construction phase, the main concern across most locations is disturbance to shorebirds. Mitigation measures such as use of sound barriers during shorebird breeding and nesting activities will help reduce the magnitude of disturbance, thus reducing the environment score from Minor Negative to Slight Negative range band. Preliminary works may cause minor disturbance to soil, hence leading to soil erosion.

During construction phase, on top of disturbance to shorebirds, other predicted impacts across many locations include changes in soil and topography, habitat loss, sediment dispersion, soil erosion and species mortality. Following mitigation measures detailed in Section 5.6.2, the environment score of these predicted impacts can be reduced from Minor Negative to Slight Negative range. For example, while the environment score of sediment dispersion was assessed to be in Minor Negative range prior to mitigation, mitigation measures such as proper Earth Control Measurements and controlled storage areas can reduce the magnitude of impact of sediment dispersion such that the final residual environment score are reduced to Slight Negative range.

During operation phase, the main concern across most locations are human-wildlife conflict and litter and plastic pollution. Mitigation measures such as educational signs, implementation of visitors’ rules and regulations, and proper bin systems can help reduce the magnitude of impact such that the residual environment score are reduced from Minor Negative to Slight Negative range.

RIAM Environmental Scoring for the Residual Impacts

Table 5.35. Environmental Scores of the predicted and residual impacts on site's biodiversity after implementation of mitigation measures listed in Table 5.31

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Ecological connectivity loss	1	-2	2	2	2	-12	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Habitat loss due to vegetation clearance for temporary working areas and hoarding	1	-2	2	2	2	-12	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Species mortality	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	Slight Negative
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions − Interlocking rings − Intertidal terrace − Rain garden	Changes in soil and topography	3	-2	3	3	3	-54	Minor Negative	3	-1	3	3	3	-27	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Ecological connectivity loss	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Habitat loss	3	-2	3	2	3	-48	Minor Negative	3	-1	3	2	3	-24	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Roadkill	1	-3	2	2	2	-18	Slight Negative	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative	4	-1	3	2	2	-28	Slight Negative
			Species and habitat disturbance	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Species mortality	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
			Coastal restoration	2	+1	2	2	3	+14	Slight Positive	2	+1	2	2	3	+14	Slight Positive
			Habitat enhancement	2	+2	3	3	3	+36	Slight Positive	2	+2	3	3	3	+36	Slight Positive
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions − Interlocking rings − Intertidal terrace − Rain garden	Human-wildlife conflict	2	-3	2	2	1	-30	Minor Negative	2	-2	2	2	1	-20	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species and habitat disturbance (e.g., light, noise)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Coastal restoration	2	+1	2	2	3	+14	Slight Positive	2	+1	2	2	3	+14	Slight Positive
			Habitat enhancement	2	+2	3	3	3	+36	Slight Positive	2	+2	3	3	3	+36	Slight Positive
Sungei Kranji Pavilion	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
			Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Hoarding	Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Impact on mangrove biodiversity due to sediment dispersion	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Roadkill	1	-3	2	2	2	-18	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
			Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Light Pollution	1	0	2	2	2	0	No Impact	1	0	2	2	2	0	No Impact
			Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
			Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Lookout viewing tower • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	Changes in soil and topography	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Human-wildlife conflict	1	-3	2	2	2	-18	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Roadkill	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Species and habitat disturbance	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
			Species mortality	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Coastal restoration	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive
			Habitat enhancement	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Lookout viewing tower • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Light Pollution	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Coastal restoration	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive
			Habitat enhancement	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Habitat loss	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-30	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Roadkill	1	-2	2	2	2	-12	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Soil erosion, runoff and silty discharge	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Coastal restoration	2	+2	2	2	2	+24	Slight Positive	2	+2	2	2	2	+24	Slight Positive
	Operation	• Public earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Roadkill	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Soil compaction	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Coastal restoration	2	+2	2	2	2	+24	Slight Positive	2	+2	2	2	2	+24	Slight Positive
			Habitat enhancement	2	+2	2	2	2	+24	Slight Positive	2	+2	2	2	2	+24	Slight Positive
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Habitat loss	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Roadkill	1	-2	2	2	2	-12	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Soil erosion, runoff and silty discharge	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Species and habitat disturbance	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
			Species mortality	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
	Operation	• Public Trail Boardwalk	Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Roadkill	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Interlocking rings	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Habitat loss (Terrestrial)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Soil erosion, runoff and silty discharge	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Coastal restoration	2	+1	2	2	3	+14	Slight Positive	2	+1	2	2	3	+14	Slight Positive
			Habitat enhancement (Intertidal)	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Earth trail • Nature-based Solutions − Interlocking rings	Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Soil compaction	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive
Public Trail (Profile B -2, <u>Option 2)</u>	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Geo bags	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Habitat loss (Terrestrial)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Species and habitat disturbance	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Coastal restoration	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive
			Habitat enhancement (Intertidal)	2	+2	2	2	3	+28	Slight Positive	2	+2	2	2	3	+28	Slight Positive
	Operation	• Earth trail • Nature-based Solutions − Geo bags	Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-3	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Soil compaction	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Habitat enhancement	2	+1	2	2	3	+14	Slight Positive	2	+1	2	2	3	+14	Slight Positive
Public Trail (Profile C)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-24	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Habitat loss	2	-2	2	2	2	-12	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Human-wildlife conflict	1	-3	2	2	2	-18	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-28	Slight Negative
			Soil erosion, runoff and silty discharge	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-42	Slight Negative
			Species and habitat disturbance	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-42	Slight Negative
			Species mortality	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
	Operation	• Elevated Boardwalk	Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-24	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Edge effect	1	-1	3	2	2	-7	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Habitat loss	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	4	-2	2	2	3	-56	Minor Negative	4	-1	2	2	3	-28	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Roadkill	2	-2	2	2	2	-12	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Soil erosion, runoff and silty discharge	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Edge effect	1	-1	3	2	2	-7	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Roadkill	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Soil compaction	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Changes in soil and topography	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Edge effect	1	-1	3	2	2	-7	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Habitat loss	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Roadkill	2	-2	2	2	2	-12	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Soil erosion, runoff and silty discharge	2	-3	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-24	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Ope ratio	• Elevated Boardwalk (1.5m	Edge effect	1	-1	3	2	2	-7	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		wide) in back mangrove zones	Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Roadkill	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Species and habitat disturbance	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space • Hoarding	Disturbance to shorebirds	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	Slight Negative
	Construction	• At-grade pedestrian connection	Disturbance to shorebirds	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Human-wildlife conflict	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Roadkill	1	-2	2	2	2	-12	Slight Negative	1	-2	2	2	2	-12	Slight Negative
			Soil erosion, runoff and silty discharge	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-12	Slight Negative
			Species and habitat disturbance	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
			Habitat enhancement	1	+2	2	2	2	+12	Slight Positive	1	+2	2	2	2	+12	Slight Positive
			Removal of invasive species	1	+1	3	2	3	+8	Slight Positive	1	+1	3	2	3	+8	Slight Positive
	Operation		Human-wildlife conflict	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• At-grade pedestrian connection	Litter and plastic pollution	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Roadkill	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Species and habitat disturbance	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Habitat enhancement	1	+2	2	2	2	+12	Slight Positive	1	+2	2	2	2	+12	Slight Positive
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Species mortality	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Changes in soil and topography	2	-1	2	2	2	-12	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Edge effect	1	-1	3	2	2	-7	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Habitat loss	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Impact on mangrove biodiversity due to sediment dispersion	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Injury cause by tree falls	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Roadkill	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Soil erosion, runoff and silty discharge	2	-3	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Species mortality	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Edge effect	1	-1	3	2	2	-7	Slight Negative	1	-1	3	2	2	-7	Slight Negative
			Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Introduction of invasive species	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Litter and plastic pollution	2	-3	2	2	2	-36	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Soil compaction	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-2	2	2	2	-24	Slight Negative
			Habitat enhancement	2	+2	3	3	2	+32	Slight Positive	2	+2	3	3	2	+32	Slight Positive
Boundary markers	**Pre-constr**	• Markers made up of rows of Bakau poles	Species and habitat disturbance	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Species mortality	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Markers made up of rows of Bakau poles	Human-wildlife conflict	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
			Introduction of invasive species	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Marine litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Species and habitat disturbance	2	-3	2	2	2	-36	Slight Negative	2	-1	2	2	2	-12	Slight Negative

6 HYDROLOGY AND WATER QUALITY

6.1 Introduction

This Section describes the relevant laws and standards for water quality that are applicable to the project, the methodology and results for the baseline hydrological conditions and water quality at the project area. It also describes potential impacts on hydrology and water quality due to the construction works of the project, and recommendation for mitigation measures. A quantitative impact assessment approach was used for the assessment of impacts.

6.2 Relevant Environmental Legislation, Guidelines and Standards

The Sewerage and Drainage Act 2001 authorises PUB to construct, maintain and improve sewerage and drainage systems, to regulate the discharge into these systems, and to issue codes of practice or specifications.

Sewerage and Drainage (Surface Water Drainage) Regulation 2007 specifies a maximum discharge limit for total suspended solids (TSS) as 50 milligrams per liter (mg/L) of the discharge. This regulation also requires every contractor to comply with the Code of Practice (COP) on Surface Water Drainage.

The discharge of wastewater into open drains, canals and rivers is regulated by the Environmental Protection and Management (EPM) Act 2002 and the EPM (Trade Effluent) Regulation 2008. The Act and its regulations prescribe allowable limits for trade effluent discharge to controlled and uncontrolled watercourse and are administered by NEA.

The ASEAN Marine Water Quality Criteria (AMWQC) were developed by ASEAN scientists, after undergoing rigorous investigations to determine 'good' marine water, focusing on a range of known pollutants such as heavy metals (e.g., lead, arsenic, zinc and cadmium), suspended solids, chemicals (e.g. nitrogen and phosphorus) and bacteria.

COPs and guidelines relevant to public utilities and watercourse are listed below.

- COP for Environmental Control Officers;
- COP on Surface Water Drainage 2018;
- COP on Pollution Control (SS 593: 2013);
- Guidebook for Qualified Erosion Control Professional (QECP) 2006;
- Guidebook on Erosion and Sediment Control at Construction Sites 2018.

6.3 Hydrology Profile

6.3.1 Catchment Profile

The project area is along the catchment areas of Sungei Pang Sua and Sungei Mandai. It is adjacent to but lies outside the Kranji Reservoir catchment area. Kranji Reservoir was created by reclamation works in conjunction with the Kranji/Pandan water scheme in 1972. Located in the Northern Region, it can also be classified as an estuary. Kranji Reservoir is the largest reservoir in western Singapore, having a surface area of approximately 450 ha and the average depth of 3.5 m.

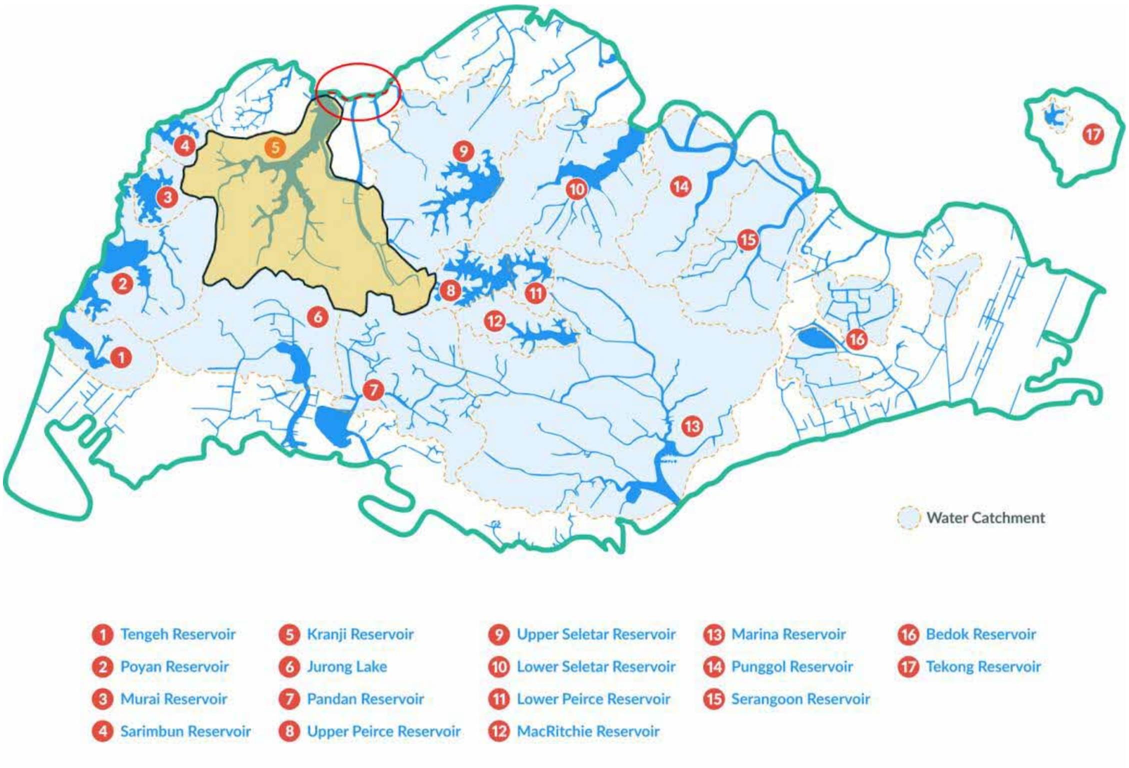


Figure 6-1. Approximate location of the project area is demarcated in the red, near the catchment areas (shaded yellow and grey) (PUB, 2023)

Three main tributaries – Sungei Peng Siang, Sungei Kangkar, and Sungei Tengah – feed into this reservoir (Figure 6-1). There are three natural waterways namely Sungei Pang Sua, Sungei Mandai Besar and Sungei Mandai Kechil passing through project area. These three waterways empty into the Straits of Johor on the north of the project area (Figure 6-2).

Sungei Pang Sua runs for about 3.5 km from mainland Singapore before feeding into the Straits of Johor. Sungei Mandai Besar runs through the mangrove forests and intertidal mudflats of MMM before also feeding into the Straits of Johor. Sungei Mandai Kechil is uniquely isolated within the mangrove forest at the north-east of the project area. The dynamic of these streams – brackish tidal waterways passing through mangrove forests and mudflats before ending in a saltwater strait – allows an interesting biodiversity to thrive in the area.

Figure 6-2. Waterways within the project area

The Straits of Johor separate mainland Singapore from Malaysia's state of Johor at their respective northern and southern borders. The ≈1 km-long Johor-Singapore Causeway connects mainland Singapore with the city of Johor Bahru in Malaysia. As many as 50 floating fish farms exist in the western side of the Straits.

There are four drain outfalls that empty into the mudflat from Kranji Way and Kranji Loop (DHI, 2018). Furthermore, small drains that empty into the Mandai Mangrove and Mudflat were observed along the coastline. The drains did not seem to operate continuously and there is no information available on the source of discharge from these drains.

Annual monthly rainfall over the last ten years at the project area is shown in Figure 6-3, adapted from historical records at the Kranji Reservoir weather station that represents the site.

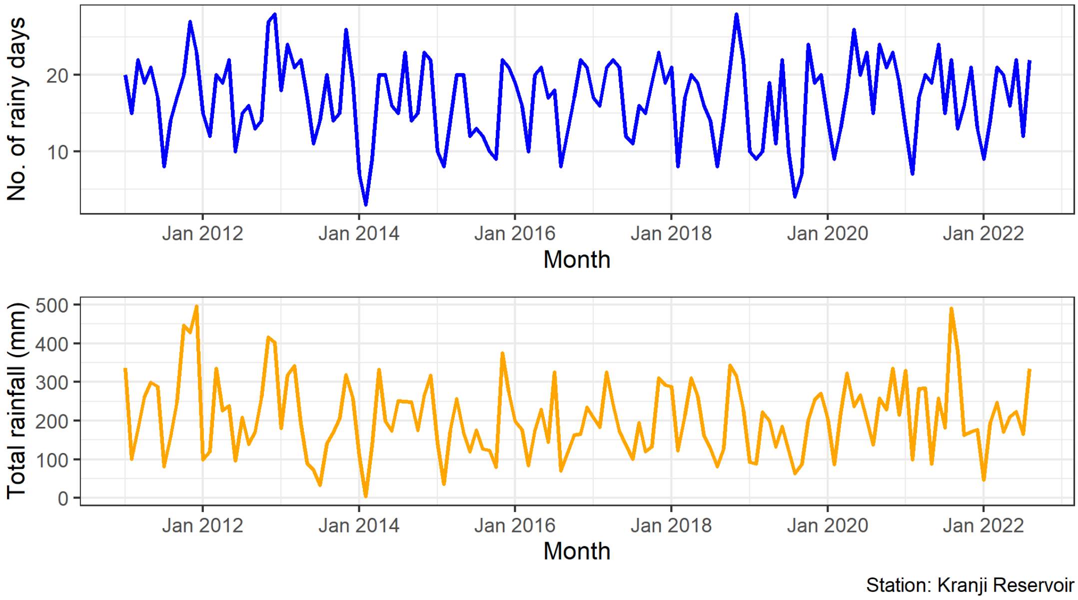


Figure 6-3. Annual monthly rainfall at the Kranji rain gauge station through 2011–2022 **(Meteorological Service Singapore, 2023)**

6.4 Surface Water Quality

6.4.1 Field Survey

Baseline Methodology

Sampling was conducted at nine accessible points covering all the water bodies in the mudflats and Sungei Pang Sua (Figure 6-4). A SINGLAS-accredited laboratory was utilised to analyse the collected surface water quality samples. Two rounds of water quality monitoring were carried out for neap and spring tides each. The samples for ex-situ analysed parameters were collected on 20 October 2022 during neap tide and 27 October 2022 during spring tide. The in-situ measured parameters were collected on 9 December 2022 during spring tide and 16 December 2022 during neap tide (Table 6.1). The secondary water quality data from previous reports from surveys carried out in the vicinity of the project area, as well as data collected by various government agencies, if available, were reviewed and utilised.

Figure 6-4. Location of surface water quality sampling points in project area

Table 6.1. Coordinates and dates of surface water quality sampling location

ID	Coordinates		Date of Sampling (Ex-Situ parameters)	Date of Sampling (In-Situ parameters)
SW1	1.440924	103.766421	Neap tide: 20/10/2022 Spring tide: 27/10/2022	Spring tide: 09/12/2022 Neap tide: 16/12/2022
SW2	1.441711	103.765728		
SW3	1.442737	103.765433		
SW4	1.433209	103.760652		
SW5	1.436316	103.761249		
SW6	1.422992	103.752754		
SW7	1.438523	103.762198		
SW8	1.435870	103.752875		
SW9	1.429332	103.751614		

The following parameters were tested using their respective testing method for each surface water quality sample (Table 6.2), where APHA is a standard method for Determination of Water and Wastewater (APHA, 2017).

Table 6.2. Surface water quality parameters tested in the laboratory

Parameter	Unit	Criteria Values	Test Method
In-situ			
Temperature	°C	Increase not more than 2°C above the maximum ambient temperature [1]	Aqua Troll 500 In-situ monitoring sensor
pH @ 25°C	pH unit	-	
Turbidity	NTU	-	
Salinity	ppt	-	
Dissolved Oxygen	mg/L	≥ 4 [2]	
Ex-situ			
Total Suspended Solids	mg/L	100 [2]	APHA 2540 D
Total Organic Carbon (TOC)	mg/L	-	APHA 5310 B
Total Nitrogen	mg/L	-	SOP-WAT-048
Total Phosphorus	mg/L	-	HI93713/HI801
Nitrate (NO_3)	mg/L	0.06 [1]	HI93713/HI801
Phosphate (PO_4)	mg/L	0.015 [1]	HI93713/HI801
Ammonia as NH3-N	mg/L	1 [2]	APHA 4500-NH_3-E
Arsenic (As)	mg/L	0.02 [2]	APHA 3120 B
Cadmium (Cd)	mg/L	0.07 [1]	APHA 3120 B
Copper (Cu)	mg/L	0.008 [1]	APHA 3120 B
Lead (Pb)	mg/L	0.02 [2]	APHA 3120 B
Zinc (Zn)	mg/L	0.05*	APHA 3120 B
Nickel (Ni)	mg/L	-	APHA 3120 B
Iron (Fe)	mg/L	-	APHA 3120 B
Chromium (Cr)	mg/L	0.05 [1]	APHA 3120 B

Parameter	Unit	Criteria Values	Test Method
Mercury (Hg)	mg/L	0.00016 [1]	VGA/ICPOES
Enterococcus	cfu/100mL	35 [1]	APHA 9230 C
Total Dissolved Solids	mg/L	1000 [2]	APHA 2540 C
Biological Oxygen Demand, BOD 5	mg/L	-	APHA 5210 B
Chemical Oxygen Demand (COD)	mg O_2/L	-	Accredited In-house Method MLS-SOP-WQ-029 Rev 1 & HACH Method 8000 (Jul 2021)

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

* Not formally adopted as AMWQC

6.4.2 Baseline Results

In this study, the results of surface water quality analysis in comparison with the relevant standards are tabulated in the tables below. Table 6.3 to Table 6.6 showcases the in-situ water quality for spring tide and neap tide. Table 6.7 to Table 6.9 ex-situ parameters during neap tide sampling and Table 6.10 to Table 6.12 for ex-situ parameters during spring tide sampling. The laboratory analysis reports are provided in **Appendix E**.

Table 6.3. Surface water quality in-situ results for spring tide (Flood Tide – 09/12/2022)

Test Parameter	Unit	Test Method	Sample 1 SW1 1115hrs	Sample 2 SW2 1101hrs	Sample 3 SW3 1048hrs	Sample 4 SW4 0958hrs	Sample 5 SW5 1010hrs
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	29.11	29.11	29.12	29.11	29.11
Salinity	ppt		28.86	28.79	28.75	28.66	28.65
pH	pH unit		8.41	8.40	8.39	8.36	8.37
Turbidity	NTU		3.68	3.56	3.89	3.48	3.52
Dissolved Oxygen	mg/L		6.99	6.86	6.45	6.43	6.53
Test Parameter	**Unit**	**Test Method**	**Sample 6 SW6 1024hrs**	**Sample 7 SW7 0912hrs**	**Sample 8 SW8 0926hrs**	**Sample 9 SW9 0936hrs**	**Threshold limit**
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	29.11	29.08	29.10	29.09	Increase not more than 2°C above the maximum ambient temperature [1]
Salinity	ppt		28.69	28.52	28.50	28.53	-
pH	pH unit		8.38	8.34	8.34	8.35	-
Turbidity	NTU		3.54	3.40	3.41	3.52	-
Dissolved Oxygen	mg/L		6.58	6.20	6.19	6.32	≥ 4[2]

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

Table 6.4. Surface water quality in-situ results for spring tide (Ebb Tide – 09/12/2022)

Test Parameter	Unit	Test Method	Sample 1 SW1 1331hrs	Sample 2 SW2 1343hrs	Sample 3 SW3 1356hrs	Sample 4 SW4 1434hrs	Sample 5 SW5 1423hrs
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	30.44	30.50	30.52	30.54	30.54
Salinity	ppt		28.92	28.95	28.98	29.09	29.00

pH	pH unit		8.44	8.44	8.44	8.47	8.45
Turbidity	NTU		0.95	4.10	4.14	4.02	4.26
Dissolved Oxygen	mg/L		7.27	6.89	6.84	6.89	6.77
Test Parameter	**Unit**	**Test Method**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Threshold limit**
			SW6 1409hrs	**SW7 1524hrs**	**SW8 1512hrs**	**SW9 1458hrs**	
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	30.58	30.59	30.55	30.55	Increase not more than 2°C above the maximum ambient temperature [1]
Salinity	ppt		28.97	29.12	29.09	29.03	-
pH	pH unit		8.45	8.48	8.48	8.47	-
Turbidity	NTU		4.06	3.85	4.08	3.97	-
Dissolved Oxygen	mg/L		6.96	6.84	6.97	6.94	≥ 4[2]

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

Table 6.5 Surface water quality in-situ results for neap tide (Flood Tide – 16/12/2022)

Test Parameter	**Unit**	**Test Method**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
			SW1 1100hrs	**SW2 1049hrs**	**SW3 1038hrs**	**SW4 0948hrs**	**SW5 1001hrs**
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	28.88	28.93	28.91	28.85	28.86
Salinity	ppt		29.36	29.33	29.31	29.24	29.23
pH	pH unit		8.24	8.23	8.24	8.24	8.23
Turbidity	NTU		3.50	3.63	3.62	3.29	3.37
Dissolved Oxygen	mg/L		6.71	6.64	6.59	6.64	6.47
Test Parameter	**Unit**	**Test Method**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Threshold limit**
			SW6 1014hrs	**SW7 0902hrs**	**SW8 0916hrs**	**SW9 0927hrs**	
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	28.86	28.84	28.82	28.84	Increase not more than 2°C

							above the maximum ambient temperature [1]
Salinity	ppt		29.29	29.17	29.20	29.20	-
pH	pH unit		8.24	8.21	8.23	8.23	-
Turbidity	NTU		3.31	3.31	3.29	3.41	-
Dissolved Oxygen	mg/L		6.71	6.49	6.74	6.55	≥ 4[2]

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

Table 6.6. Surface water quality in-situ results for neap tide (Ebb Tide – 16/12/2022)

Test Parameter	Unit	Test Method	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
			SW1 1316hrs	**SW2 1326hrs**	**SW3 1338hrs**	**SW4 1427hrs**	**SW5 1415hrs**
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	29.66	29.69	29.69	29.50	29.50
Salinity	ppt		29.38	29.37	29.28	28.01	28.11
pH	pH unit		8.16	8.15	8.15	8.14	8.13
Turbidity	NTU		2.84	2.92	2.86	3.14	3.12
Dissolved Oxygen	mg/L		6.79	6.80	6.67	6.71	6.81
Test Parameter	**Unit**	**Test Method**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Threshold limit**
			SW6 1406hrs	**SW7 1517hrs**	**SW8 1505hrs**	**SW9 1452hrs**	
Temperature	°C	Aqua troll 500 In-Situ Monitoring sensor	29.56	29.52	29.51	29.48	Increase not more than 2°C above the maximum ambient temperature [1]
Salinity	ppt		28.39	28.26	28.30	27.97	-
pH	pH unit		8.14	8.21	8.20	8.17	-
Turbidity	NTU		3.09	3.06	3.10	3.09	-
Dissolved Oxygen	mg/L		6.87	7.09	6.91	7.06	≥ 4[2]

[1] ASEAN Marine Water Quality Standard (2008)
[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

Table 6.7. Surface water quality ex-situ results for neap tide (20/10/2022)

Test Parameter	Unit	Test Method	Sample 1A SW1 Surface 20/10/2022 1145hrs	Sample 2A SW2 Surface 20/10/2022 1155hrs	Sample 3A SW3 Surface 20/10/2022 1205hrs	Sample 4A SW4 Surface 20/10/2022 1000hrs	Sample 5A SW5 Surface 20/10/2022 1010hrs	Sample 6A SW6 Surface 20/10/2022 1020hrs	Criteria Values
Total Phosphorus, TP	mg/L	APHA Pt 4500-P (J)	0.14	0.14	0.15	0.47	0.36	0.31	-
Total Nitrogen, TN	mg/L	APHA Pt 4500-P (J)	1.26	1.27	1.22	12.2	5.12	3.70	-
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**0.52**	**0.48**	**0.52**	**9.29**	**3.30**	**2.15**	0.06 [1]
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.12**	**0.13**	**0.14**	**0.27**	**0.26**	**0.30**	0.015 [1]
Total Suspended Solids, TSS	mg/L	APHA 2540D	2.80	4.20	10.5	3.70	4.30	3.30	100 [2]
Total Dissolved Solids, TDS	mg/L	APHA 2540C	**12,995**	**13,391**	**12,848**	476	**8,655**	**11,272**	1000 [2]
Total Organic Carbon, TOC	mg/L	APHA 5310B	3.15	3.31	3.71	8.56	6.16	5.57	-
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	0.38	0.35	0.30	**2.41**	**1.29**	**1.01**	1 [2]
Enterococcus	cfu/100mL	APHA 9230C	**150**	8	**280**	**690**	**570**	**440**	35 [1]
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.07 [1]
Chromium as Cr	mg/L	APHA 3125B	0.0013	0.0014	0.0015	0.0033	0.0025	0.0023	0.05 [1]
Mercury as Hg	mg/L	APHA 3125B	**0.00020**	0.00011	**0.00018**	**0.0030**	**0.0018**	**0.0012**	0.00016 [1]
Iron as Fe	mg/L	APHA 3125B	0.014	0.011	0.0053	0.075	0.048	0.021	-
Nickel as Ni	mg/L	APHA 3125B	ND	ND	ND	0.010	0.0068	0.0045	-
Zinc as Zn	mg/L	APHA 3125B	0.0098	0.0072	0.0069	0.044	0.025	0.013	0.05*
Copper as Cu	mg/L	APHA 3125B	0.0016	0.0013	ND	0.0031	0.0021	0.0017	0.008 [1]
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]

Test Parameter	Unit	Test Method	Sample 1A SW1 Surface 20/10/2022 1145hrs	Sample 2A SW2 Surface 20/10/2022 1155hrs	Sample 3A SW3 Surface 20/10/2022 1205hrs	Sample 4A SW4 Surface 20/10/2022 1000hrs	Sample 5A SW5 Surface 20/10/2022 1010hrs	Sample 6A SW6 Surface 20/10/2022 1020hrs	Criteria Values
Arsenic as As	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND	ND	-
Chemical Oxygen Demand, COD	mg O_2/L	Accredited In-house Method MLS-SOP-WQ-029 Rev 1	ND	ND	ND		ND	ND	-
Chemical Oxygen Demand, COD	mg O_2/L	HACH Method 8000 (Jul 2021)				ND			-
Turbidity	NTU	APHA 2130B	2.5	2.8	2.6	5.8	5.2	3.0	-

Note: Values in bold and shaded grey denote non-conformity to the respective water quality standard.
[1] ASEAN Marine Water Quality Standard (2008)
[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)
* Not formally adopted as AMWQC

Table 6.8. Surface water quality ex-situ results for neap tide (20/10/2022)

Test Parameter	Unit	Test Method	Sample 7A SW7 Surface 20/10/2022 0915hrs	Sample 8A SW8 Surface 20/10/2022 0925hrs	Sample 9A SW9 Surface 20/10/2022 0935hrs	Sample 1B SW1 Surface 20/10/2022 1515hrs	Sample 2B SW2 Surface 20/10/2022 1525hrs	Sample 3B SW3 Surface 20/10/2022 1535hrs	Criteria Values
Total Phosphorus, TP	mg/L	APHA Pt 4500-P (J)	0.27	0.25	0.17	0.15	0.16	0.18	-
Total Nitrogen, TN	mg/L	APHA Pt 4500-P (J)	1.30	1.44	1.59	1.08	1.29	1.30	-
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**0.46**	**0.58**	**0.82**	**0.47**	**0.65**	**0.73**	0.06 [1]
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.13**	**0.14**	**0.15**	**0.15**	**0.11**	**0.17**	0.015 [1]

Test Parameter	Unit	Test Method	Sample 7A SW7 Surface 20/10/2022 0915hrs	Sample 8A SW8 Surface 20/10/2022 0925hrs	Sample 9A SW9 Surface 20/10/2022 0935hrs	Sample 1B SW1 Surface 20/10/2022 1515hrs	Sample 2B SW2 Surface 20/10/2022 1525hrs	Sample 3B SW3 Surface 20/10/2022 1535hrs	Criteria Values
Total Suspended Solids, TSS	mg/L	APHA 2540D	3.00	3.00	3.10	3.10	4.00	4.60	100 [2]
Total Dissolved Solids, TDS	mg/L	APHA 2540C	**7,641**	**10,029**	**11,702**	**14,908**	**12,994**	**12,495**	1000 [2]
Total Organic Carbon, TOC	mg/L	APHA 5310B	3.35	3.28	3.74	3.35	3.35	3.86	-
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	0.57	0.58	0.55	0.41	0.28	0.37	1 [2]
Enterococcus	cfu/100mL	APHA 9230C	**260**	**140**	**110**	**110**	**60**	**260**	35 [1]
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.07 [1]
Chromium as Cr	mg/L	APHA 3125B	0.0014	0.0012	0.0017	0.0018	0.0016	0.0015	0.05 [1]
Mercury as Hg	mg/L	APHA 3125B	ND	0.00012	**0.00030**	**0.00026**	**0.00046**	**0.00037**	0.00016 [1]
Iron as Fe	mg/L	APHA 3125B	0.024	0.010	0.014	0.017	0.013	0.016	-
Nickel as Ni	mg/L	APHA 3125B	ND	ND	ND	ND	ND	0.0025	-
Zinc as Zn	mg/L	APHA 3125B	0.0088	0.0077	0.0068	0.0068	0.0077	0.017	0.05*
Copper as Cu	mg/L	APHA 3125B	0.0013	0.0012	0.0013	0.0013	0.0015	0.0020	0.008 [1]
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Arsenic as As	mg/L	APHA 3125B	0.017	0.013	ND	ND	ND	ND	0.02 [2]
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND	ND	-
Chemical Oxygen Demand, COD	mg O_2/L	Accredited In-house Method MLS-SOP-WQ-029 Rev 1	ND	ND	ND	ND	ND	ND	-
Chemical Oxygen Demand, COD	mg O_2/L	HACH Method 8000 (Jul 2021)							-
Turbidity	NTU	APHA 2130B	3.1	2.6	2.9	2.7	3.2	2.9	-

Note: Values in bold and shaded grey denote non-conformity to the respective water quality standard.
[1] ASEAN Marine Water Quality Standard (2008)
[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)
* Not formally adopted as AMWQC

Table 6.9. Surface water quality ex-situ results for neap tide (20/10/2022)

Test Parameter	Unit	Test Method	Sample 4B SW4 Surface 20/10/2022 1555hrs	Sample 5B SW5 Surface 20/10/2022 1605hrs	Sample 6B SW6 Surface 20/10/2022 1615hrs	Sample 7B SW7 Surface 20/10/2022 1635hrs	Sample 8B SW8 Surface 20/10/2022 1645hrs	Sample 9B SW9 Surface 20/10/2022 1655hrs	Criteria Values
Total Phosphorus, TP	mg/L	APHA Pt 4500-P (J)	0.41	0.33	0.33	0.20	0.16	0.19	-
Total Nitrogen, TN	mg/L	APHA Pt 4500-P (J)	10.9	3.18	3.89	1.25	1.34	1.56	-
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**5.72**	**1.55**	**1.93**	**0.47**	**0.56**	**0.85**	0.06 [1]
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.29**	**0.31**	**0.33**	**0.13**	**0.14**	**0.16**	0.015 [1]
Total Suspended Solids, TSS	mg/L	APHA 2540D	3.70	4.30	3.30	3.20	2.50	4.00	100 [2]
Total Dissolved Solids, TDS	mg/L	APHA 2540C	476	**11,531**	**10,070**	**7,237**	**10,050**	**11,850**	1000 [2]
Total Organic Carbon, TOC	mg/L	APHA 5310B	9.21	5.07	5.73	3.53	3.39	3.83	-
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	0.14	0.95	**1.20**	0.57	0.59	0.56	1 [2]
Enterococcus	cfu/100mL	APHA 9230C	**370**	**530**	**110**	**310**	**190**	**70**	35 [1]
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.07 [1]
Chromium as Cr	mg/L	APHA 3125B	0.0039	0.0020	0.0021	0.0014	0.0015	0.0013	0.05 [1]
Mercury as Hg	mg/L	APHA 3125B	**0.0028**	**0.0011**	**0.0026**	0.00014	ND	**0.00030**	0.00016 [1]
Iron as Fe	mg/L	APHA 3125B	0.087	0.031	0.024	0.016	0.010	0.011	-
Nickel as Ni	mg/L	APHA 3125B	0.011	0.0045	0.0051	ND	ND	ND	-

Test Parameter	Unit	Test Method	Sample 4B SW4 Surface 20/10/2022 1555hrs	Sample 5B SW5 Surface 20/10/2022 1605hrs	Sample 6B SW6 Surface 20/10/2022 1615hrs	Sample 7B SW7 Surface 20/10/2022 1635hrs	Sample 8B SW8 Surface 20/10/2022 1645hrs	Sample 9B SW9 Surface 20/10/2022 1655hrs	Criteria Values
Zinc as Zn	mg/L	APHA 3125B	0.042	0.015	0.015	0.0074	0.0082	0.0070	0.05*
Copper as Cu	mg/L	APHA 3125B	0.0032	0.0016	0.0013	0.0013	0.0017	ND	0.008 [1]
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Arsenic as As	mg/L	APHA 3125B	ND	ND	ND	0.018	0.014	ND	0.02 [2]
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND	1.17	-
Chemical Oxygen Demand, COD	mg O2/L	Accredited In-house Method MLS-SOP-WQ-029 Rev 1		ND	ND	ND	ND	ND	-
Chemical Oxygen Demand, COD	mg O2/L	HACH Method 8000 (Jul 2021)	26						-
Turbidity	NTU	APHA 2130B	5.4	3.9	2.6	2.9	2.5	3.5	-

Note: Values in bold and shaded grey denote non-conformity to the respective water quality standard.

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

* Not formally adopted as AMWQC

Table 6.10. Surface water quality ex-situ results for spring tide (27/10/2022)

Test Parameter	Unit	Test Method	Sample 1A	Sample 2A	Sample 3A	Sample 4A	Sample 5A	Sample 6A	Criteria Values
			SW1 Surface 27/10/2022 1200hrs	**SW2 Surface 27/10/2022 1150hrs**	**SW3 Surface 27/10/2022 1140hrs**	**SW4 Surface 27/10/2022 1110hrs**	**SW5 Surface 27/10/2022 1100hrs**	**SW6 Surface 27/10/2022 1050hrs**	
Total Phosphorus, TP	mg/L	APHA Pt 4500-P (J)	0.79	0.97	0.89	4.79	0.62	0.88	-
Total Nitrogen, TN	mg/L	APHA Pt 4500-P (J)	3.19	3.21	3.24	8.68	2.12	3.05	-
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**1.23**	**1.57**	**1.49**	**5.06**	**0.9**	**1.21**	0.06 [1]
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.76**	**0.94**	**0.87**	**4.7**	**0.59**	**0.81**	0.015 [1]
Total Suspended Solids, TSS	mg/L	APHA 2540D	2.90	5.80	4.60	7.10	2.90	2.30	100 [2]
Total Dissolved Solids, TDS	mg/L	APHA 2540C	**11,658**	**9,157**	**11,038**	**2,681**	**12,799**	**12,152**	1000 [2]
Total Organic Carbon, TOC	mg/L	APHA 5310B	3.84	3.63	3.53	7.62	3.2	3.37	-
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	**1.39**	**1.35**	**1.43**	**2.02**	0.96	**1.3**	1 [2]
Enterococcus	cfu/100mL	APHA 9230C	**200**	**560**	**820**	**720**	**550**	**60**	35 [1]
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.07 [1]
Chromium as Cr	mg/L	APHA 3125B	0.001	ND	ND	ND	ND	0.001	0.05 [1]
Mercury as Hg	mg/L	APHA 3125B	**0.00076**	**0.00076**	**0.00073**	**0.0028**	**0.00041**	**0.00064**	0.00016 [1]
Iron as Fe	mg/L	APHA 3125B	0.0071	0.013	0.0078	0.025	0.0099	0.0081	-
Nickel as Ni	mg/L	APHA 3125B	0.0032	0.0023	0.0023	0.0076	ND	0.0022	-
Zinc as Zn	mg/L	APHA 3125B	0.027	0.013	0.017	0.03	0.0069	0.0085	0.05*
Copper as Cu	mg/L	APHA 3125B	0.0031	0.0017	0.0014	0.0028	0.0011	0.0012	0.008 [1]
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Arsenic as As	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]

Test Parameter	Unit	Test Method	Sample 1A	Sample 2A	Sample 3A	Sample 4A	Sample 5A	Sample 6A	Criteria Values
			SW1 Surface 27/10/2022 1200hrs	SW2 Surface 27/10/2022 1150hrs	SW3 Surface 27/10/2022 1140hrs	SW4 Surface 27/10/2022 1110hrs	SW5 Surface 27/10/2022 1100hrs	SW6 Surface 27/10/2022 1050hrs	
Biochemical Oxygen Demand, BOD5	mg/L	APHA 5210B	1.8	ND	1.35	2.53	1.26	1.04	-
Chemical Oxygen Demand, COD	mg O/L	Accredited In-house Method MLS-SOP-WQ-029 Rev 1	ND	ND	ND	ND	ND	ND	-
Turbidity	NTU	APHA 2130B	2.9	4.2	3.1	9.3	2.2	2.5	-

Note: Values in bold and shaded grey denote non-conformity to the respective water quality standard.

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

* Not formally adopted as AMWQC

Table 6.11. Surface water quality ex-situ results for spring tide (27/10/2022)

Test Parameter	Unit	Test Method	Sample 7A	Sample 8A	Sample 9A	Sample 1B	Sample 2B	Sample 3B	Criteria Values
			SW7 Surface 27/10/2022 1000hrs	SW8 Surface 27/10/2022 0950hrs	SW9 Surface 27/10/2022 0940hrs	SW1 Surface 27/10/2022 1330hrs	SW2 Surface 27/10/2022 1340hrs	SW3 Surface 27/10/2022 1350hrs	
Total Phosphorus, TP	mg/L	APHA Pt 4500-P (J)	0.17	0.17	0.16	0.83	0.87	1.07	-
Total Nitrogen, TN	mg/L	APHA Pt 4500-P (J)	1.14	1.15	1.17	2.9	2.86	3.09	-
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**0.30**	**0.27**	**0.29**	**1.28**	**1.37**	**1.37**	0.06 [1]
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.16**	**0.16**	**0.16**	**0.82**	**0.86**	**0.88**	0.015 [1]

Test Parameter	Unit	Test Method	Sample 7A	Sample 8A	Sample 9A	Sample 1B	Sample 2B	Sample 3B	Criteria Values
			SW7 Surface 27/10/2022 1000hrs	**SW8 Surface 27/10/2022 0950hrs**	**SW9 Surface 27/10/2022 0940hrs**	**SW1 Surface 27/10/2022 1330hrs**	**SW2 Surface 27/10/2022 1340hrs**	**SW3 Surface 27/10/2022 1350hrs**	
Total Suspended Solids, TSS	mg/L	APHA 2540D	7.30	4.70	4.00	2.20	3.70	1.20	100 [2]
Total Dissolved Solids, TDS	mg/L	APHA 2540C	**16,116**	**16,131**	**16,200**	**11.572**	**8,424**	**10,603**	1000 [2]
Total Organic Carbon, TOC	mg/L	APHA 5310B	2.62	2.53	2.44	3.5	3.44	3.33	-
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	0.59	0.59	0.58	**1.3**	**1.27**	**1.38**	1 [2]
Enterococcus	cfu/100mL	APHA 9230C	**50**	**40**	**60**	**190**	**750**	**940**	35 [1]
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.07 [1]
Chromium as Cr	mg/L	APHA 3125B	0.0012	0.0012	0.0013	ND	ND	ND	0.05 [1]
Mercury as Hg	mg/L	APHA 3125B	ND	ND	ND	**0.00062**	**0.00072**	**0.00056**	0.00016 [1]
Iron as Fe	mg/L	APHA 3125B	0.0055	0.0044	0.0056	0.01	0.01	0.0095	-
Nickel as Ni	mg/L	APHA 3125B	ND	ND	ND	ND	0.0021	ND	-
Zinc as Zn	mg/L	APHA 3125B	0.010	0.0061	0.0089	0.013	0.014	0.011	0.05*
Copper as Cu	mg/L	APHA 3125B	0.0026	0.0013	0.0022	0.0016	0.0018	0.0014	0.008 [1]
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Arsenic as As	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	1.07	ND	ND	1.12	ND	1.08	-
Chemical Oxygen Demand, COD	mg O/L	Accredited In-house Method MLS-SOP-WQ-029 Rev 1	ND	ND	ND	ND	ND	ND	-
Turbidity	NTU	APHA 2130B	2.2	2.3	2.1	2.9	4.7	3.2	-

Note: Values in bold and shaded grey denote non-conformity to the respective water quality standard.

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

* Not formally adopted as AMWQC

Table 6.12. Surface water quality ex-situ results for spring tide (27/10/2022)

Test Parameter	Unit	Test Method	**Sample 4B** SW4 Surface 27/10/2022 1410hrs	**Sample 5B** SW5 Surface 27/10/2022 1420hrs	**Sample 6B** SW6 Surface 27/10/2022 1430hrs	**Sample 7B** SW7 Surface 27/10/2022 1510hrs	**Sample 8B** SW8 Surface 27/10/2022 1520hrs	**Sample 9B** SW9 Surface 27/10/2022 1530hrs	**Criteria Values**
Total Phosphorus, TP	mg/L	APHA Pt 4500-P (J)	4.86	0.7	0.92	0.16	0.18	0.17	-
Total Nitrogen, TN	mg/L	APHA Pt 4500-P (J)	8.61	2.33	2.92	1.23	1.23	1.14	-
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**5.12**	**1.06**	**1.38**	**0.27**	**0.28**	**0.27**	0.06 [1]
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**4.62**	**0.7**	**0.86**	**0.16**	**0.17**	**0.16**	0.015 [1]
Total Suspended Solids, TSS	mg/L	APHA 2540D	5.30	3.90	3.40	7.50	2.90	1.80	100 [2]
Total Dissolved Solids, TDS	mg/L	APHA 2540C	**2,546**	**12,522**	**12,027**	**16,135**	**15,792**	**16,078**	1000 [2]
Total Organic Carbon, TOC	mg/L	APHA 5310B	7.41	3.23	3.47	2.58	2.41	2.4	-
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	**2.23**	1	**1.25**	0.6	0.59	0.57	1 [2]
Enterococcus	cfu/100mL	APHA 9230C	**460**	**390**	**80**	30	ND	**50**	35 [1]
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.07 [1]
Chromium as Cr	mg/L	APHA 3125B	ND	ND	ND	0.0011	0.0011	0.0012	0.05 [1]
Mercury as Hg	mg/L	APHA 3125B	**0.0028**	**0.00048**	**0.00062**	ND	ND	ND	0.00016 [1]
Iron as Fe	mg/L	APHA 3125B	0.023	0.0068	0.0093	0.0026	0.004	0.0042	-
Nickel as Ni	mg/L	APHA 3125B	0.0074	ND	0.002	ND	ND	ND	-
Zinc as Zn	mg/L	APHA 3125B	0.029	0.0085	0.0087	0.0043	0.0009	0.005	0.05*
Copper as Cu	mg/L	APHA 3125B	0.0029	0.001	0.0011	ND	0.0014	ND	0.008 [1]
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]

Arsenic as As	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.02 [2]
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	2.01	1.01	1	1.2	1.12	ND	-
Chemical Oxygen Demand, COD	mg O/L	Accredited In-house Method MLS-SOP-WQ-029 Rev 1	ND	ND	ND	ND	ND	ND	-
Turbidity	NTU	APHA 2130B	9.2	2.2	1.8	1.9	2	2.1	-

Note: Values in bold and shaded grey denote non-conformity to the respective water quality standard.

[1] ASEAN Marine Water Quality Standard (2008)

[2] Vietnam's National Technical Regulation on Surface Water Quality for Protection of Aquatic Lives (QCVN 38: 2011/TTBTNMT) (2011)

* Not formally adopted as AMWQC

In general, the surface water quality of streams within the project area complied with the applicable standards (MONRE, 2011; ARMCANZ, 2000; ASEAN Secretariat, 2008). For the water quality parameters that were measured in-situ i.e. Temperature, pH and Dissolved oxygen all samples were within the allowable water quality thresholds.

For the ex-situ analysed parameters, there were several instances where the readings were outside the acceptable threshold limits. Nitrate (NO_3) concentrations exceeded the threshold for all samples during spring and neap tide. Specifically, high exceedances were noted during spring tide at SW4 – sample 4A and 4B and during neap tide at SW4 sample 4A and 4B. Similarly, Phosphate (PO_4) concentrations exceeded the threshold for all samples during spring and neap tide. Specifically, high exceedances were noted during spring tide at SW4 – sample 4A and 4B. Total Dissolved Solids (TDS) concentrations exceeded threshold in all samples during spring and neap tide except the two instances during neap tide at SW4 – sample 4A and 4B. Ammonia as NH3-N concentrations exceeded the threshold during neap tide at SW4 – sample - 4A; SW5 - sample 5A; and SW6 - sample 6A and 6B. Ammonia as NH3-N concentrations also exceeded the threshold during spring tide at SW1 - sample 1A and 1B; SW2 - sample 2A and 2B; SW3 - sample 3A and 3B; SW4 - sample 4A and 4B and SW6 – sample 6A and 6B. For the Enterococcus, the values exceeded threshold in all samples during spring and neap tide except for the two instances one during spring tide SW7 – sample 7B and one during neap tide SW2 – sample 2B. Mercury (Hg) concentrations exceeded the threshold at neap tide at SW1 – sample 1A and 1B; SW2 – sample 2B; SW3 – sample 3A and 3B; SW4 – sample 4A and 4B; SW5 – sample 5A and 5B; SW6 – sample 6A and 6B; SW9 – sample 9A and 9B. Mercury (Hg) concentrations exceeded the threshold during spring tide at SW1 – sample 1A and 1B; SW2 – sample 2A and 2B; SW3 – sample 3A and 3B; SW4 – sample 4A and 4B; SW5 – sample 5A and 5B; SW6 – sample 6A and 6B.

The above exceedances can be potentially explained by certain human activities (e.g., waste accumulation, fertilizing) happening outside the project area and polluting the downstream portion of the water body. The project is located along the northern Lim Chu Kang coast and in proximity to the floating fish farms in the West Johor Strait as well as land-based farms in Lim Chu Kang area. The agricultural activities conducted in the area, especially the use of fertilizers, could possibly increase the concentration of the ammonia as NH3-N, phosphate, total suspended solids, and nitrates in the streams. The higher mercury concentrations can potentially be caused by anthropogenic activities in the area.

These results provide the short-term trend based on current surveys. An extended period of water quality monitoring could help to define the water quality of these streams more accurately based on long-term trend.

6.5 Marine Water Quality

6.5.1 Baseline Methodology

Sampling was conducted at six points covering different marine locations across the project boundary (Figure 6-5). A SINGLAS-accredited laboratory was utilised to analyse the collected marine water quality samples. One round of water quality monitoring was carried out for neap and spring tides each. The samples were collected on 18 Oct 2022 during neap tide and 27 Oct 2022 during spring tide (Table 6.13). The secondary water quality data from previous reports from surveys carried out in the vicinity of the project area, as well as data collected by various government agencies, if available, were reviewed and utilised.

Figure 6-5. Location of the marine water quality sampling points in project area

Table 6.13. Coordinates and dates of Marine water quality sampling location

ID	Coordinates		Date of Sampling
MW1	1.442752	103.7607424	Neap tide: 18/10/2022 Spring tide: 27/10/2022
MW2	1.439143	103.7554313	
MW3	1.439031	103.7496867	
MW4	1.441490	103.7472895	
MW5	1.439716	103.7422672	
MW6	1.440792	103.7371782	

Tolerance limits for water quality has been based on the ASEAN Marine Water Quality Criteria (MWQC) as shown in Table 6.14.

Table 6.14. Marine water quality parameters tested in the laboratory

Test Parameter	Unit	ASEAN Marine Water Quality Criteria	mg/L
Ammonia as NH3-N	µg/L	70	0.07
Cadmium as Cd	µg/L	10	0.01
Chromium as Cr6+ (VI)	µg/L	50	0.05
Copper as Cu	µg/L	8	0.008
Lead as Pb	µg/L	8.5	0.0085
Mercury as Hg	µg/L	0.16	0.00016
Cyanide	µg/L	7	0.007
Nitrate as NO3-N	µg/L	60	0.06
Nitrate as NO2-N	µg/L	55	0.055
Oil and Grease by FTIR	mg/L	0.14	
Phenolic compounds (as Phenols)	mg/L	0.12	
Phosphate as PO4-P	µg/L	15 µg L^{-1} (coastal) 45 µg L^{-1} (estuarine)	0.015
Total Suspended Solids, TSS	mg/L	Permissible 10% maximum increase over seasonal average concentration	
Enterococcus	cfu/100mL	35	
Faecal Coliform	cfu/100mL	100	
Tributyltin (TBT)*	µg/L	10	0.01

6.5.2 Baseline Results

In this study, the results of marine water quality analysis in comparison with the relevant standards are tabulated in Table 6.15 and Table 6.16 for the neap tide sampling and Table 6.17 and Table 6.18 for the spring tide sampling. The laboratory analysis reports are provided in **Appendix E**.

Table 6.15. Marine water quality results for neap tide (Flood Tide – 18/10/2022)

Test Parameter	Unit	Test Method	Sample 1A	Sample 2A	Sample 3A	Sample 4A	Sample 5A	Sample 6A	ASEAN Marine Water Quality Criteria
			MW 1 Flood Tide 18/10/2022 1100hrs	**MW 2 Flood Tide 18/10/2022 1110hrs**	**MW 3 Flood Tide 18/10/2022 1120hrs**	**MW 4 Flood Tide 18/10/2022 1130hrs**	**MW 5 Flood Tide 18/10/2022 1140hrs**	**MW 6 Flood Tide 18/10/2022 1150hrs**	
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	**0.25**	**0.34**	**0.37**	**0.2**	**0.074**	**0.086**	0.07
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.01
Chromium 6 as Cr (VI)	mg/L	APHA 3500-Cr (B)	ND	ND	ND	ND	ND	ND	0.05
Copper as Cu	mg/L	APHA 3125B	0.001	ND	0.0011	ND	0.0012	0.0011	0.008
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.0085
Mercury as Hg	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.00016
Cyanide	mg/L	APHA Pt 4500-CN (N)	ND	ND	ND	ND	ND	ND	0.007
Nitrate as N03-N	mg/L	APHA 4500-N03 (I)	**0.48**	**0.6**	**0.64**	**0.54**	**0.36**	**0.2**	0.06
Nitrate as N02-N	mg/L	APHA 4500-N03 (I)	**0.07**	**0.076**	**0.076**	**0.07**	**0.062**	**0.059**	0.055
Oil and Grease by FTIR	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev O (adapted from APHA 5520C)	**0.27**	ND	ND	ND	ND	**0.16**	0.14
Phenolic compounds (as Phenols)	mg/L	Accredited In-house Method MLS-SOP-WQ-009 Rev 2	ND	ND	ND	0.026	ND	ND	0.12
Phosphate as P04-P	mg/L	APHA 4500-P (G)	**0.11**	**0.18**	**0.17**	**0.12**	**0.039**	**0.035**	0.015
Total Suspended Solids, TSS	mg/L	APHA 2540D	5.55	5.80	7.65	4.25	19.3	12.1	Permissible 10% maximum increase over seasonal average concentration

Enterococcus	cfu/100 mL	APHA 9230C	4	**100**	2	22	15	7	35
Faecal Coliform	cfu/100 mL	APHA 9221 D	**260**	**600**	80	13	70	26	100
Tributyltin (TBT)*	µg/L	GC-ICPMS (by UK lab)	**0.02**	ND	**0.07**	0.01	ND	**0.04**	0.01

Note: Values in **bold** and shaded grey denote non-conformity to the respective water quality standard.

Table 6.16. Marine water quality results for neap tide (Ebb Tide – 18/10/2022)

Test Parameter	Unit	Test Method	Sample 1B Ebb Tide MW 1 18/10/2022 1560hrs	Sample 2B Ebb Tide MW 2 18/102022 1550hrs	Sample 3B Ebb Tide MW 3 18/10/2022 1540hrs	Sample 4B Ebb Tide MW 4 18/10/2022 1530hrs	Sample 5B Ebb Tide MW 5 18/10/2022 1520hrs	Sample 6B Ebb Tide MW 6 18/10/2022 1510hrs	ASEAN Marine Water Quality Criteria
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	0.055	**0.26**	**0.29**	**0.23**	**0.17**	**0.13**	0.07
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.01
Chromium 6 as Cr (VI)	mg/L	APHA 3500-Cr (B)	ND	ND	ND	ND	ND	ND	0.05
Copper as Cu	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.008
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.0085
Mercury as Hg	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.00016
Cyanide	mg/L	APHA Pt 4500-CN (N)	ND	0.0055	ND	ND	0.0064	ND	0.007
Nitrate as N03-N	mg/L	APHA 4500-N03 (I)	**0.21**	**0.36**	**0.50**	**0.50**	**0.47**	**0.41**	0.06
Nitrate as N02-N	mg/L	APHA 4500-N03 (I)	**0.062**	**0.073**	**0.068**	**0.072**	**0.070**	**0.063**	0.055
Oil and Grease by FTIR	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev O (adapted from APHA 5520C)	ND	ND	ND	ND	ND	ND	0.14
Phenolic compounds (as Phenols)	mg/L	Accredited In-house Method MLS-SOP-WQ-009 Rev 2	ND	ND	ND	ND	ND	ND	0.12
Phosphate as P04-P	mg/L	APHA 4500-P (G)	**0.025**	**0.12**	**0.15**	**0.12**	**0.10**	**0.077**	0.015
Total Suspended Solids, TSS	mg/L	APHA 2540D	9.90	12.2	9.40	10.1	11.4	12.4	Permissible 10% maximum increase over seasonal average concentration

Enterococcus	cfu/100 m	APHA 9230C	2	**320**	ND	22	**280**	**250**	35
Faecal Coliform	cfu/100 m	APHA 9221 D	**100**	**80**	**110**	24	**260**	90	100
Tributyltin (TBT)*	µg/L	GC-ICPMS (by UK lab)	0.01	ND	**0.03**	ND	ND	**0.06**	0.01

Note: Values in **bold** and shaded grey denote non-conformity to the respective water quality standard.

Table 6.17. Marine water quality results for spring tide (Flood tide 27/10/2022)

Test Parameter	Unit	Test Method	Sample 1C MW1 MID 27/10/2022 1035hrs	Sample 2C MW2 MID 27/10/2022 1020hrs	Sample 3C MW3 MID 27/10/2022 0930hrs	Sample 4C MW4 MID 27/10/2022 0920hrs	Sample 5C MW5 MID 27/10/2022 0910hrs	Sample 6C MW6 MID 27/10/2022 0900hrs	ASEAN Marine Water Quality Criteria
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	**0.53**	**0.51**	**0.61**	**0.58**	**0.59**	0.47	0.07
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.01
Chromium as Cr6+ (VI)	mg/L	APHA 3500-Cr (B)	ND	ND	ND	ND	ND	ND	0.05
Copper as Cu	mg/L	APHA 3125B	0.0010	ND	0.0013	0.0015	0.0021	0.0020	0.008
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.0085
Mercury as Hg	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.00016
Cyanide	mg/L	APHA Pt 4500-CN (N)	ND	ND	ND	**0.0114**	0.0051	0.0050	0.007
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**0.28**	**0.36**	**0.27**	**0.27**	**0.34**	0.23	0.06
Nitrate as NO2-N	mg/L	APHA 4500-NO3 (I)	**0.12**	**0.11**	**0.13**	**0.12**	**0.12**	**0.12**	0.055
Oil and Grease by FTIR	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev 0 (adapted from APHA 5520C)	ND	ND	ND	ND	ND	0.14	0.14
Phenolic compounds (as Phenols)	mg/L	Accredited In-house Method MLS-SOP-WQ-009 Rev 2	ND	**0.030**	**0.028**	**0.025**	**0.030**	ND	0.12
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.13**	**0.12**	**0.13**	**0.11**	**0.12**	**0.12**	0.015

Test Parameter	Unit	Test Method	Sample 1C	Sample 2C	Sample 3C	Sample 4C	Sample 5C	Sample 6C	ASEAN Marine Water Quality Criteria
			MW1 MID	**MW2 MID**	**MW3 MID**	**MW4 MID**	**MW5 MID**	**MW6 MID**	
			27/10/2022 1035hrs	**27/10/2022 1020hrs**	**27/10/2022 0930hrs**	**27/10/2022 0920hrs**	**27/10/2022 0910hrs**	**27/10/2022 0900hrs**	
Total Suspended Solids, TSS	mg/L	APHA 2540D	6.00	2.30	5.90	4.80	5.70	5.60	Permissible 10% maximum increase over seasonal average concentration
Enterococcus	cfu/100mL	APHA 9230C	10	**170**	10	ND	**200**	ND	35
Faecal Coliform	cfu/100mL	APHA 9221D	**240**	**280**	**500**	**600**	**800**	**230**	100
Tributyltin (TBT)*	µg/L	GC-ICPMS (by UK lab)	ND	ND	**0.02**	**0.03**	ND	**0.05**	0.01

Note: Values in **bold** and shaded grey denote non-conformity to the respective water quality standard.

Table 6.18. Marine water quality results for spring tide (Ebb tide 27/10/2022)

Test Parameter	Unit	Test Method	Sample 1D	Sample 2D	Sample 3D	Sample 4D	Sample 5D	Sample 6D	ASEAN Marine Water Quality Criteria
			MW1	MW2	MW3	MW4	MW5	MW6	
			MID	MID	MID	MID	MID	MID	
			27/10/2022	27/10/2022	27/10/2022	27/10/2022	27/10/2022	27/10/2022	
			1445hrs	1455hrs	1540hrs	1550hrs	1605hrs	1615hrs	
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	**0.50**	**0.41**	**0.58**	**0.62**	**0.47**	**0.48**	0.07
Cadmium as Cd	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.01
Chromium as Cr6+ (VI)	mg/L	APHA 3500-Cr (B)	ND	ND	ND	ND	ND	ND	0.05
Copper as Cu	mg/L	APHA 3125B	0.0015	ND	ND	ND	ND	0.0018	0.008
Lead as Pb	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.0085
Mercury as Hg	mg/L	APHA 3125B	ND	ND	ND	ND	ND	ND	0.00016
Cyanide	mg/L	APHA Pt 4500-CN (N)	0.00592	ND	0.00615	ND	ND	ND	0.007
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	**0.30**	**0.36**	**0.27**	**0.28**	**0.37**	**0.22**	0.06
Nitrate as NO2-N	mg/L	APHA 4500-NO3 (I)	**0.11576**	**0.10245**	**0.15078**	**0.12133**	**0.10535**	**0.11**	0.055
Oil and Grease by FTIR	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev 0 (adapted from APHA 5520C)	0.12	ND	ND	ND	ND	ND	0.14
Phenolic compounds (as Phenols)	mg/L	Accredited In-house Method MLS-SOP-WQ-009 Rev 2	ND	ND	0.02665	0.03247	0.03553	ND	0.12
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	**0.13**	**0.11**	**0.14**	**0.13**	**0.4**	**0.13**	0.015

Test Parameter	Unit	Test Method	Sample 1D	Sample 2D	Sample 3D	Sample 4D	Sample 5D	Sample 6D	ASEAN Marine Water Quality Criteria
			MW1	**MW2**	**MW3**	**MW4**	**MW5**	**MW6**	
			MID	**MID**	**MID**	**MID**	**MID**	**MID**	
			27/10/2022	**27/10/2022**	**27/10/2022**	**27/10/2022**	**27/10/2022**	**27/10/2022**	
			1445hrs	**1455hrs**	**1540hrs**	**1550hrs**	**1605hrs**	**1615hrs**	
Total Suspended Solids, TSS	mg/L	APHA 2540D	2.3	3.2	3.1	4.1	3.1	4.2	Permissible 10% maximum increase over seasonal average concentration
Enterococcus	cfu/100mL	APHA 9230C	20	**120**	ND	ND	30	10	35
Faecal Coliform	cfu/100mL	APHA 9221D	**400**	**400**	**440**	**350**	**190**	**110**	100
Tributyltin (TBT)*	µg/L	GC-ICPMS (by UK lab)	**0.02**	ND	**0.06**	ND	ND	**0.04**	0.01

Note: Values in **bold** and shaded grey denote non-conformity to the respective water quality standard.

Generally, marine water quality is poor throughout the entire site, with many of the points exceeding multiple test parameters. Generally, the parameters with consistent exceedances consist of ammonia as NH3-N, NO3-N and NO2-N, phosphate, phenolic compounds, enterococcus, faecal coliform and tributyltin.

Ammonia as NH3-N in marine water indicates the presence of decaying organic matter. Ammonia is highly soluble and can be found in excretory products of aquatic fauna. Ammonia as NH3-N, NO3-N and NO2-N concentrations exceeded the threshold at all the locations during neap (flood) tide. Similarly, NO3-N and NO2-N concentrations exceeded the threshold at all the locations during neap (ebb) tide and spring tide, except for MW1-sample 1A having a concentration for ammonia as NH3-N below the threshold. The exceedance can be potentially explained by certain human activities (e.g., waste accumulation, fertilizing) and animal contributions happening within and/or outside the project area and polluting the downstream portion of the water body.

Phosphates refers to the sum of total inorganic and organic phosphorous, which is a nutrient that stimulates aquatic plant growth. Phosphate concentrations exceeded the threshold at all locations during flood tide, neap tide and at both surface and mid-depth levels. The exceedance is potentially due to agricultural run-offs. When present in excess, eutrophication can be accelerated which will result in lower dissolved oxygen levels in the water.

Bacteria counts comprise of Faecal coliform and Enterococcus concentrations, both can be found in faeces and normally resides in the intestinal tract of warm-blooded animals. From the results both types of bacteria exhibited exceedances. Enterococcus concentrations exceeded the threshold during neap (flood) tide at MW1-sample 1A. Enterococcus concentrations exceeded the threshold during neap (ebb) tide at MW5-sample 5B MW6-sample 6B. Faecal coliform concentrations exceeded the threshold during neap (flood) tide at MW1-sample 1A, MW2-sample 2A. Faecal coliform concentrations exceeded the threshold during neap (ebb) tide at MW2-sample 2D. Faecal coliform concentrations exceeded the threshold during spring tide at all locations at mid-depth. The presence of faecal coliforms is indicative of faecal contamination, as such swimming and consuming organisms (i.e. shellfish) from these water bodies might pose as a potential health risk.

Phenols in aqueous environments are mildly acidic and can lower the water pH. Phenolic compounds concentrations exceeded the threshold during spring tide at MW2-sample 2C, MW3-sample 3C, MW4-sample 4C and MW5-sample 5C. Their presence is likely due to discharges from industrial and domestic activities. Phenols are carcinogens and long-term interaction can cause damage to the red blood cells and the liver, even at low concentrations (Anku et al., 2017).

Tributyltin (TBT) is a highly toxic biocide used in antifouling paints to protect the hulls of large ships, commercial vessels and pleasure crafts. TBT concentrations exceeded the threshold during neap (flood) tide at MW1-sample 1A, MW3-sample 3A, MW6-sample 6A. TBT concentrations exceeded the threshold during neap (ebb) tide at MW6-sample 6B. High concentrations of TBT can be hazardous to marine organisms, especially bivalves in which TBT acts as an endocrine disruptor (Belzunce & Pérez, 2004), causing various deformities in mussels and whelks and affects oyster farming.

Oil and grease are typical pollutants found and measured in water bodies, consisting of fats, oils, waxes, and other related constituents. Oil and grease by FTIR concentrations exceeded the threshold during neap (flood) tide at MW1-sample 1A, MW-sample 6A. The exceedances can be attributed to discharge, sewerage, if left unmanaged oil and grease can threaten habitats especially aquatic environments. Since oil is non-soluble in water, it spreads over the water surface creating unsightly films and prevents oxygen from penetrating which harms the plants and animals that live in the water.

6.6 Natural Waterway Mapping

6.6.1 Mapping Approach

Together, three main waterways have been identified with the location of sampling points shown in Figure 6-6. The characterisation survey covers details such as substrate type, riparian vegetation composition, wetted width and depth, and flow velocity of waterway as explained below. The survey locations were selected based on coverage of the waterway profile variations, site conditions and safe access. Results are interpreted in 2 parts. The first part consists of the collection of baseline parameters, while the second part projects the sectional profile of the river with its associated vegetation composition.

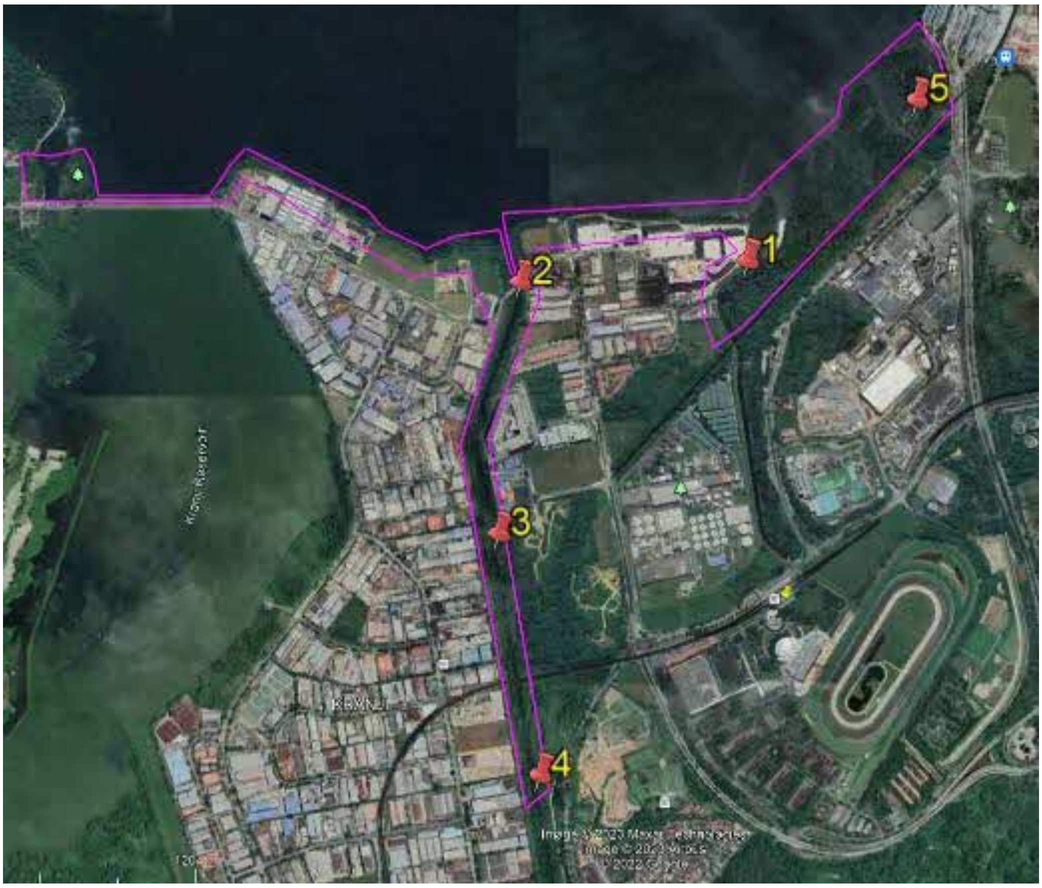


Figure 6-6. Location map of waterway characterisation survey points

Valeport Model 106 Current Meter was dipped into the water at the designated locations for the recording of the speed and direction parameters of current at 5-minute interval. The mapping was done after heavy rain on the 5th of December 2022. Pre-deployment checks were conducted to ensure The Valeport Model 106 was functioning properly. The current meter was inspected to be in good condition and free of any damage. Power supply, communication cables, and display unit were connected and working. The current meter was also calibrated according to manufacturer specifications prior to deployment. The current meter was deployed on 5 locations for waterway mapping characterization as shown in Figure 6-6. The current meter was attached to a secure mooring line and lowered into the water. It was lowered and placed in the desired depth and the mooring line was anchored securely. The depth by which the meter was submerged was determined by placed depth interval markings on the mooring line.

Figure 6-7. Deployment of current meter

Valeport Model 106 current meter was equipped with a control display for continuous monitoring of data obtained by the current meter (Figure 6-8). The control display unit provided real time and averaged display of velocity and direction of current. The readings were continuously monitored and recorded on 5-minute intervals to ensure that the readings were accurate, and the meter was functioning properly.

Figure 6-8. Valeport control display unit

Measurements for the width and depth of the waterway were taken from combined hydrographic and topographic surveys. Hydrographic surveys using singlebeam echosounder were done during highest tides (survey dates as follows: 31st of August; 1st and 2nd, 27th and 28th of September; 9th and 10th, 13th and 15th of October, 2022) while Topographic survey using aerial LIDAR on drone was done during the lowest tide (27th of July 2022).

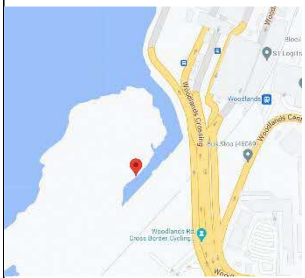
6.6.2 Waterway Characterisation Results

Characterisation of Sungei Mandai Kechil River

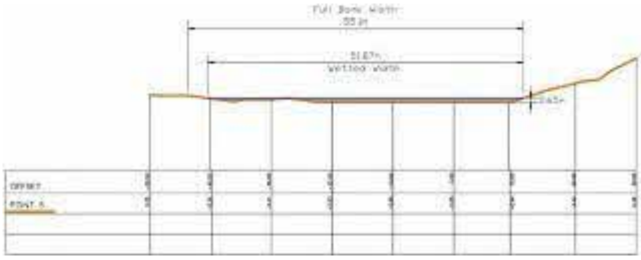
This is identified as one of the major waterways that cuts from the east side of the project project area and is named Sungei Mandai Kechil. Sungei Mandai Kechil is an established river and is easily seen during high tide levels. The river is largely influenced by the tide level in the Straits of Johor. Table 6.19 provides the results of the characterisation survey.

The trees along Sungei Mandai Kechil were not identified as it was outside the VTA area.

Table 6.19. Results of Sungei Mandai Kechil River characterisation survey

Survey Point ID	River Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity[11] (m/s)	Flow Direction (°)
5	Overview:  Location:  Cross-section:  Canopy: 	Width: 51.87m Depth: 0.65m	Stream: Silt/clay Bank: Silt, Revetment rock	0.010	65.6°

[11] Flow velocity was measured during Ebb tide.

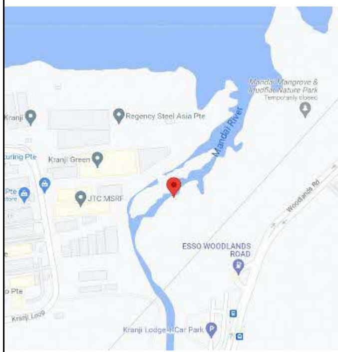
	Cross-section Profile: 

Characterization of Sungei Mandai Besar

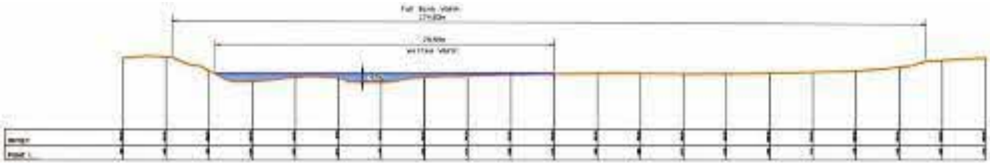
Sungei Mandai Besar is identified as another major waterway that cuts from the east side of the project area. Similar to Sungei Mandai Kechil, Sungei Mandai Besar is largely influenced by the Straits of Johor due to its proximity.

Many individuals of *Avicennia* and *Sonneratia* can be found at the mouth of Sungei Mandai Besar. The VTA survey showed many *Sonneratia alba* individuals with a small girth size, which suggests regenerating mangrove forests in the area. The mouth of the river is also the only location within the project area with the locally endangered *Heritiera littoralis*.

Table 6.20. Results of Sungei Mandai Besar characterisation survey

Survey Point ID	River Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity[12] (m/s)	Flow Direction (°)
1	Overview:  Location:  Cross-section:  Canopy: 	Width: 78.60m Depth: 1.92m	Stream: Silt/clay Bank: Silt/clay	0.092	45.6°

[12] Flow velocity was measured during Ebb tide.

Survey Point ID	River Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity[12] (m/s)	Flow Direction (°)
	Cross-section Profile: 				

Characterization of Sungei Pang Sua

Sungei Pang Sua starts off as an earth stream from the bottom of the project area and mainly has its sources from runoff from the mangrove forest nearby. It then continues along Sungei Pang Sua and has its source coming from man-made culverts feeding into the cannel from the nearby industrial area. The stream then continues as towards the north of the project area and empties into the Straits of Johor. As the Sungei Pang Sua is rather long, three points has been chosen to be surveyed. Table 6.21 provides the results of the stream characterisation survey.

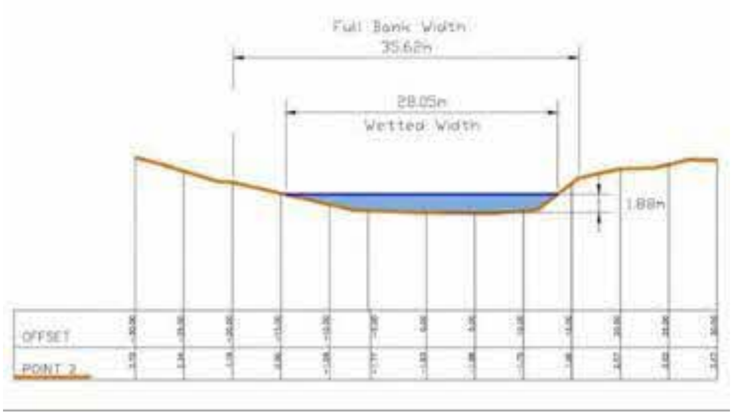
The eastern bank of Sungei Pang Sua is dominated by *Hibiscus tiliaceus*, whereas species of *Avicennia* dominate the mudflat section of the river. Several metres above the high tide waterline, species of early-successional secondary forest can be found. Few species of conservation significance are present at Sungei Pang Sua.

Table 6.21. Results of Sungei Pang Sua River characterisation survey

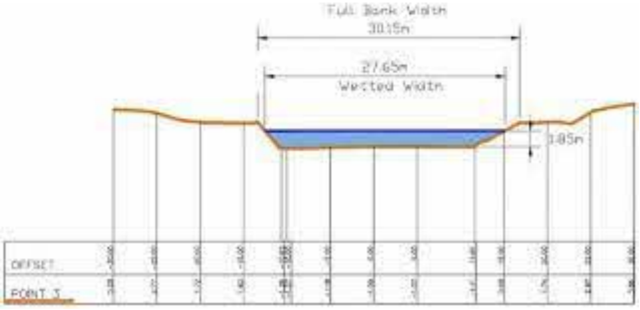
Survey Point ID	River Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity[13] (m/s)	Flow Direction (°)
2	Overview:  Location:	Width: 28.05m Depth: 1.88m	Stream: Silt/clay Bank: Silt/clay	0.125	15.3°

[13] Flow velocity was measured during Ebb tide.

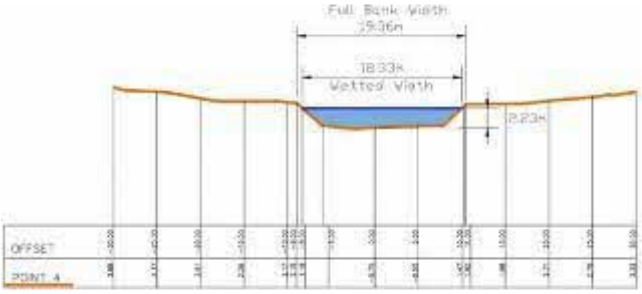
Survey Point ID	River Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity[13] (m/s)	Flow Direction (°)
	 Cross-section:   Canopy: 				

Survey Point ID	River Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity[13] (m/s)	Flow Direction (°)
	Cross-section Profile: 				

Survey Point ID	Stream Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity (m/s)	Flow Direction (°)
3	Overview:  Location:  Cross-section:  Canopy: 	Width: 27.65m Depth: 1.85m	Stream: Silt/clay Bank: Silt/clay	0.199	315.2°

	Cross-section Profile: 

Survey Point ID	Stream Cross-Section and Canopy Photograph	Wetted Width and Depth	Soil Substrate	Flow Velocity (m/s)	Flow Direction (°)
4	Overview:  Location:  Cross-section:  Canopy: 	Width: 18.33m Depth: 2.23m	Stream: Silt/clay Bank: Silt/clay	0.086	1.3°

	Cross-section Profile: 

6.7 Impact Assessment

Environmental quality within the vicinity of the proposed Nature Park may be influenced by changes in water quality and discharges arising during the construction of the Nature Park's Infrastructure. The sensitive receptors that may be affected by these changes in water quality consist mainly of flora & fauna within the project area, including mangrove and shorebirds. Based on the proposed spatial layout plan (Figure 2.5), the environmental scoring for the residual impacts for each impact component (after accounting for the recommended mitigation measures) according to the RIAM was Slight Negative to No Impact.

6.7.1 Predicted Impacts

The potential for the generation of water quality pollution is assessed qualitatively and recommendations on the appropriate mitigation actions to minimise any potential impacts are provided. These are to ensure compliance with PUB and NEA requirements.

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

Overall, the predicted impacts are expected to be mainly Slight Negative for all locations. During pre-construction phase only minor works are expected, such as clearance for working space, create site access and setting up of hoardings. Similarly, during operation phase minimal works will be carried out. Thus, at both phases, the impacts would be generally in the Slight Negative range.

Nonetheless, some predicted impacts are expected to be Minor Negative, especially for the predicted impacts of soil erosions and surface runoff.

RIAM Environmental Scoring for the Predicted Impacts

Table 6.22. Predicted hydrology and water quality impacts from proposed works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre-construction	• Construction site access • Construction site boundary • Storage space • Temporary working space	• Vegetation clearance	Soil Erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Sungei Pang Sua Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation Clearance	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities	• Earthworks • Land-based development with piling	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		• Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Demolition of existing building	Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Soil erosions and surface runoff	1	-2	2	2	1	-10	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="4">Public Trail (Profile B -1)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space</td><td>• Vegetation clearance</td><td>Soil Erosions and Surface Runoff</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Boardwalk (using existing PCG fence footing as foundation)</td><td rowspan="2">• Earthworks - Slope cut at gradient of 1:5
• Land and intertidal based development</td><td>Sediment runoff and siltation</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
<tr><td>Accidental spillage of oil & fuel and waste disposal</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>1</td><td>-10</td><td>Slight Negative</td></tr>
<tr><td>Operation</td><td>• Public Trail Boardwalk</td><td>• Recreational visits
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Impact to water quality due to routine maintenance activities of the park facilities</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>1</td><td>-10</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Public Trail (Profile B -2, Option 1)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space</td><td>• Earthworks
• Vegetation clearance</td><td>Soil erosions and surface runoff</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td>Construction</td><td>• Earth trail
• Nature-based Solutions
– Interlocking rings</td><td>• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation.
• Earthworks</td><td>Sediment runoff and siltation</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative
Public Trail (Profile C)	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
Public Trail (Profile C)	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
Public Trail (Profile C)	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative
Guided Trail (Profile D, Option 1)	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
Guided Trail (Profile D, Option 1)	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative
Guided Trail (Profile D, Option 2)	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
Guided Trail (Profile D, Option 2)	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	2	-12	Slight Negative
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Hoarding installation	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Sediment runoff and siltation	2	-2	2	2	3	-28	Slight Negative
				Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Boundary markers	**Pre-construct**	• Markers made up of rows of Bakau poles	• Vegetation clearance • Boundary marker installation	Increase in total suspended solids and turbidity	2	-2	2	2	2	-24	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	• Maintenance works	Impact to water quality due to routine maintenance activities	2	-2	2	2	2	-24	Slight Negative

Pre-Construction / Construction Phase

Soil Erosions and Surface Runoff

Impacts to surface waterways within the project area will potentially arise during the construction stage of the proposed Nature Park as considerable amounts of site clearance and earthworks will be required for the construction of Nature Park infrastructure. During the construction phase, adverse impacts to surface water quality of waterways (i.e. Sungei Pang Sua, Sungei Mandai Besar) could occur from soil erosion and sediment transport during storm events. Effects might be greater in linear construction areas such as the Public trail and Guided trail areas where the possibility of exposed and disturbed soils is much higher than other infrastructure. This impact could worsen if there are soil stockpiles left unprotected within the construction area. Run-off containing particulates will increase the concentrations of sediments, suspended solids and other contaminants, and can impact water quality of these waterways.

It is anticipated that soil stabilisation works within the intertidal zone and other coastal restoration works along the Public trail and Guided trail will be mostly carried out during low tide period. This will help to prevent construction waste and unwanted materials from flowing out to waterways or the sea during construction.

In addition, soil stabilization works such as cutting back of slopes within the Guided Trail may lead to soil erosion which in turn can result in sediment transport to a sensitive mangrove area. Rapid sedimentation may cause the burying of pneumatophores on the roots of mangrove species, thus causing oxygen stress. Studies have shown that *Avicennia* and *Sonneratia* species are highly affected by rapid sediment burial, resulting in the dying off of trees due to oxygen stress (Lee, Tan, & Havanond, 1996).

As no infrastructure is planned in the vicinity of Sungei Mandai Kechil, it is not likely to be affected by project construction activities.

In addition, other non-storm related effects could contribute sediments to water streams, including:

- Land clearance and site preparation of construction work areas (Sungei Kranji Pavilion, Sungei Pang Sua Pavilion, Public trail, Guided trail etc.)
- Run-off from exposed soil surface and earthwork areas.
- Run-off from dust suppression sprays.
- Earthworks e.g. excavation or backfilling.

Entry of significant amounts of silt into waterways will potentially affect the ecology of the whole Mandai Mangrove and Mudflat area if proper mitigation measures are not implemented, especially for mangrove health (Noor et al., 2015).

Oil & Fuel Spillage and Waste Disposal

The construction activities may require the onsite storage and handling of potential polluting material such as fuel, lubricant, cement, packaging materials etc. The following sources can affect the water quality within the project area:

- Fuel and lubricants from maintenance of construction vehicles and equipment.
- Concrete washout and excess grouting materials from construction activities.

- Illegal dumping of debris and rubbish such as packaging, construction materials and refuse; and
- Accidental spillage of liquids stored on-site e.g., oil/grease, solvents.

No hazardous chemicals as specified under EPM (Hazardous Substances) regulations are expected to be used in the construction activities within the project area. It is expected that the contractor will deploy adequate portable chemical toilets for construction personnel. These toilets will be cleaned and maintained by an approved sanitary waste collector. Hence, No Impact is expected from sewage discharge to water quality.

The impacts and effects on water quality from the construction activities are expected to be controlled with the implementation of a well-designed temporary drainage system and proposed mitigation measures.

The discharge water quality of various outfalls is expected to adhere to PUB standards. As noted earlier, four drains were spotted along the adjacent coastline that drains into the Mandai Mangrove and Mudflat, though no discharges were observed during site surveys. Adverse water quality of discharges from these drains could impact the population of mudflat invertebrates that the shorebirds feed on. It is recommended that a regular water quality monitoring programme should be established to study the discharge from these drains. This will help in managing any pollution impact to ecosystem in intertidal habitat.

Overall, the potential impacts have been considered to be negative, direct, short term, reversible, avoidable, local and of minor in magnitude.

Operation Phase

Operation phase will include activities linked with the recreational use of Nature Park by the general public and routine maintenance of Nature Park infrastructure. It is anticipated that the expected recreational activities (hiking, birdwatching) will not generate significant amounts of slit that would negatively affect natural waterway and marine water quality.

If major maintenance work is required for the Nature Park infrastructure, it is expected that such impacts will only last for the duration of the maintenance works and would be limited in scope. Overall, the potential for long-term operation phase impacts is considered to be insignificant.

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to location.

The predicted impacts are expected to be mainly Slight Negative across all locations, except for locations with heavy construction and sensitive areas (i.e., mangroves and intertidal habitats).

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc.) are expected. The predicted impacts from these works would mostly be species and habitat disturbances due to soil erosion and accidental spillage limited to the boundary of the project footprint. As such, there will be limited to no changes in baseline conditions and the predicated impacts are Slight Negative.

During the construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas along the coastline (i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion). The main hydrological concerns arising from these works are sediment runoff and siltation which would decrease the water quality in the area, this being assessed to be more severe than Minor Negative.

Despite the cessation of construction works during the operation phase, it is predicted that mild impacts are expected during the maintenance of park facilities and are assessed as Slight Negative.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

6.7.2 Mitigation Measures

Mitigation measures are to be implemented wherever negative impacts are predicted, in order to reduce the impacts of the works on the environment. A majority of hydrology mitigation measures are covered in this Chapter.

Table 6.23. Hydrology impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Soil Erosions and Surface Runoff	• Implementation of ECM. • Construction activities to be limited to the smallest footprint areas possible. • No heavy construction machinery should be located on intertidal areas.
	Increase in total suspended solids and turbidity	• Construction activities to be limited to the smallest footprint areas possible. • No heavy construction machinery should be located on intertidal areas • Care should be taken to minimize wakes and stirring up of sediment
Construction	Sediment runoff and siltation	<u>For Sungei Pang Sua Trail (Profile F):</u> • Implementation of ECM. • Storage and stockpiles areas to be identified and approved by NParks. • To locate stockpiles as far as possible away from water streams & mudflat areas. • Water used for dust control should not be allowed to cause erosion within work area • Excess loose soil and rock to be contained prior to the commencement of the works. <u>For all other areas:</u> • Implementation of ECM. • Construction activities to be limited to the smallest footprint areas possible. • Storage and stockpiles areas to be identified and approved by NParks. • Construction to be carried out during low tide period as far as possible. • All machinery and equipment to be located on dry land as far as possible. • No heavy construction machinery should be located on intertidal areas.
	Accidental spillage of oil & fuel and waste disposal	• Disposal of waste into water streams is strictly prohibited. • Waste bins to be provided within the construction work area. • Foreign material to be removed from site by a licensed waste collector. • Contractor to provide adequate portable chemical toilets for construction personnel • Vehicle fuelling and major maintenance not to be allowed in project area.
Operation	Routine maintenance	• Mitigation measures proposed for the construction phase to be applied.

Pre-Construction / Construction Phase

The following measures will mitigate some of the impacts from water pollution sources identified above during the construction period.

Earth Control Measures (ECM)
An appropriate ECM plan is to be prepared and endorsed by a Qualified Erosion Control Professional (QECP) before the commencement of the construction works. The ECM plan should include:

- Earth control measures are to be implemented by the contractor according to the QECP endorsed plans before starting the work.
- Proper sediment control measures designed to capture and retain silt are to be implemented which may include perimeter cut-off drains, perimeter silt fence, silt traps and silt treatment systems.
- QECP to review ECM plan implementation regularly during construction to ensure that the measures put in place remain effective.
- Regular monitoring of ECM treatment plant performance is to be carried out by Environmental Control Officer (ECO).
- Regular maintenance of ECM is to be carried out.
- After rain events, earth control measures in the field to be inspected and maintained over the course of construction.

Specific Mitigation Measures for Construction within Intertidal Area

- To avoid construction work during peak migratory bird season i.e., August to April.
- To limit construction activities to one area at a time to minimise disturbance to shorebirds.
- Construction activities shall be limited to the smallest footprint areas possible.
- Construction to be carried out during low tide period as far as possible to prevent sediment transport.
- All machinery and equipment to be located on dry land as far as possible.
- No heavy construction machinery should be located on intertidal areas.
- All construction personnel should be educated about the sensitive ecological nature of work areas before commencing the work and regular briefing during work should be carried out.

Other Best Construction Practices
The following best practices should be adopted throughout the construction site:

- Storage and stockpiles areas to be identified and approved by NParks.
- To locate stockpiles as far away as possible from waterways & mudflat areas.
- Disposal of waste into waterways, mangrove forests, and mudflats is strictly prohibited.
- Waste bins to be provided within the construction work area for proper disposal of construction debris and rubbish.
- Foreign material should not be illegally disposed of at waterways but removed from site by a licensed waste collector.
- Contractor to provide adequate portable chemical toilets for construction

personnel and to appoint an approved sanitary waste collector for regular collection of sewage.

- All liquids should be properly labelled and stored in appropriate containers at a safe location on site. Personnel handling these liquids should also be suitably trained.
- Vehicle fueling and major maintenance should not be allowed in the project area.
- Water used for dust control should not be allowed to cause erosion within the work area or to run offsite.
- Excess loose soil and rock to be contained prior to the commencement of the works.

With the adoption of these necessary mitigation measures, the potential impacts on water quality during construction activities are considered to be negligible.

Operation Phase

As the Operation phase impacts were assessed to be insignificant, no mitigation measures are proposed. Should major maintenance be undertaken during the operation phase, mitigation measures proposed for the construction phase should apply.

6.7.3 Residual Impacts

The residual impacts were evaluated using the RIAM method (Section 3.6) with due consideration that the recommended mitigation measures are implemented by Contractor. The residual impacts are likely to be in the band of No Impact to Minor Negative.

During both the pre-construction and construction phases, the main concern across most locations is the soil erosions and surface runoff experienced. Mitigation measure such as proper implementation of ECM and limiting construction activities to smallest footprint areas will help to reduce the magnitude, thus reducing the environment score from to a lower score in the Slight Negative range band.

During operation phase, the main concern across most locations are the impacts to water quality due to routine maintenance activities of the park facilities Mitigation measures such as proper disposal would lower the magnitude of impact such that the residual environment score is reduced from Slight Negative to No Impact range.

RIAM Environmental Scoring for the Residual Impacts

Table 6.24 Environmental Scores of the predicted and residual impacts on site's hydrology after implementation of mitigation measures listed in Table 6.23

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Impact Component</th><th colspan="7">RIAM for Predicted Impacts</th><th colspan="7">RIAM for Residual Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="4">Kranji Reservoir Park</td><td>Pre- construction</td><td>• Construction site access
• Construction site boundary
• Storage space
• Temporary working space</td><td>Soil erosions and surface runoff</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td><td>2</td><td>-1</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Bird sanctuary/ Coastal Forest
• Heron rookery
• Lookout shelter
• Pedestrian bridge
• Pedestrian path
• Nature-based Solutions
– Interlocking rings
– Intertidal terrace
– Rain garden</td><td>Sediment runoff and siltation</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td><td>3</td><td>-1</td><td>2</td><td>2</td><td>3</td><td>-21</td><td>Slight Negative</td></tr>
<tr><td>Accidental spillage of oil & fuel and waste disposal</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>1</td><td>-10</td><td>Slight Negative</td><td>1</td><td>-1</td><td>2</td><td>2</td><td>1</td><td>-5</td><td>No Impact</td></tr>
<tr><td>Operation</td><td>• Bird sanctuary/ Coastal Forest
• Heron rookery
• Lookout shelter
• Pedestrian bridge
• Pedestrian path</td><td>Impact to water quality due to routine maintenance activities of the park facilities</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>1</td><td>-10</td><td>Slight Negative</td><td>1</td><td>-1</td><td>2</td><td>2</td><td>1</td><td>-5</td><td>No Impact</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	2	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Public Trail Boardwalk	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Elevated Boardwalk	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil Erosions and Surface Runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	3	-21	Slight Negative
	Construction	• At-grade pedestrian connection	Sediment runoff and siltation	3	-2	2	2	3	-42	Minor Negative	2	-1	2	2	3	-14	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• At-grade pedestrian connection	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Soil erosions and surface runoff	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Sediment runoff and siltation	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Accidental spillage of oil & fuel and waste disposal	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Impact to water quality due to routine maintenance activities of the park facilities	1	-2	2	2	1	-10	Slight Negative	1	-1	2	2	1	-5	No Impact
Boundary markers	Pre-construct	• Markers made up of rows of Bakau poles	Increase in total suspended solids and turbidity	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	Impact to water quality due to routine maintenance activities	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

7 COASTAL HYDRAULICS

7.1 Hydrological Modelling

7.1.1 Approach and Methodology

Hydrological Model

The environmental impacts of the future MMM Nature Park development were further assessed by means of hydrodynamic modelling. This model included the setting up and recalibration of the baseline conditions in the project area (water levels, currents, waves) with reference to the modelling system that was built during the feasibility study stage in 2019. The hydrodynamic model was developed using Delft3D-FLOW and Delft3D-WAVE for running scenarios to assess the impacts of the new Nature Park development on sea water levels, currents and waves. These include short-term scenarios to study the base-case; medium-term scenarios to study the operation and long-term scenarios to simulate the impact of climate change (sea level rise). Short-term and medium-term hydrodynamic scenarios represent normal spring-neap conditions, extreme tides, monsoons, El Niño, La Niña and extreme small events. Long-term hydrodynamic scenarios represent a spring-neap with moderate and high sea level rise projections.

The assessment of the hydrodynamic model must consider the development of any 'wet infrastructure' that would be built in the waters or mudflat. With reference to Section 2.3.3 and Figure 2-7, the main future development identified for which wet infrastructure would be built would be the Experiential Walk within the Sungei Pang Sua Pavilion node. At Kranji Reservoir Park, a portion of eroded coastline was also identified to showcase Nature-based Solutions whereby interlocking rings are stacked to stabilise the edge. Elevated boardwalks along both Public & Guided Trails will be built on terrestrial land and will not be protruding into the mudflats. Hence, elevated boardwalks will not be taken into consideration in the hydrodynamic model.

As input to the EIA, the following aspects were assessed:

- changes to the hydrodynamics (water levels, currents, and waves) as a result of the construction of the Experiential Walk (i.e., placement of the boardwalk and excavation) in the intertidal zone ('wet infrastructure')

7.2 Baseline Model Setup and Calibration

7.2.1 Wind Analysis

To better understand the wind condition surrounding the project area, in particular the occurrence and severity of wind during squalls, wind data were collected from the Meteorological Service Singapore (MSS) for the following stations (see Figure 7-1) for respective period of data collection:

- S024 Changi (June 2009 – May 2019)
- S104 Admiralty (February 2009 – May 2019)
- S115 Tuas South (April 2011 – May 2019)

Figure 7-1. Location of MSS wind stations, adapted from MSS website

Wind data was collected at 1-minute intervals to allow detection of squalls. This is due to squall events usually lasting for only less than one hour, which is the standard averaging period in wind climate analyses.

To assess the average wind climate and seasonal variations (monsoon), the collected wind data for all stations were first averaged to one-hour intervals, classified to wind speed and wind direction classes, and presented in the form of wind roses in Figure 7-2.

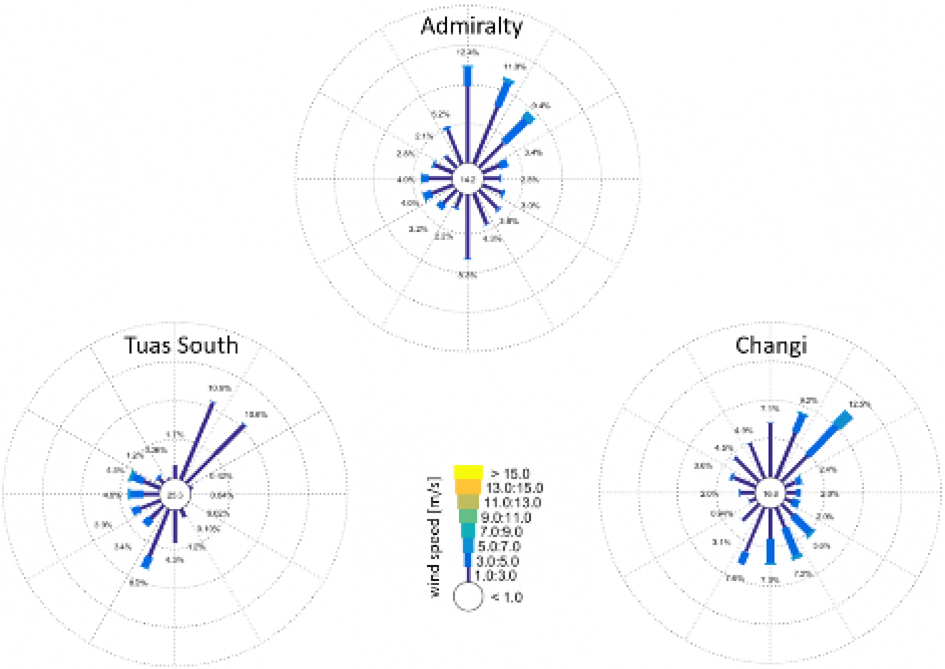


Figure 7-2. All-year wind roses at Admiralty, Tuas South, and Changi stations

Figure 7-2 shows that the wind is mild for all three stations, with hourly-averaged wind speeds not exceeding 9 m/s. All three stations show dominant North to North-east and

South to South-west wind directions, although there are relatively large differences between the stations. This difference is likely to be related to disturbances effects from the surrounding land.

Analysis of the hourly-averaged wind data from June 2009 to May 2019 at Admiralty wind station, which is the nearest wind station to the project area, shows the two distinct monsoon seasons clearly:

- North-east monsoon from November till April.
- South-west monsoon from June till September.

This is illustrated in the box plot in Figure 7-3.

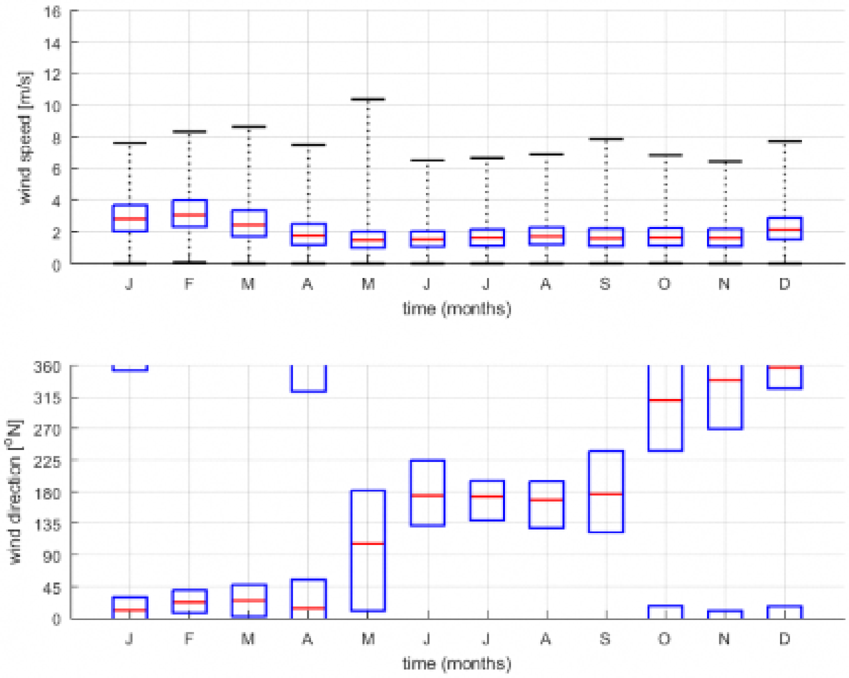


Figure 7-3. Seasonal box plot of Admiralty wind station

Note: The red line indicates the median value, the blue box the middle 50% of the data values, and the dotted whiskers the range between minimum and maximum wind speed.

Daily variations of hourly-averaged wind are illustrated for a North-east monsoon season and a South-west monsoon season respectively in Figure 7-4 and Figure 7-5.

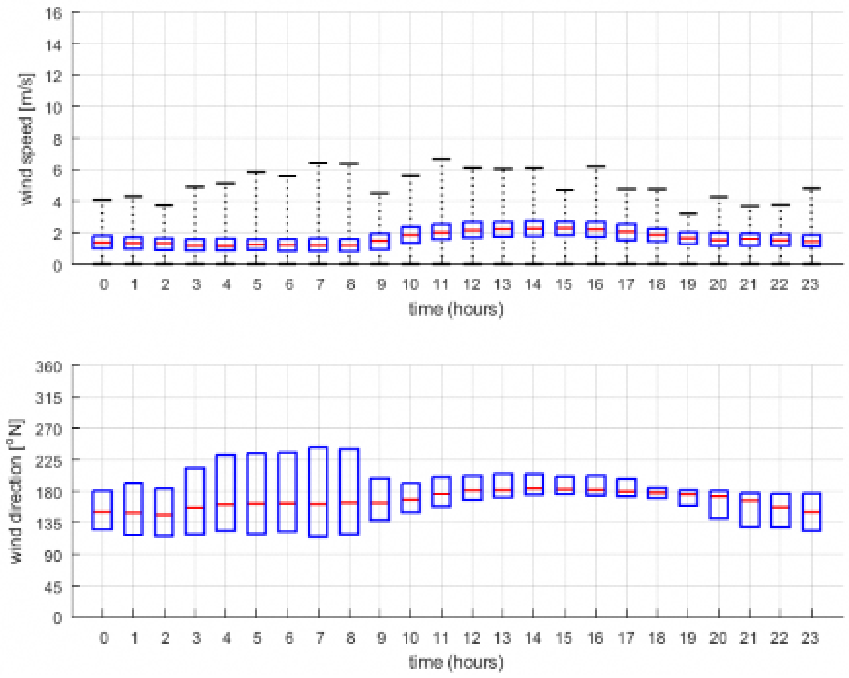


Figure 7-4. Daily box plot of Admiralty wind station in July

Note: The red line indicates the median value, the blue box the middle 50% of the data values, and the dotted whiskers the range between minimum and maximum wind speed.

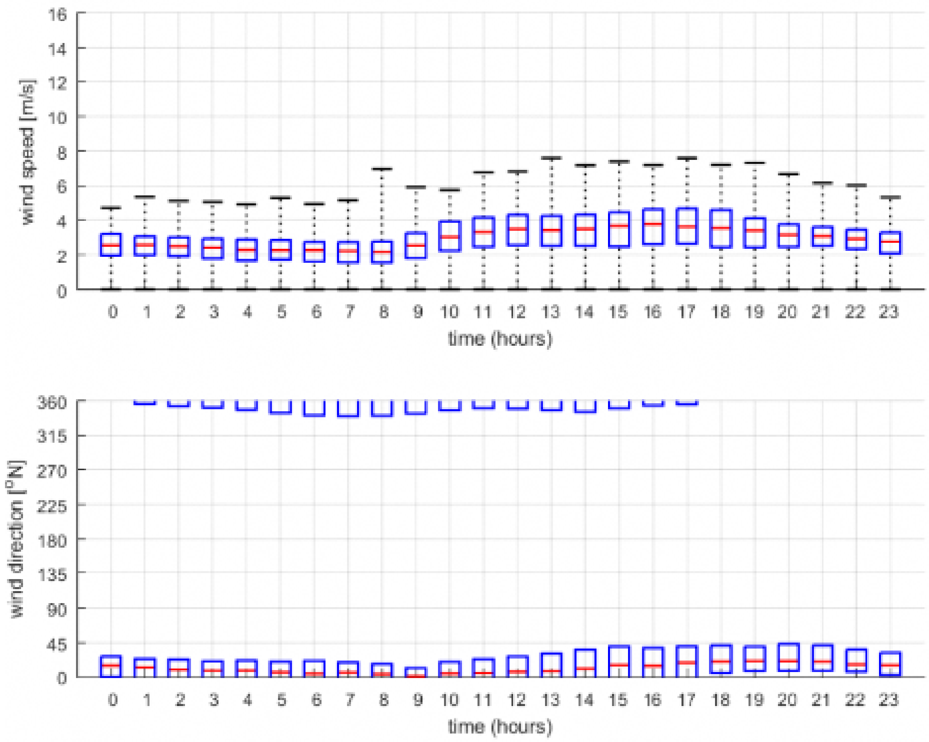


Figure 7-5. Daily box plot of Admiralty wind station in January

The red line indicates the median value, the blue box the middle 50% of the data values, and the dotted whiskers the range between minimum and maximum wind speed.

Figure 7-4 and Figure 7-5 show that during both North-east (NE) and South-west (SW) monsoons, the hourly-averaged wind speed is rather low (< 8 m/s), with faster winds during the afternoon, and from constant directions (South to South-west and North to North-east in respective monsoon) throughout the day.

Apart from monsoon winds, strong winds can occur in the project area during squalls. However, squall events have a timescale of less than one hour and are therefore not apparent in hourly-averaged time records. This is illustrated in Figure 7-6 for Admiralty wind station, with the measured 1-minute peak value of approximately 14 m/s, calculated 10-minute average peak of approximately 10 m/s, and calculated 1-hourly average peak at approximately 7 m/s.

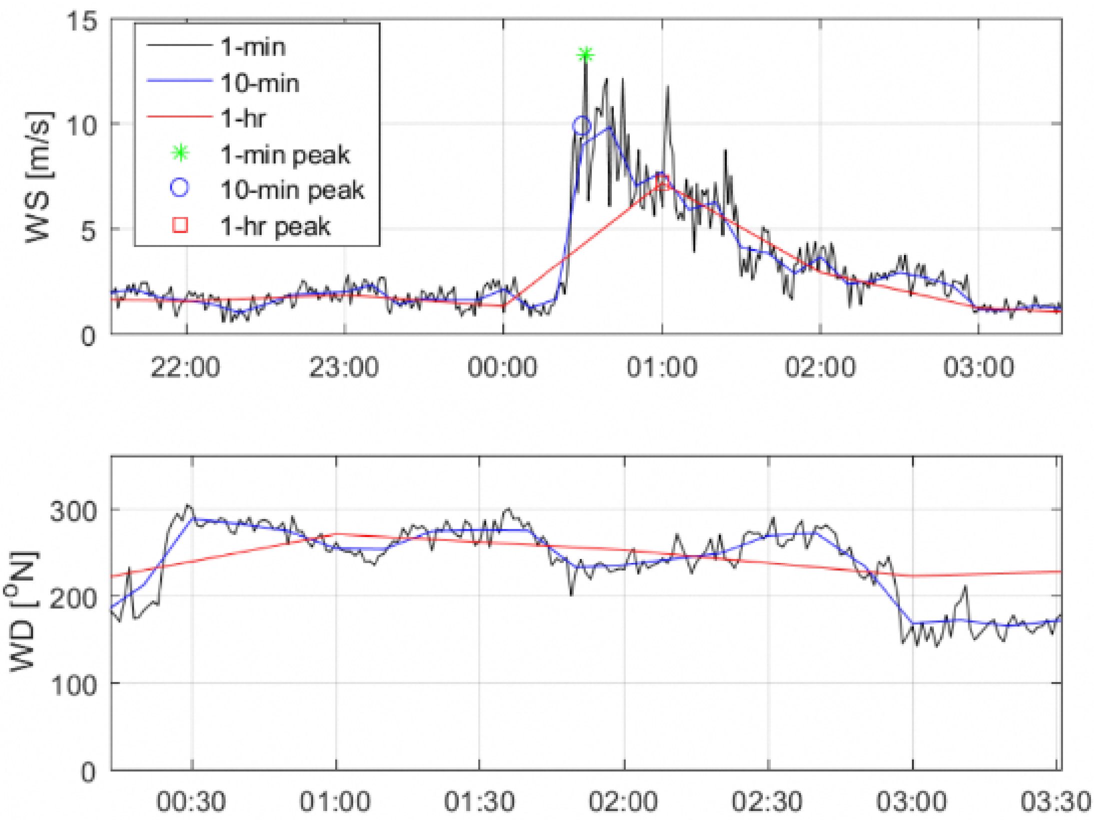


Figure 7-6. Measured 1-minute, 10-minute, and 1-hourly averaged time-series of wind speed (top) and direction (bottom) at Admiralty station for a squall that occurred on 8 August 2018

7.2.2 Modelling of Water Levels and Currents

Figure 7-7 shows the computational grid for the entire model domain. The bathymetry is updated with the latest data surveyed in 2022. In addition, the Experiential Walk supporting piles and excavation were incorporated into the models. As the resolution of the model's computational grid (approximately 10 m × 10 m) is larger than the Experiential Walk structures (order of a few decimetres), the piles that are in the wet model domain are included as sub-grid features which cause partial blocking of flow and waves. The bathymetry of the model at the location of the Experiential Walk was deepened by 1 m, as the proposed design of the Experiential walk required excavation of mudflat to allow water to partially inundate the area.

Along the model boundary, local tides from the Singapore Regional Model are used to nest the detailed model. This spatially varying tidal signal along the open boundary is more suitable compared to the forcing observation data from a single station that is not located at the boundary. As the tides propagate through the Johor strait in the model for Mandai Mangrove and Mudflat which is in close proximity to Lim Chu Kang, the resulting tidal water level at Lim Chu Kang has been sufficiently captured.

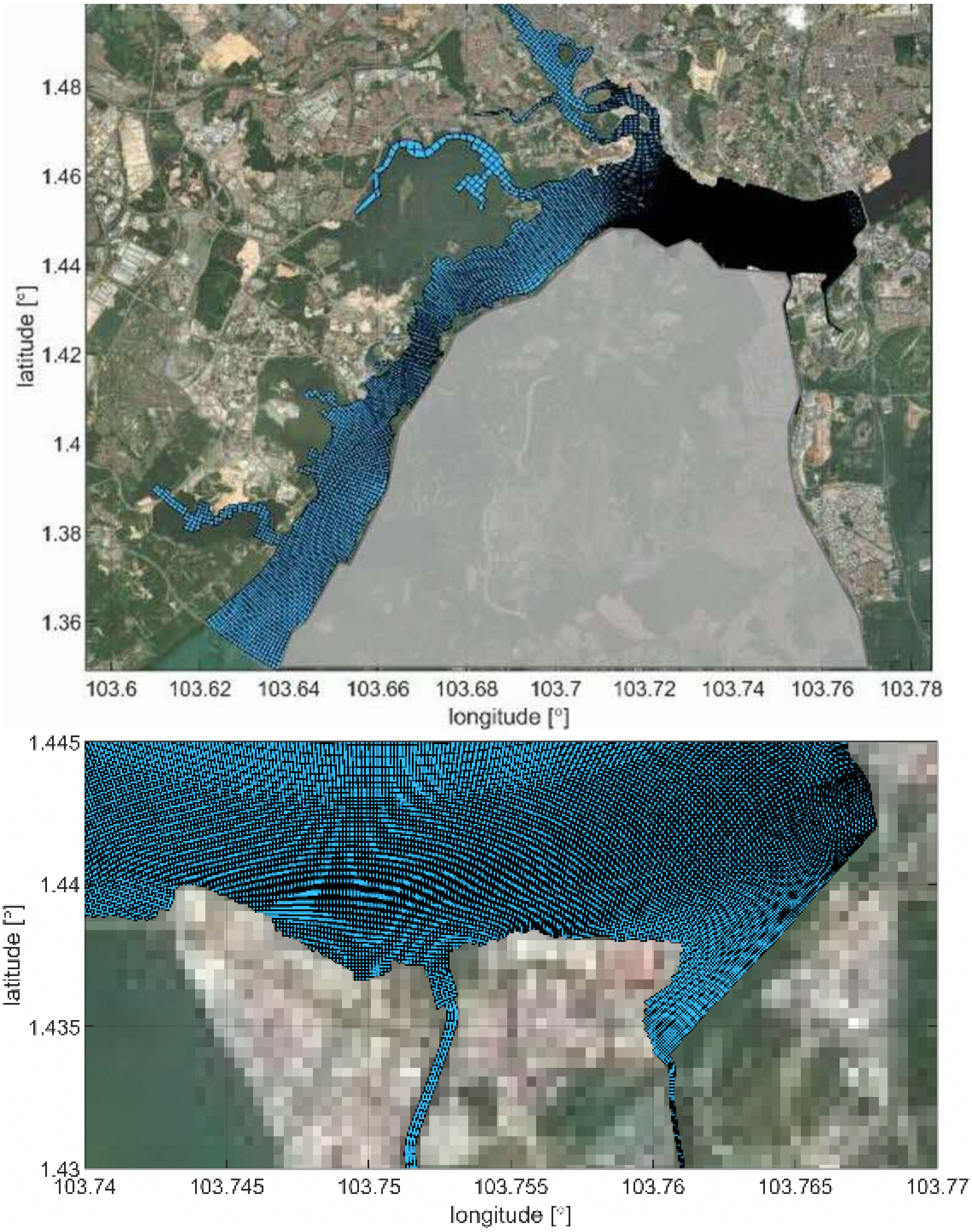


Figure 7-7. Extent of the computational grid for the entire model domain (upper panel) and zoomed (bottom panel) into the project area of Mandai Mangrove and Mudflat

A model rerun was conducted where the computational grids of the hydrodynamic and wave models) were updated to include cells landward along the coast. This area was not previously part of the model domain as the original topography was above the High-Water Mark and would not be inundated in the simulations. Grid cells have been added in the new simulations to cover the upper beach slopes along the coast up to a distance of 20 to 30 m from the High-Water Mark (SHD +1.36m) to ensure sufficient model space is available to capture the 1:5 slope. Depth values were defined to each added grid cell, assuming a profile slope of about 1:5. Note however, that with a 10 m grid resolution, the slope will not be continuous but seen as a stair-case shape in the models. Figure 7-8 and Figure 7-9 present the added grid cells and depth schematization. The excavation and sub-grid schematisation of the supporting piles of the Experiential Walk are also included in the updated models.

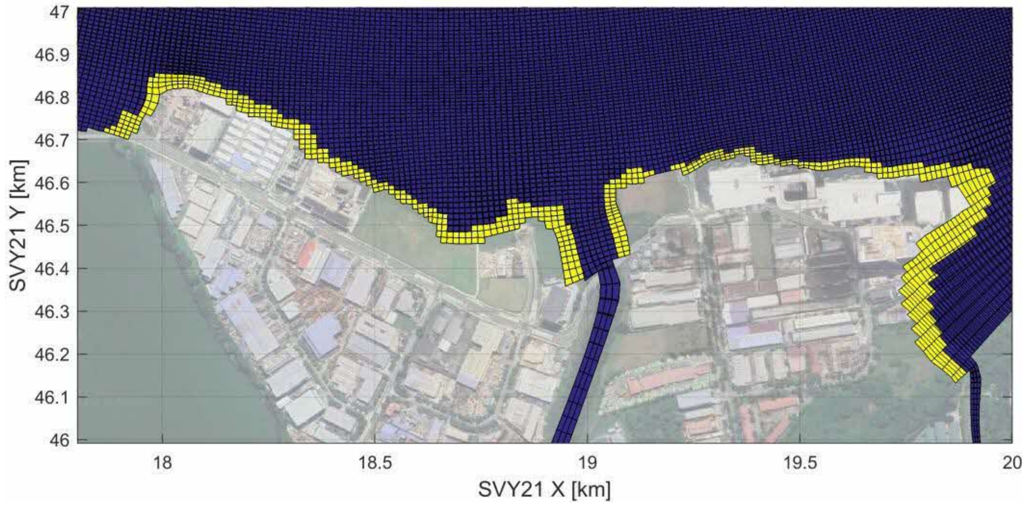


Figure 7-8 Computational grid used in the main study (dark blue) and added cells for this memo (yellow).

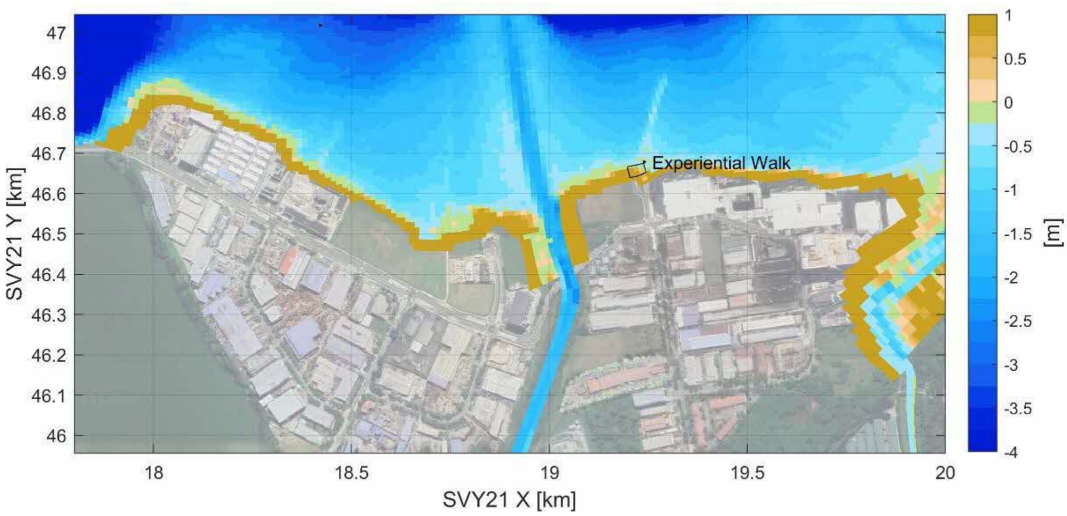


Figure 7-9 Bathymetry taken from the hydrographic survey and Lidar measurements carried out in 2022. The Experiential Walk excavation is labelled and marked with a black rectangle.

After implementing these changes, the models are run for scenarios representing normal monsoon conditions, extreme high tide (King Tide), squall, and scenarios accounting for El Niño Southern Oscillation (ENSO). To assess the impact of sea level rise on the area, simulations are performed with predicted water levels for 2030, 2050, and 2100.

The results of the hydrodynamic modelling are presented in Section 7.3 as difference plots between the baseline modelling result and the scenario with the park wet infrastructure included. Differences are presented spatially in map figures and as time series at representative locations in the model domain. The update of the models and considered modelling scenarios are also described below.

7.2.3 Model Configuration and scenarios

Model configuration

Updated grid and bathymetry

In comparison with the 2019 study, the grid was improved to match the exact locations of the channels and additional cells on the coastline. A hydrographic survey and Lidar measurements were carried out in 2022 to take into account the expanded site boundary. This set of new data was merged with the 2019 bathymetric information to form the model domain. In comparison with the 2019 bathymetry, the most significant changes are in front of the Kranji Dam. In the area extending away from the dam there is a deepening of approximately 4 meters, while some areas along the coast are now shallower by 4 metres. During the set-up of the model, this area was outside of the area of interest and no high-resolution bathymetric data was available for this channel. Around the mudflat and in Sungei Pang Sua, many areas are deeper in the new bathymetry, with differences of up to 2 metres. Water levels and currents with the updated bathymetry were compared with 2019 data collected at the 2 ADCP points (Figure 7-10) and showed no significant difference (Figure 7-11).

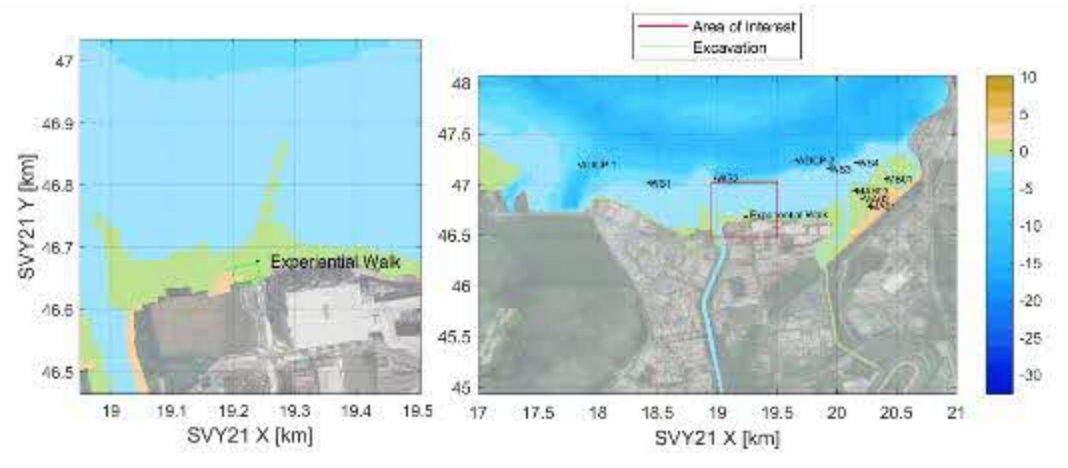


Figure 7-10: Model bathymetry and control points

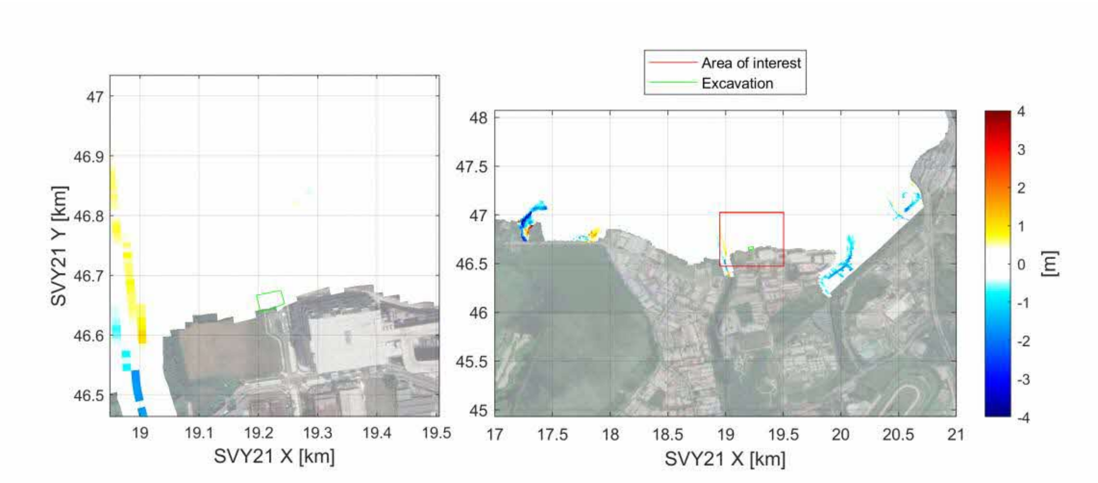


Figure 7-11. The change in bathymetry from Mandai the 2019 study to this study, incorporating new measurements taken in 2022. Negative values indicate a deepening, compared to the 2019 study.

Discharge from Kranji Dam

A discharge from the Kranji Dam (see location in Figure 7-10) is included in the hydrodynamic model based on the study of Xing et al. (2012), who stated that within their 59-day observation period from April to June 2007, release events were observed ranging from 1 - 6 hours and averaging 3 hours and 15 minutes. The total discharge recorded was 1.6×10^7 m^3 within this time period. From this information, one discharge event was included every two days approximately (specifically every 4 tidal cycles), such that the discharge coincides with the ebb tide. The motivation behind this tidal timing is that operators would likely discharge during ebb tide, when the currents are directed towards the open sea. The rate of the discharge is 40 m^3/s, which is computed from the total discharge mentioned. Each discharge event lasts for 3 hours and 15 minutes, except during the large squall simulations when heavy rainfall is assumed and then the duration would be the longest possible (6 hours) with the same discharge rate.

Vegetation
Around the Johor Strait there are many mangrove areas. In our model, they are implemented as shown in Figure 7-12 where the amount of vegetation per polygon would exert shear stresses on the flow computed by the model software depending on the prevailing water level condition, vegetation type, stem diameter, and amount of vegetation. Extensive mangrove areas are also located at Sungei Buloh Wetland Reserve and at the existing Mandai Mangrove and Mudflat area in the East. Along the extended Mandai Mangrove and Mudflat (project area) a narrow strip of mangroves is schematised in the model. The mangroves areas implemented in the model have not been altered since the 2019 study.

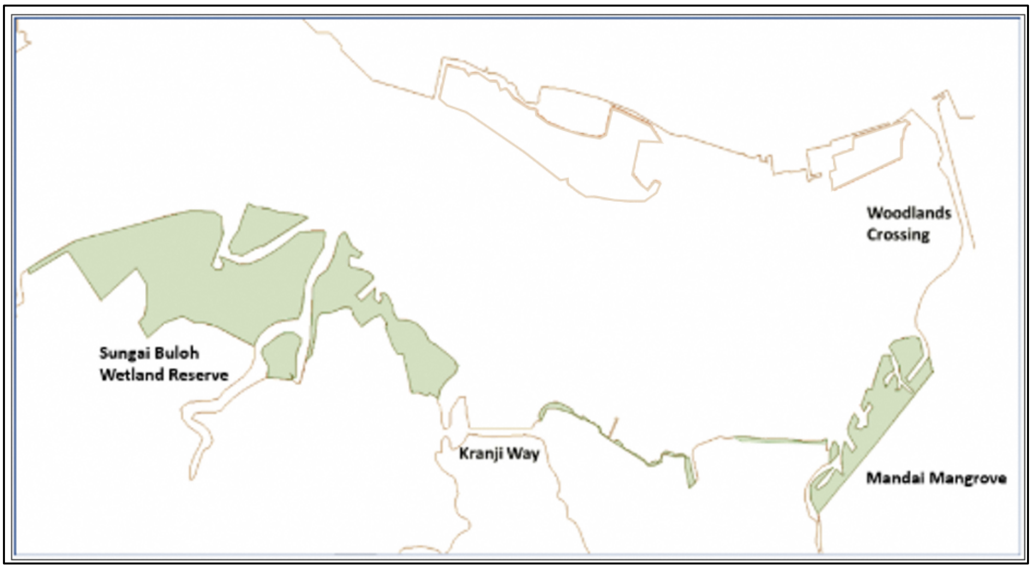


Figure 7-12. Overview of mangrove areas (green color polygons) in the model.

Updated scenarios
Descriptions of the most relevant model inputs are provided below. A summary of the various runs is presented in Table 7.1.

Tides
Tidal action in the model is included by means of astronomic boundary conditions at the southwestern entrance of the Johor Strait, obtained from the Singapore Regional Model (Kurniawan et al., 2011). Tidal constituents were extracted from the model to compute the water levels at southwestern Johor Strait, from which the water levels and tides will reach

Mandai Mangrove and Mudflat area. Since the planned wet infrastructure is in the more elevated locations in the model, the selected simulation period includes an extreme high tide event with a water level of 2.08 m above Singapore Height Datum (SHD, approximately equal to mean sea level) on 6 June 2019. The Highest Astronomical Tide (HAT) at Mandai Mangrove and Mudflat is of a similar height of 2.14 m above SHD. The total model simulation period covers a complete spring-neap tide cycle in June 2019, covering this so-called King Tide event.

Meteorological forcing

During this spring-neap cycle, hydrodynamic modelling was performed for both NE and SW monsoon conditions. The applied wind for these conditions was based on the 10-minute measured time series at station Admiralty (TAC, 2020), identical to the implementation in the 2019 study. In addition to these seasonal conditions, a separate simulation was performed for an extreme squall event coinciding with extreme high water on June 6, 2019. The squall event is also taken to be representative of La Niña conditions during which such weather events can be amplified. Such a situation was observed during the June months of 2010 where rains and squall events were intensified by the rapidly developing La Niña conditions in the region during June-July of that year (MSS, 2010). The parameterized squall event has wind speeds of 15 m/s, originates from the West or 270°, and occurs from June 5 at 23:00 – June 6 at 03:00. This is identical to the squall implemented in the 2019 study, except with higher wind speeds (previously 12 m/s) which were observed in the 2010 La Niña conditions. Due to the effect on rainfall, the duration of the Kranji dam discharge is also increased to the maximum observed in the study of Xing et al. (2012), i.e., six hours. On the other hand, taking one of the worst recent El Niño occurrences, 2015 as an example, Singapore experienced record low rainfall and high temperatures in the months of June and July, respectively (MSS, 2015a). Although warm and dry conditions are typical of El Niño, they cannot be represented in the model because precipitation, temperature, and salinity are not included. The winds from June-July 2015 are consistent with SW monsoon conditions and thus, this scenario is representative of El Niño conditions.

Sea level rise

To assess the impact of sea level rise on the experiential walk, simulations were performed to compare the present-day and future hydrodynamic conditions around the structure. The worst-case scenario sea level rise projections are used for the years 2030, 2050, and 2100. As such, the upper values for RCP8.5[14] were used, based on local predictions by the Meteorological Service Singapore (2015b) for the years 2050 and 2100. The value for 2030 was a linear interpolation from present-day to 2050. Thus, the final values implemented were 0.10 m for 2030, 32 cm for 2050 and 102 cm for 2100. It is notable that the upper value presented for RCP4.5, a more moderate scenario, in 2050 is quite similar (0.30 m) to the RCP 8.5 upper value (32 cm), so the model results for 2030 and 2050 can be interpreted as representative for both RCP scenarios.

[14] Representative Concentration Pathways 8.5, which is the scenario where human society fails to reduce the rate of anthropogenic carbon emissions.

Table 7.1. Scenarios with and without Sungei Pang Sua Pavilion and Experiential Walk. Four sea level rise (SLR) conditions are considered. All runs include a King Tide

No SLR 0.00 m	**SLR in 2030 0.10 m**	**SLR in 2050 32 cm**	**SLR in 2100 102 cm**
SW monsoon with King Tide (also representative of El Niño)	SW monsoon with King Tide (also representative of El Niño)	SW monsoon with King Tide (also representative of El Niño)	SW monsoon with King Tide (also representative of El Niño)
NE monsoon with King Tide	-	-	-
Extreme squall with 15 m/s winds (also representative of La Niña) with King Tide	-	-	-

7.3 Hydrodynamic modelling results

Monsoon conditions

7.3.1 Water levels

At the site of the Experiential Walk, water levels reach a maximum of approximately 2.3 m above Singapore Height Datum (SHD, approximately equal to mean sea level). This is due to the extreme high-water event or "King Tide" and is consistent in both NE and SW monsoon conditions. Figure 7-13 up to Figure 7-16 show spatial pictures of the water level differences between scenarios with and without the Experiential Walk. These figures show the timestep during high water at 06:00 a.m. on June 6. Simulated water level differences are minor, and at the few locations where differences occur these are less than 1 centimetre large. Only locally, at the location of the excavation, bed level differences are up to a metre when the area is dry due to the excavation itself, as these grid cells were not wet in the present situation.

Figure 7-17 is a two-day timeseries immediately in front of the Experiential Walk. The figures on the right show the difference in water levels due to the planned wet infrastructure. Differences are not provided when the computational cells are dry. These figures reveal that the magnitude of these differences is millimetres, and therefore the effect of the planned infrastructure on the water levels is negligible. Thus, the impact of the Experiential Walk is small and local with the largest effect at the excavation site itself. A minimal increase in water levels in the order of millimetres is visible to the east in the direct vicinity.

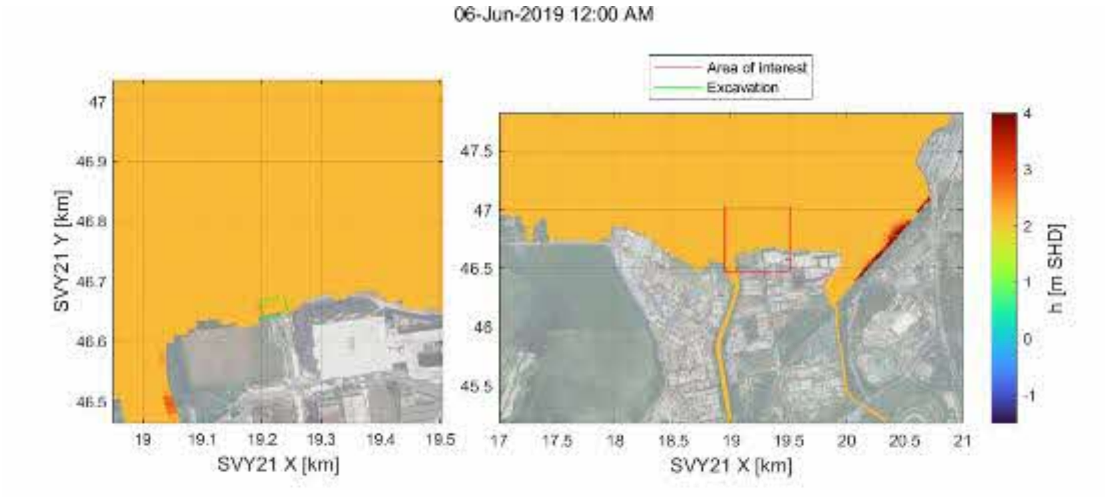


Figure 7-13. Modelled water levels (h) after the implementation of the experiential walk at high water 12:00 a.m. of June 6, 2019 for SW monsoon conditions.

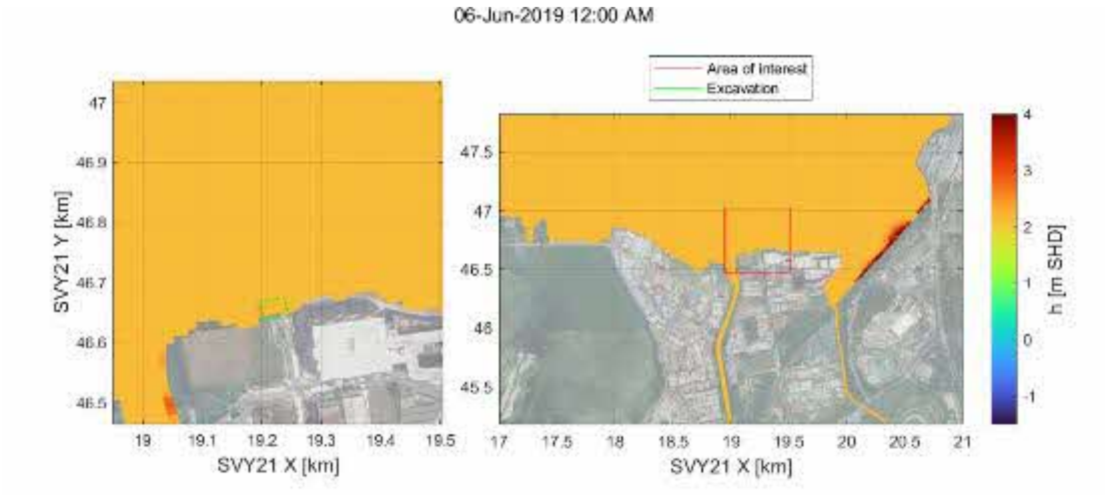


Figure 7-14. Modelled water levels (h) after the implementation of the experiential walk at high water 12:00 a.m. of June 6, 2019 for NE monsoon conditions.

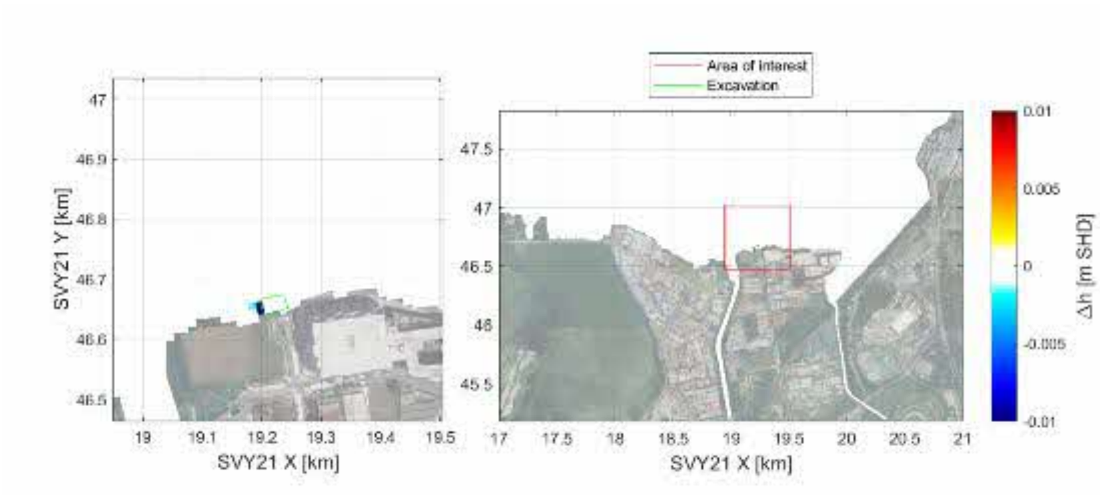


Figure 7-15. Modelled water level differences (Δh) after the implementation of the experiential walk at high water 12:00 a.m. of June 6, 2019 for SW monsoon conditions.

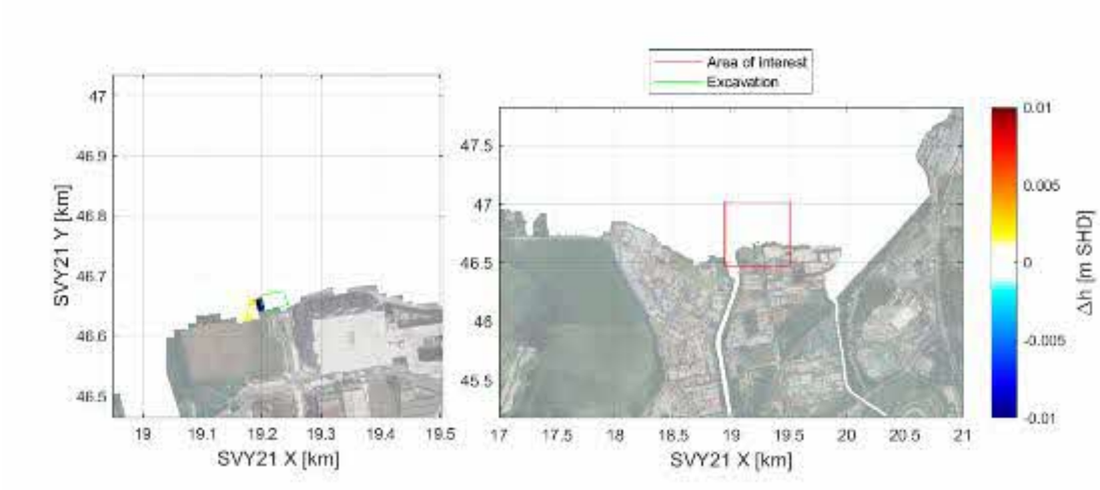


Figure 7-16. Modelled water level differences (Δh) after the implementation of the experiential walk at high water 12:00 a.m. of June 6, 2019 for NE monsoon conditions.

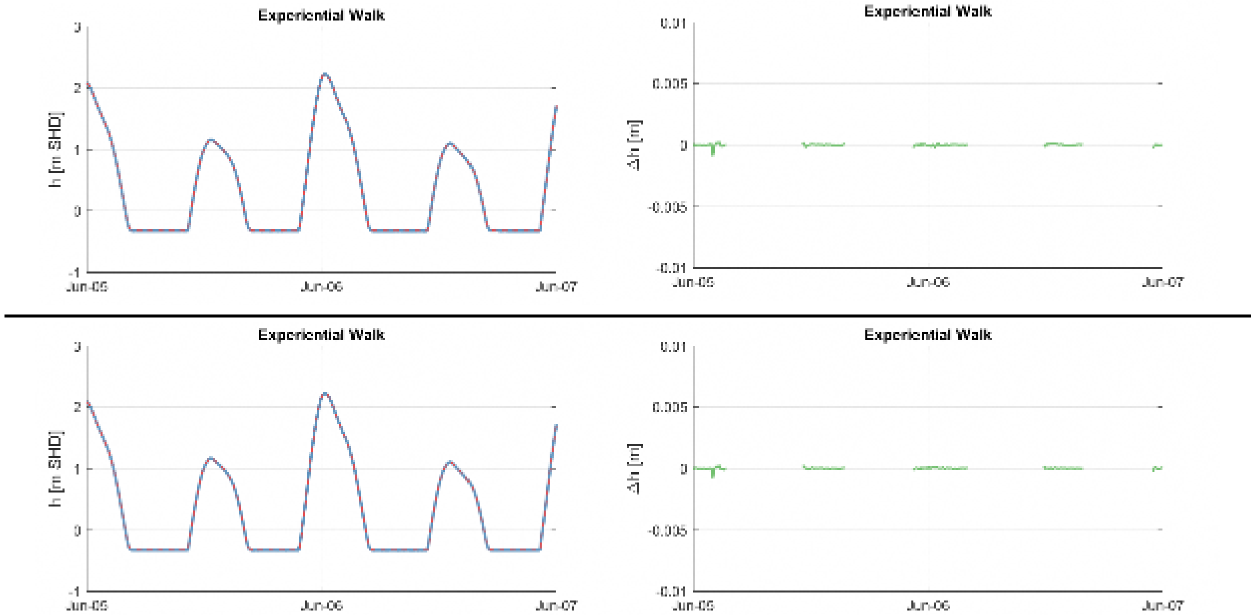


Figure 7-17. Water levels (h) at the Experiential Walk without (blue) and with (red) the wet infrastructure and water level differences (green) for a NE monsoon (top) and SW monsoon (bottom).

7.3.2 Currents

Current magnitudes at the coastline where the Sungei Pang Sua Pavilion and Experiential Walk will be located are very small, generally less than 0.02 m/s (TAC, 2020). This holds true in the model simulations with and without the Experiential Walk. In Figure 7-18 and Figure 7-19, the modelled currents show low velocity magnitudes around the coast respectively for SW monsoon and NE monsoon conditions. Differences in the simulations with the Experiential Walk are revealed in Figure 7-20 and Figure 7-21. In Figure 7-22, the time series shows velocity magnitudes around 0.02 m/s throughout the two-day period with very small (<0.01 m/s) differences caused by the Experiential Walk.

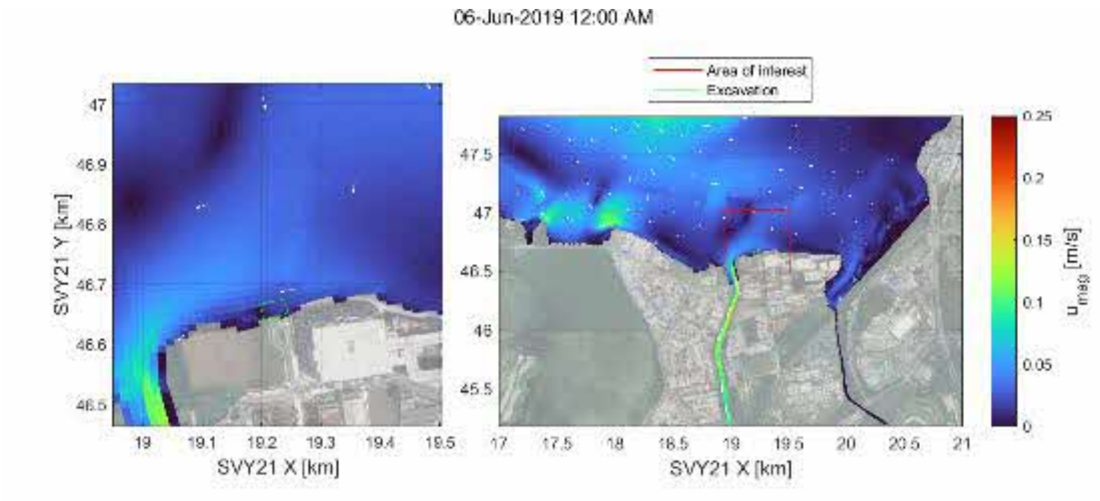


Figure 7-18. Modelled currents (u_{mag}) with the experiential walk at high tide, 00:00 a.m. of June 6 for SW monsoon conditions.

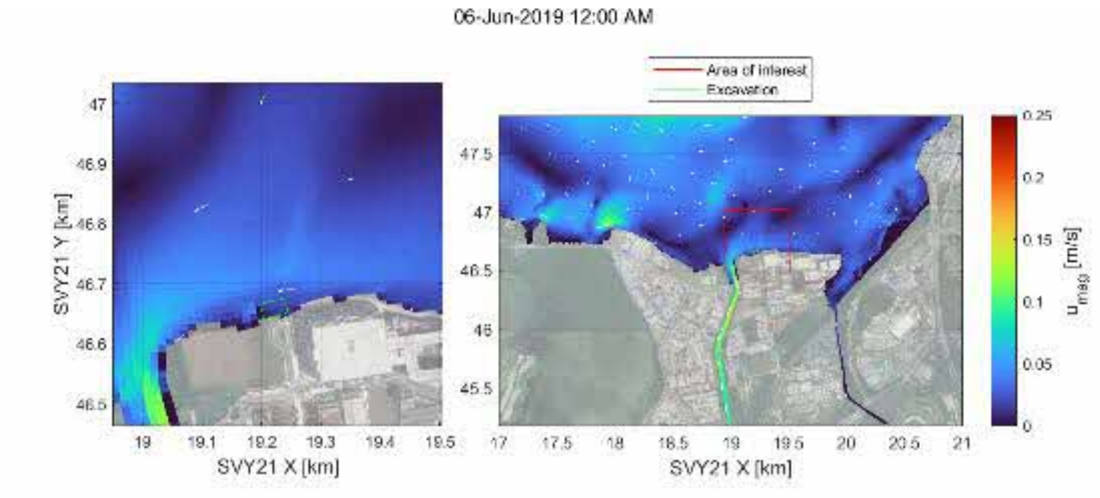


Figure 7-19. Modelled currents (u_{mag}) with the experiential walk at high tide, 00:00 a.m. of June 6 for NE monsoon conditions.

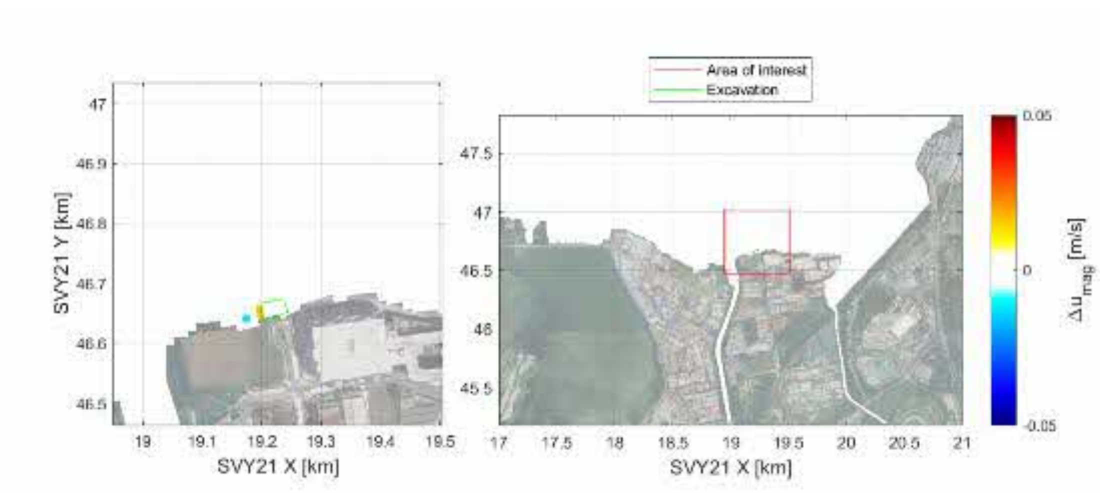


Figure 7-20. Modelled current differences (Δu_{mag}) with the experiential walk at high tide, 00:00 a.m. of June 6 for SW monsoon conditions**.**

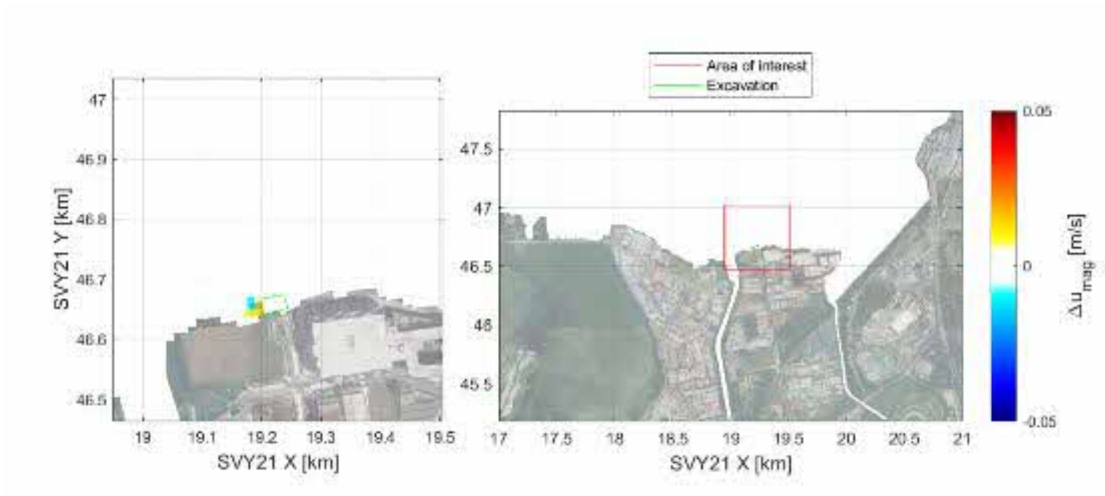


Figure 7-21. Modelled current differences (Δu_{mag}) with the experiential walk at high tide, 00:00 a.m. of June 6 for NE monsoon conditions.

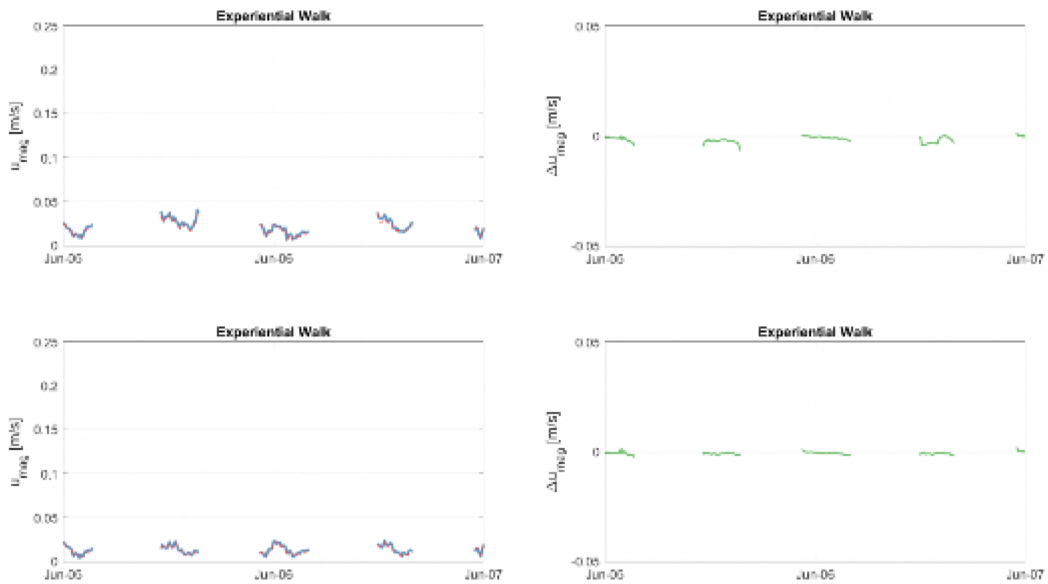


Figure 7-22. Velocity magnitudes (u_{mag}) at the Experiential Walk without (blue) and with (red) the wet infrastructure and velocity magnitude differences (green) for NE monsoon (top) and SW monsoon (bottom).

7.3.3 Waves

Significant wave heights at the Experiential Walk are small during both monsoon conditions (Figure 7-23 and Figure 7-24) with a height of up to 0.2 m approximately. During the NE monsoon, Figure 7-26 shows no differences in significant wave height while during the SW monsoon, differences up to 0.05 m can be seen (Figure 7-25). These differences are located away from the coast (approximately 200 m away) and are relatively small. In the timeseries plots at the Experiential Walk (Figure 7-27), the differences in significant wave height are seen to be less than 0.005 m. Thus, the effect of the planned wet infrastructure on the water levels is not significant.

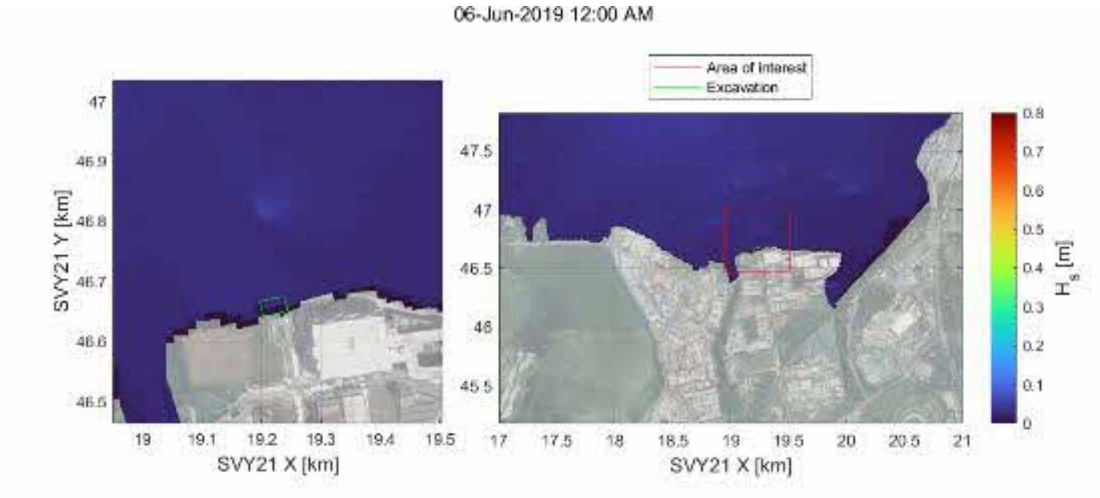


Figure 7-23. Modelled significant wave heights (H_s) with the experiential walk at high tide, 00:00 a.m. of June 6 for SW monsoon conditions.

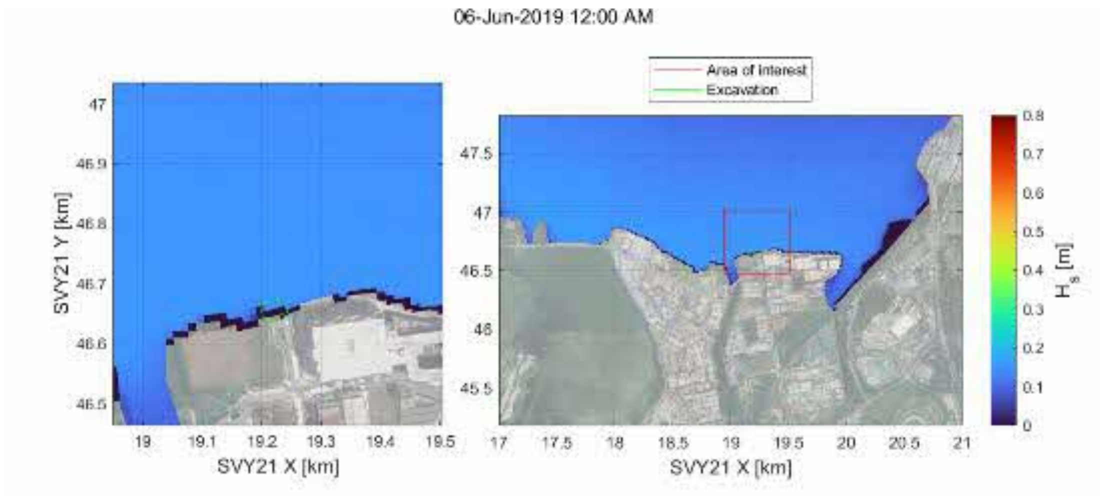


Figure 7-24. Modelled significant wave heights (H_s) with the experiential walk at high tide, 00:00 a.m. of June 6 for NE monsoon conditions.

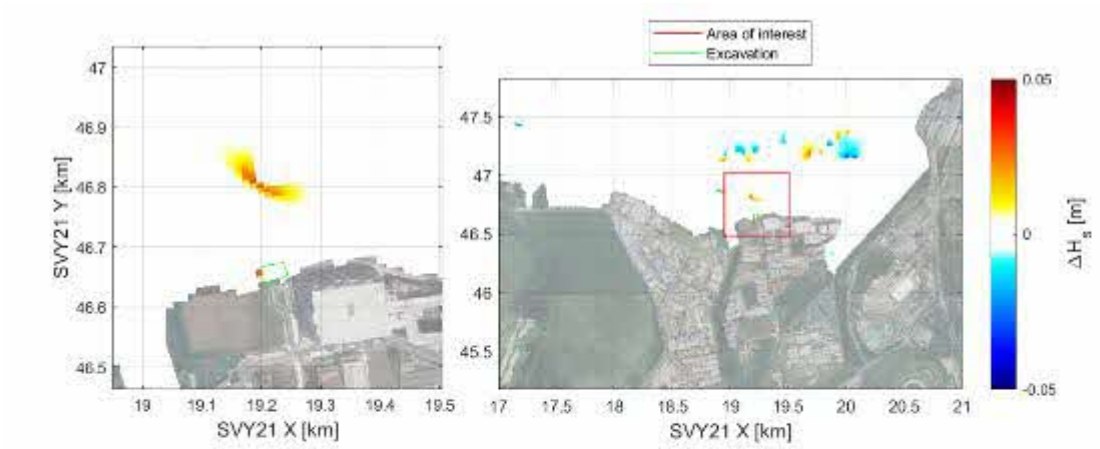


Figure 7-25. Modelled significant wave height differences (ΔH_s) with and without the experiential walk at high tide, 00:00 a.m. of June 6 for SW monsoon conditions.

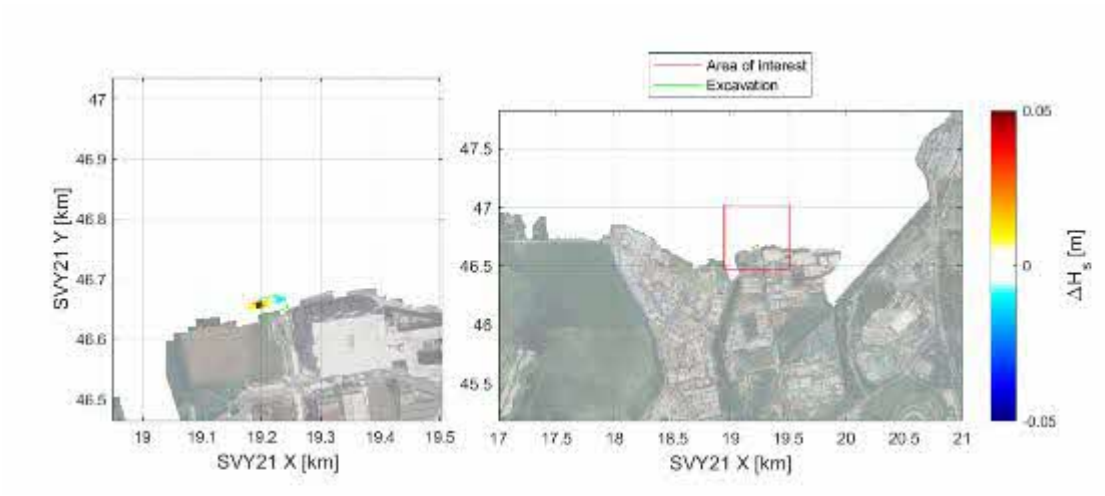


Figure 7-26. Modelled significant wave height differences (ΔH_s) with and without the experiential walk at high tide, 00:00 a.m. of June 6 for NE monsoon conditions.

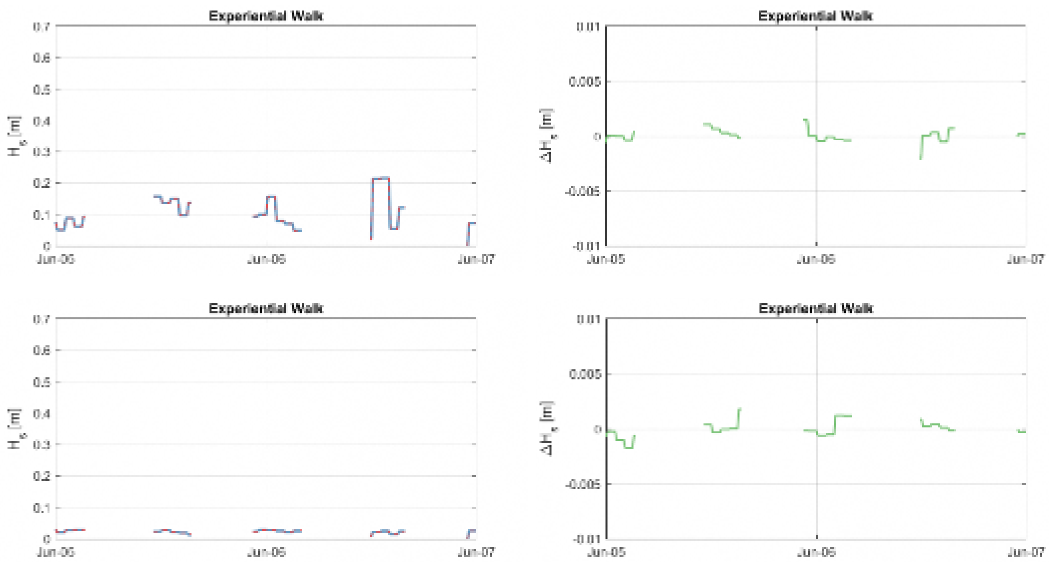


Figure 7-27 Significant wave heights (H_s) at the Experiential Walk without (blue) and with (red) the wet infrastructure and significant wave height differences (green) for NE monsson (top) and SW monsoon (bottom).

Comparison between simulations with and without the changes showed no noticeable changes in the modelled water levels, for all the scenarios (Figure 7-28 for SLR 2030; Figure 7-29 for SLR 2050; Figure 7-30 for SLR 2100) around high water at 00:00 on June 6, 2019.

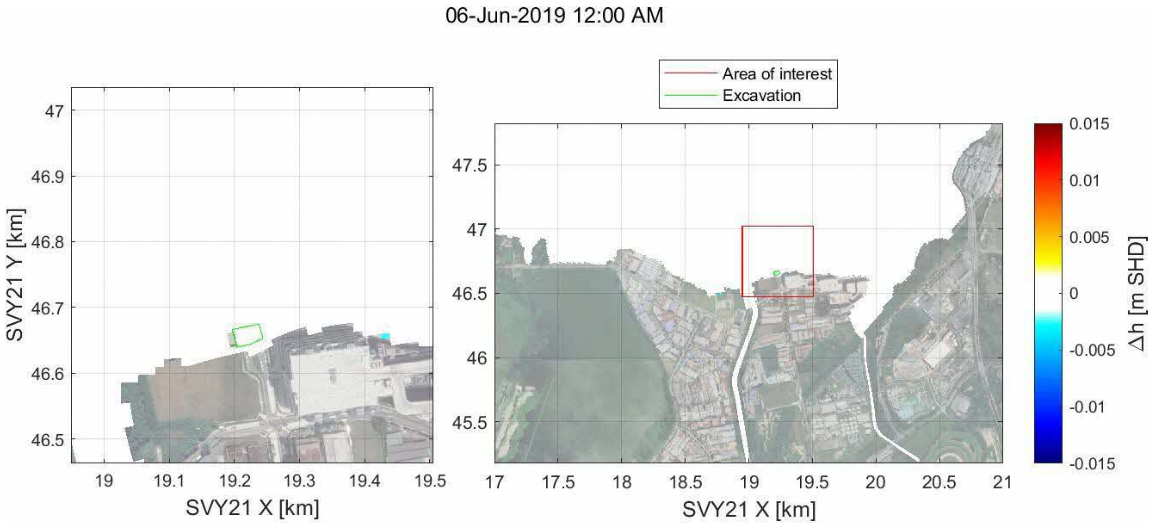


Figure 7-28 Differences in water level (Δh) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2030.

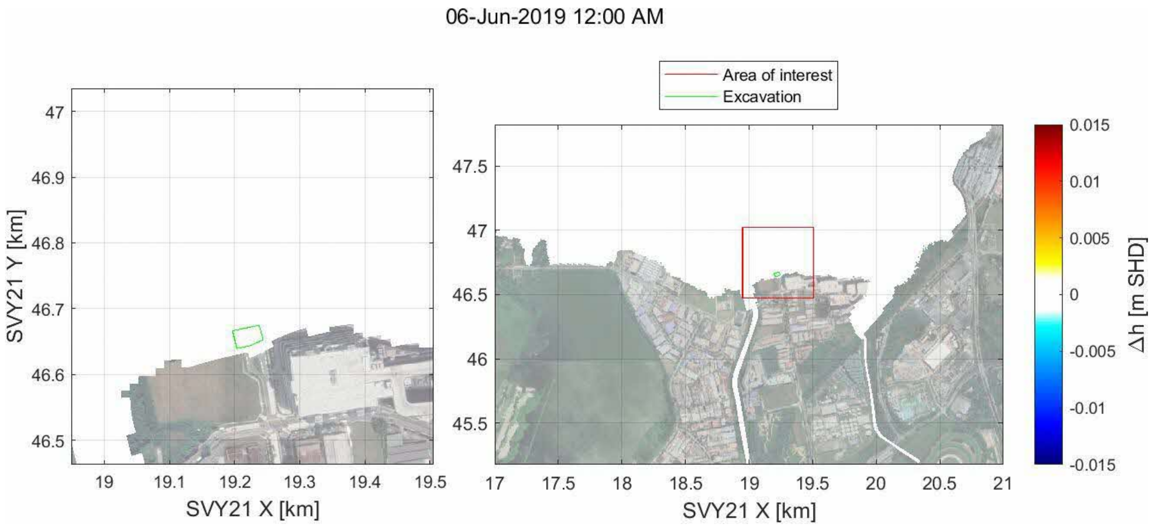


Figure 7-29 Differences in water level (Δh) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2050.

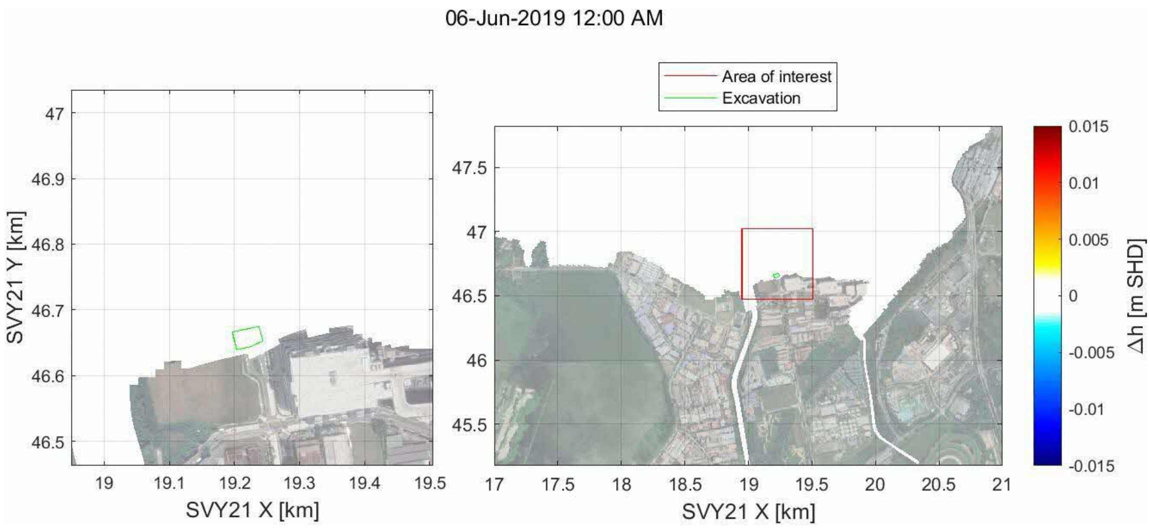


Figure 7-30 Differences in water level (Δh) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2100.

There are differences in significant wave height (Figure 10 for SLR 2030; Figure 11 for SLR 2050; Figure 12 for SLR 2100) in the order of 0.03 m near the coast, in and adjacent to the added grid cells. In general, the slope change and Experiential Walk had little to no effect in each scenario.

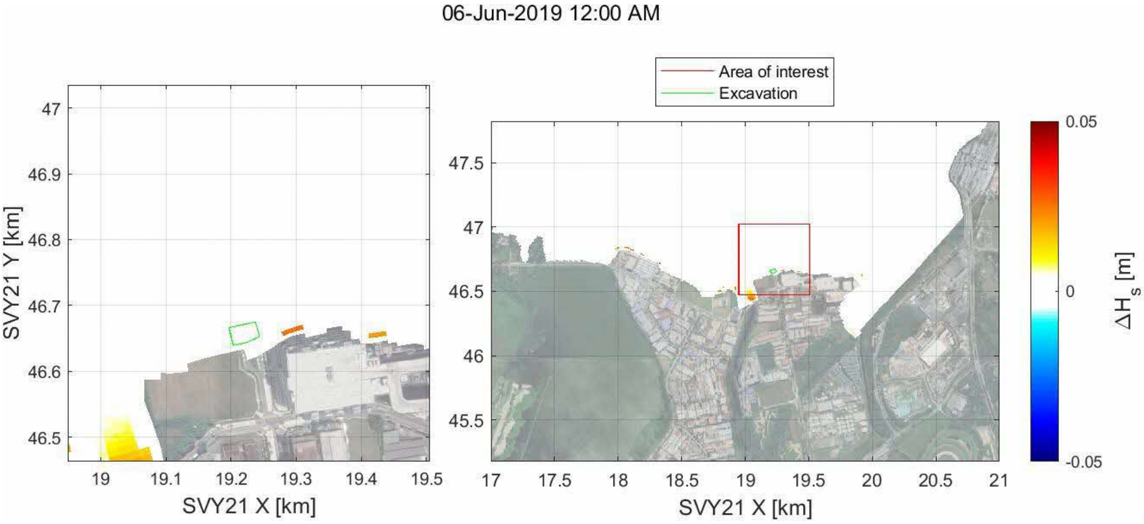


Figure 7-31 Differences in significant wave height (ΔHs) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2030.

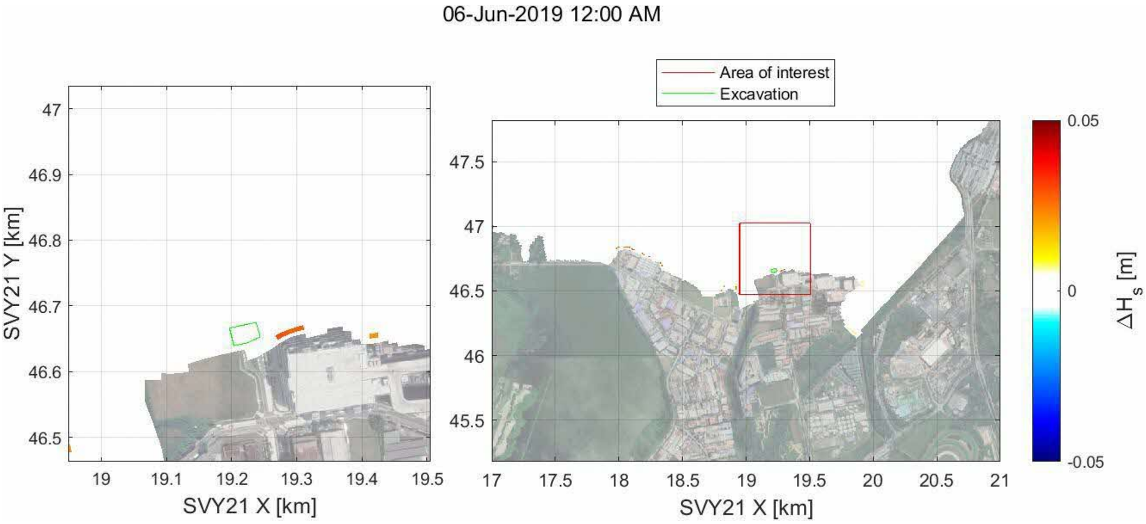


Figure 7-32 Differences in significant wave height (ΔHs) between the simulations with and without slope change and Experiential Walk wave height differences around high water of a King Tide event for SLR scenario 2050.

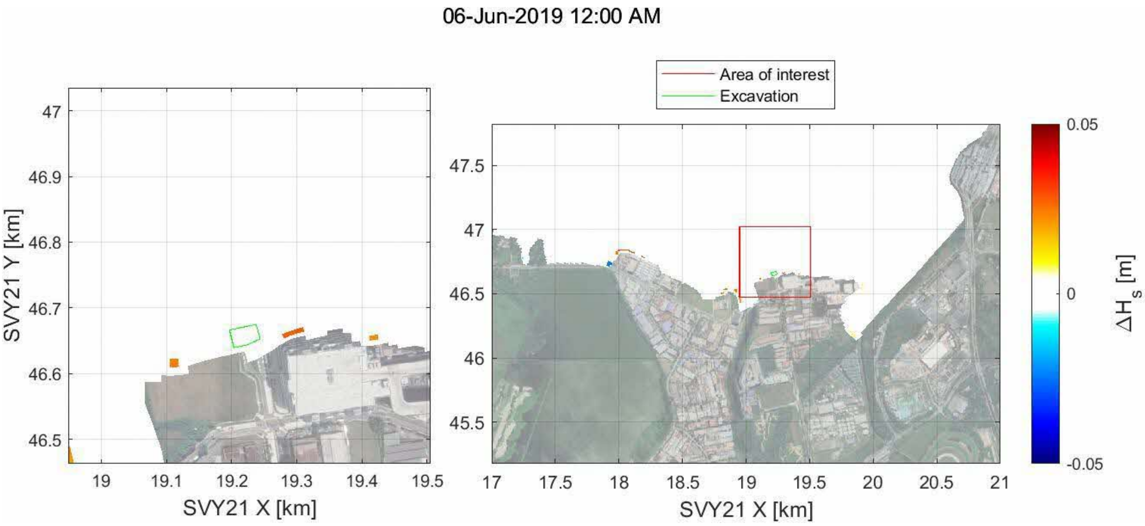
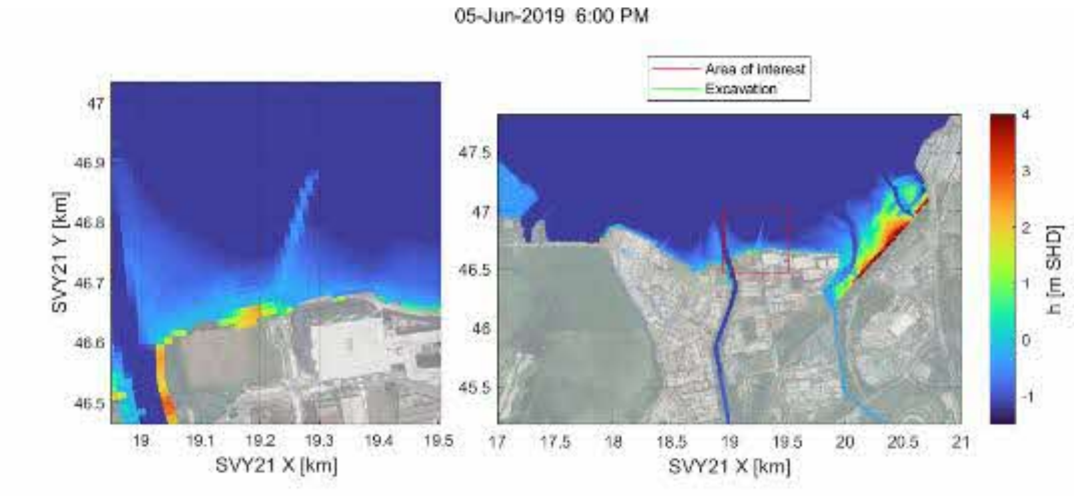


Figure 7-33 Differences in significant wave height (ΔHs) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2100.

7.3.4 *Extreme squall event*

The parameterized squall event occurs from June 5 at 11:00 p.m. – June 6 at 03:00 a.m. with winds of 15 m/s, originating from the West or 270°. Figure 7-34 shows the water levels before the event, on June 5 at 06:00 p.m. then water levels during the squall at high water or June 6 at 12:00 a.m. The differences are shown in Figure 7-35 and during the squall event, little difference is shown except at the excavation itself. The timeseries shows that water levels at high tide reach 2.26 m above SHD at the Experiential Walk between midnight and 01:00 a.m. on June 6, 2019 (Figure 7-36). Water level set-up in comparison with both the NE and SW monsoon is limited to 0.04 m and is therefore negligible. With a squall event, the water level differences are shown as a time series and are still less than 0.002 m (Figure 7-36).

Although the squall event may not have much effect on the water levels, the magnitude of the currents in Figure 7-37 appear higher than in the normal monsoon conditions (e.g., up to 0.25 m/s). However, at the location of the Experiential Walk, the timeseries (Figure 7-38) shows current magnitudes up to 0.15 m/s during the duration of the squall. The difference plots show a change of less than 0.02 m/s by adding the wet infrastructure. Thus, during a squall event the current magnitudes are higher, but the addition of the Experiential Walk does not significantly change them.



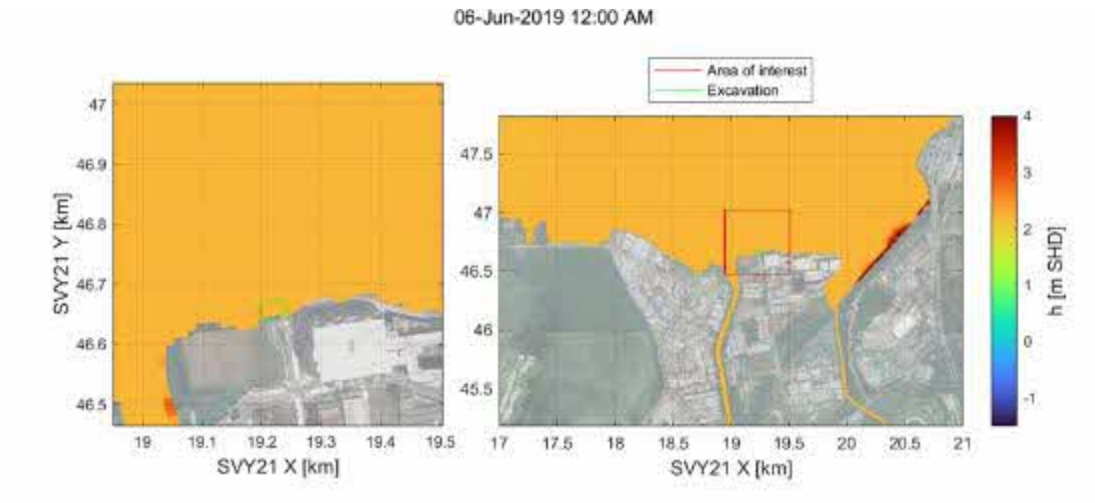


Figure 7-34. Modelled water level (h) relative to SHD around low water at 06:00 p.m. on June 5, 2019 (top) and at around high water at 00:00 a.m. on June 6, 2019 (bottom) for an extreme squall event.

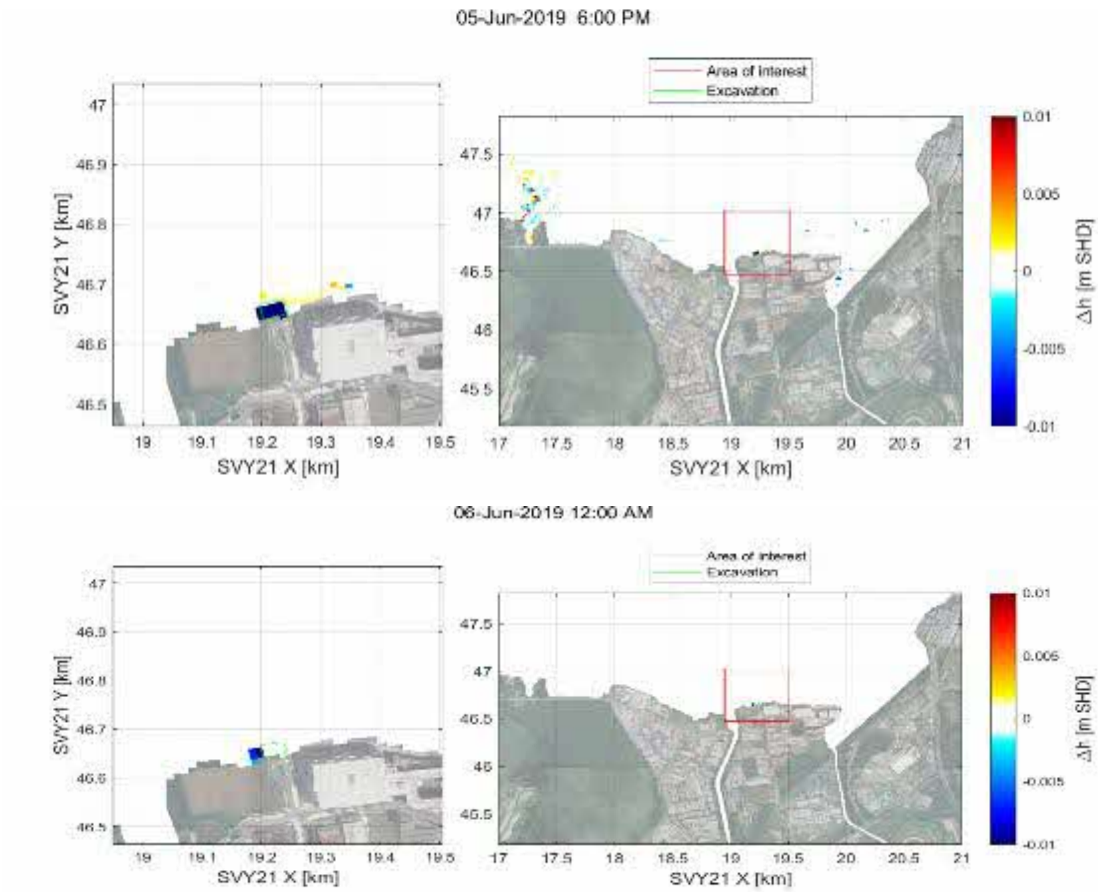


Figure 7-35. Modelled water level differences (Δh) around low water at 06:00 p.m. on June 5, 2019 (top) and at around high water at 12:00 a.m. on June 6, 2019 (bottom) for an extreme squall event.

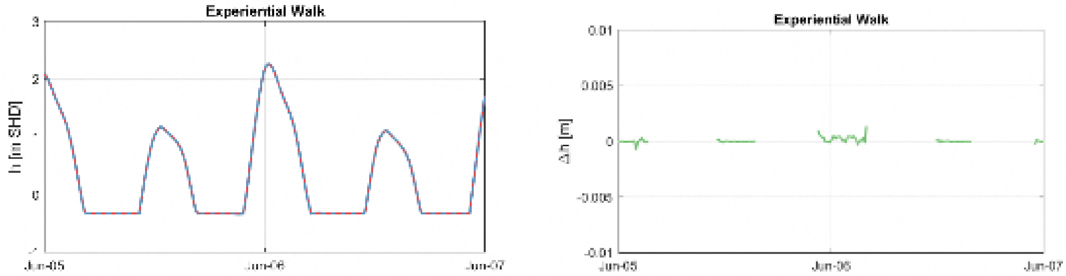


Figure 7-36. Water levels (h) at the experiential walk without (blue) and with wet infrastructure (red) and water level differences (green) for an extreme squall event.

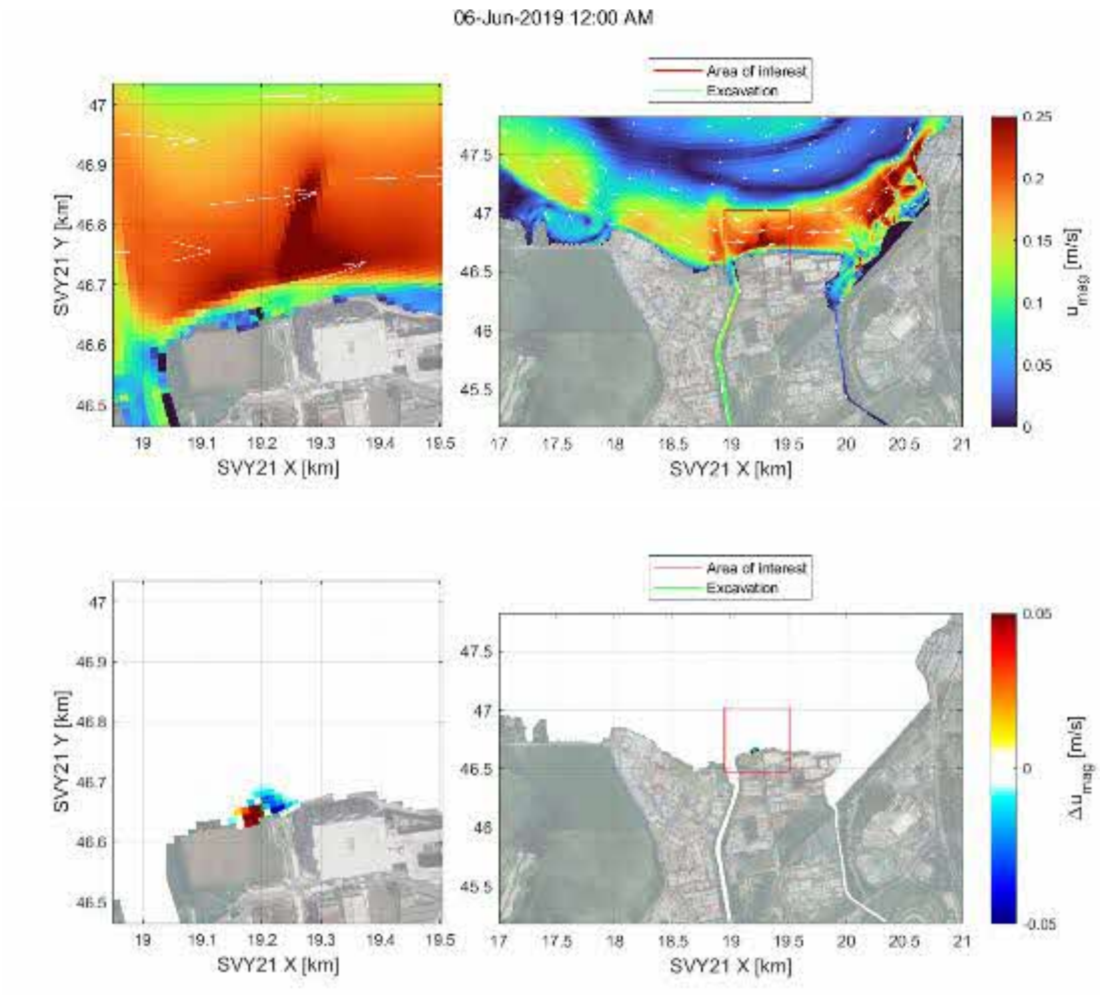


Figure 7-37. Modelled velocity magnitudes (u_{mag}) at 00:00 a.m. of June 6 (top) and the and the differences (bottom) for an extreme squall event.

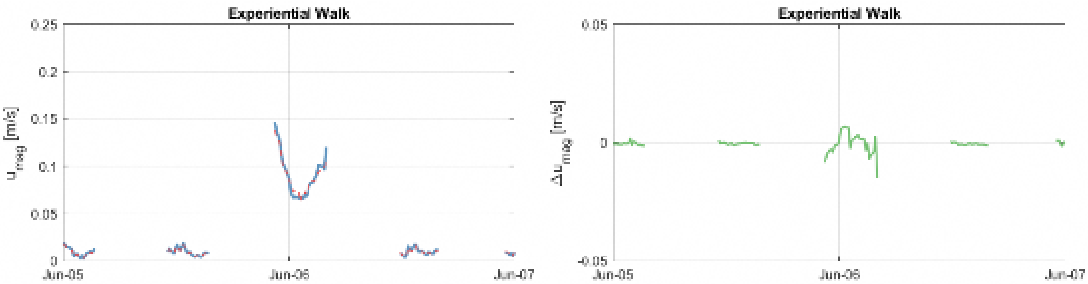


Figure 7-38. Velocity magnitudes (u_{mag}) at the Experiential Walk without (blue) and with wet infrastructure (red) and velocity magnitude differences (green) for an extreme squall

event differences (right) for an extreme squall event.

The squall event also causes higher wave heights in comparison with the monsoon conditions, with significant wave heights up to 0.8m (Figure 7-39, Figure 7-40). This is slightly larger than the significant wave height of 0.6 m that was computed during the previous study (TAC, 2020), and is caused by the increased wind speed of the squall condition (from 12 m/s to 15 m/s). At the Experiential Walk itself, the wave heights reach approximately 0.6 m. However, just like the current magnitudes, there is not much difference between the model scenarios with the wet infrastructure and without (differences up to 0.015 m). Thus, the building of the Experiential Walk will have a negligible impact on significant wave heights.

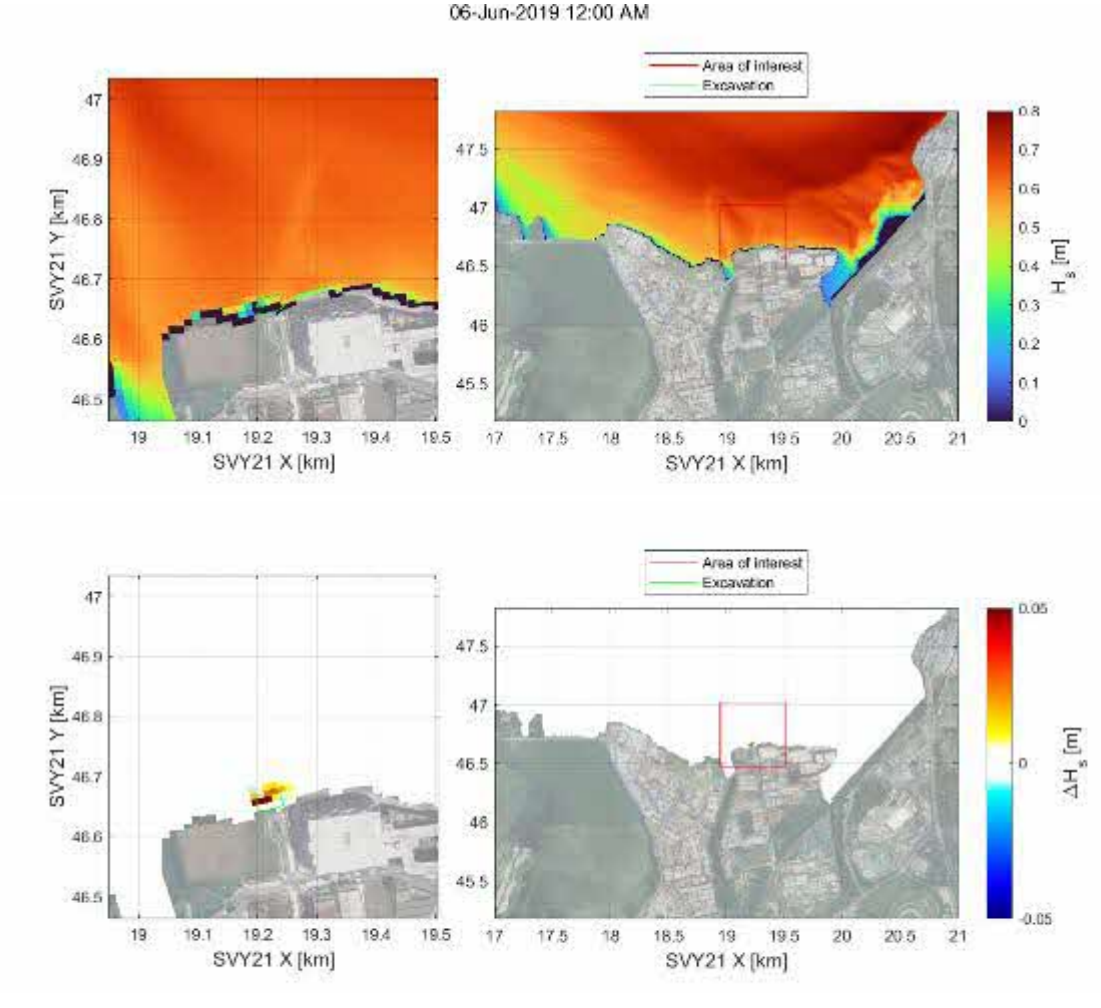


Figure 7-39. Modelled significant (H_s) wave heights at 00:00 a.m. of June 6 (top) and differences (bottom) for an extreme squall event.

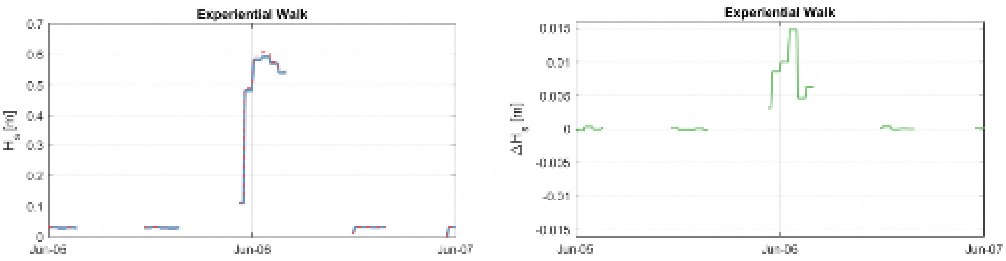


Figure 7-40. Modelled significant (H_s) wave heights at 00:00 a.m. of June 6 (left) and differences (right) for an extreme squall event.

7.3.5 *Effect of future sea level rise on the hydrodynamics at Mandai Mangrove and Mudflat*

Three different sea level rise scenarios are considered. The timeseries for the 2100 scenario with 102 cm sea level rise forced with SW monsoon wind conditions is shown in Figure 7-41. 2050 scenario with 32 cm sea level rise and 2030 with 10 cm sea level rise forced with SW monsoon wind conditions are in **Appendix F**. Sea level rise influences the duration throughout which the Experiential Walk area is dry during low water, and in all the scenarios, the area will be inundated for longer, increasing with the height of the sea level rise. The modelled velocities and their differences are approximately the same magnitude, namely, below 0.02 m/s (Figure 7-41). The wave heights show an increase of up to 0.03 m from the scenario with no sea level rise to the 2100 scenario (Figure 7-41). Such differences largely result from the instances when the area is dry in the no-sea level rise scenario and when it is still inundated in the sea level rise scenario. Nonetheless, the differences are small. The differences in velocity magnitude and significant wave height in the area are shown in Figure 7-42 for the 102 cm sea level rise scenario; 32cm and 10cm scenario in **Appendix F**. Thus, the impact of the wet infrastructure is similar for a situation with and without sea level rise, and sea level rise is not expected to have a significant effect on the feasibility or technical lifetime of the Experiential Walk.

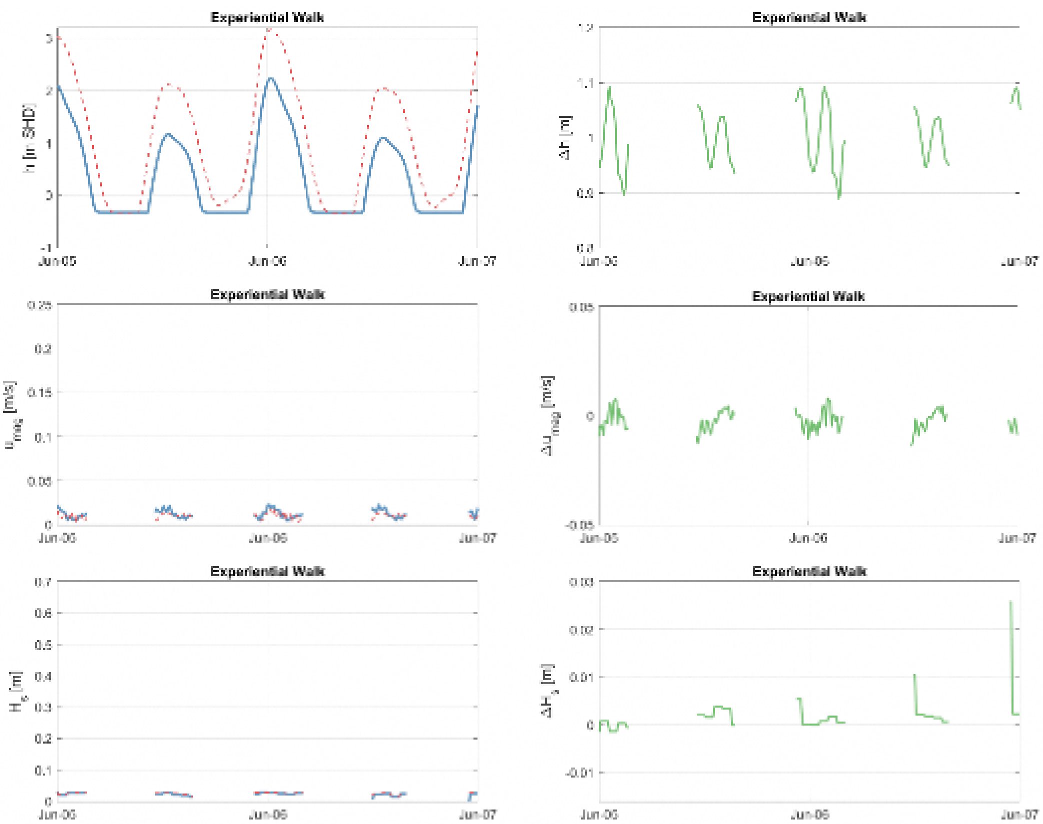


Figure 7-41. Model results without (blue) and with sea level rise (red) at the Experiential Walk, and the differences (green) for water levels (h, top), velocity magnitudes (u_{mag}, middle) and significant wave heights (H_s, bottom) for SW monsoon conditions.

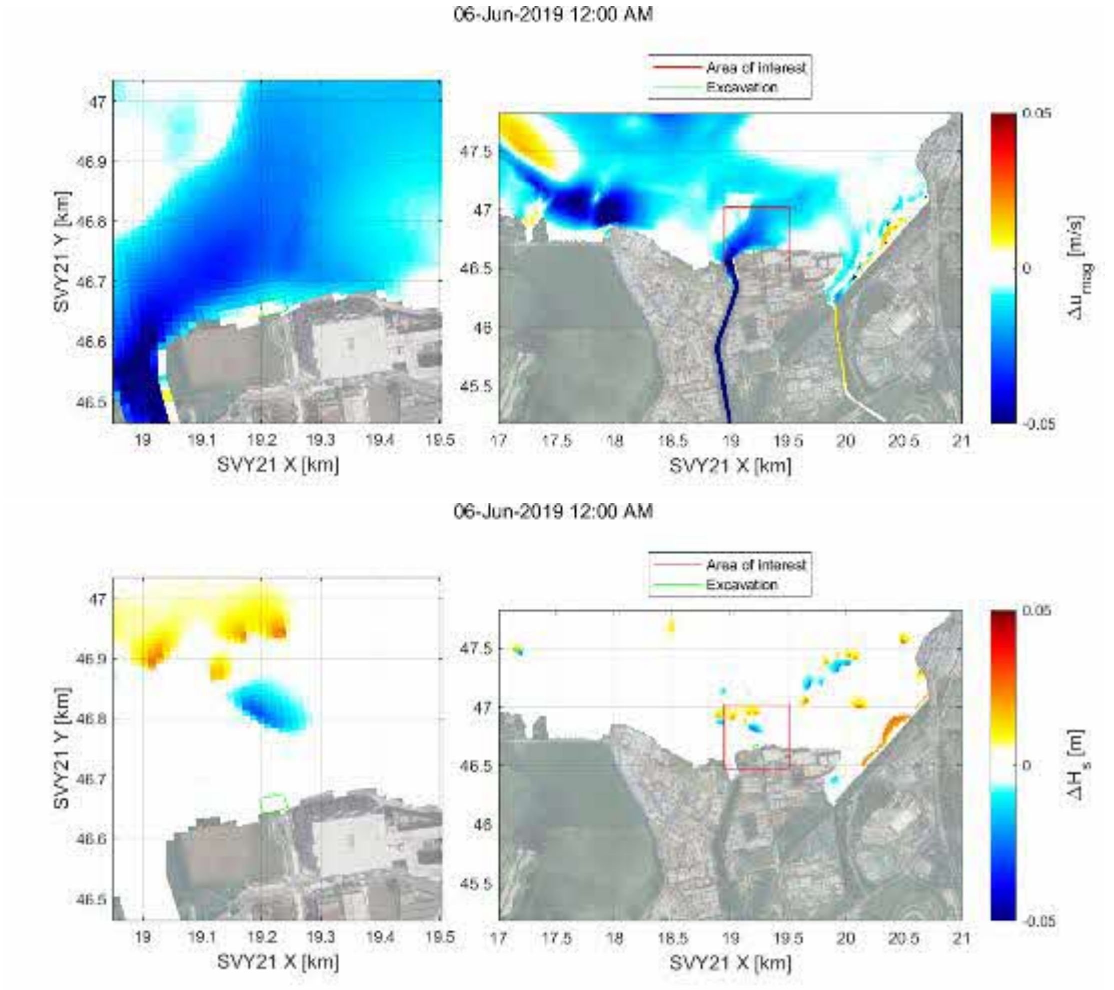


Figure 7-42. Differences in velocity magnitude (Δu_{mag}, top) and significant wave height (ΔH_s, bottom) at 00:00 a.m. on June 6, nearly high water, between a situation with and without sea level rise for SW monsoon conditions.

The impact of the slope can be seen near the coast, in and adjacent to the added grid cells with the new slope. There are differences in velocity magnitudes (Figure 7-43 for SLR 2030; Figure 7-44 for SLR 2050; Figure 7-45 for SLR 2100) in the order of 0.02 m/s. These changes in velocity are very small and considered negligible.

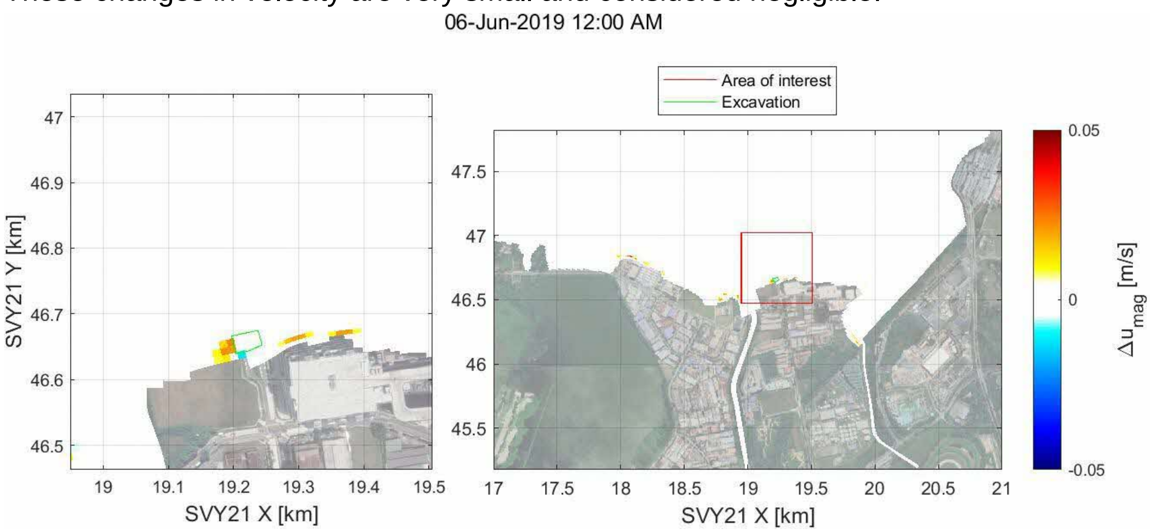


Figure 7-43 Differences in velocity magnitude (Δumag) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2030.

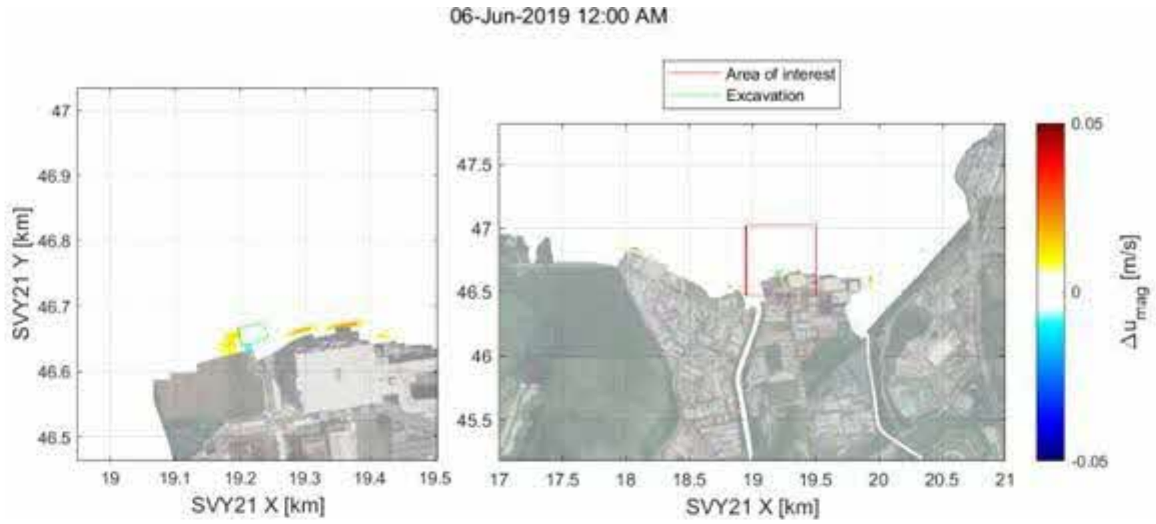


Figure 7-44 Differences in velocity magnitude (Δumag) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2050.

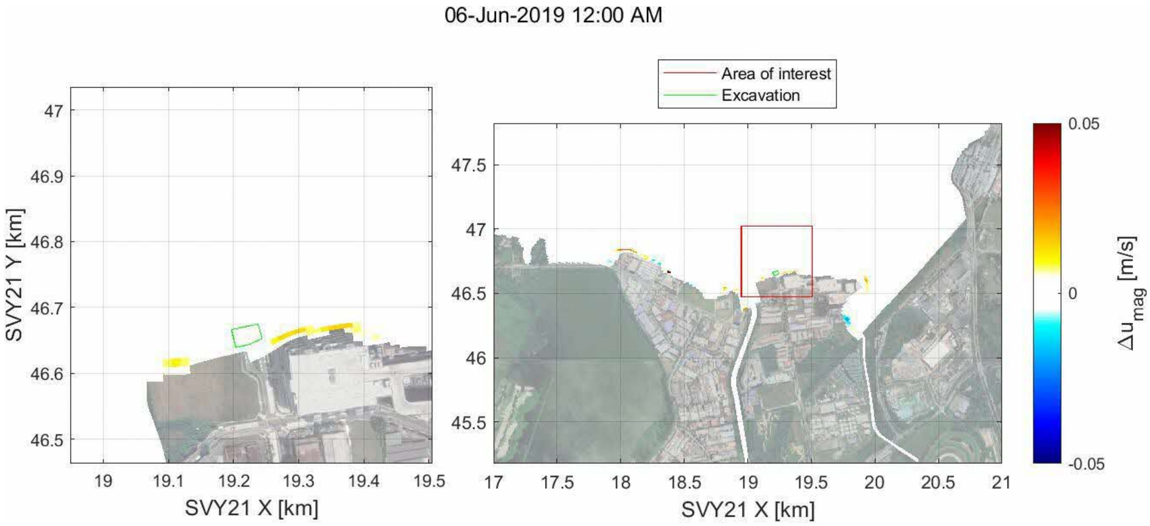


Figure 7-45 Differences in velocity magnitude (Δumag) between the simulations with and without slope change and Experiential Walk around high water of a King Tide event for SLR scenario 2100.

7.3.6 Conclusions

An analysis of the impact of the placement of the proposed wet infrastructure on the hydrodynamics around the MMM Nature Park shows no or very limited effects. According to our model results, this holds true for normal monsoon conditions and squall events, both during King Tide conditions. For the monsoon conditions and an extreme squall event, the impact of the Experiential Walk on water levels is small and local with the largest effect at the excavation site itself. A minimal increase in water levels in the order of millimeters is visible to the east in the direct vicinity. Differences in current magnitude and wave heights are only expected within a few meters of the Experiential Walk and excavation.

The results showed that the current magnitudes and velocity at the coastline where the Sungei Pang Sua Pavilion and Experiential Walk will be located is very small. The modelled currents showed low velocity magnitudes around the coast respectively for SW monsoon and NE monsoon conditions and significant wave heights at the Experiential Walk are small during both monsoon conditions. The results demonstrated that the proposed development will not have an adverse impact even under worst-case scenarios of sea level rise projections (for the years 2030, 2050, and 2100).

7.4 Impact Assessment

Coastal hydraulics within the vicinity of the proposed Nature Park may be influenced by the construction of the Nature Park's Infrastructure. The sensitive receptors that may be affected by these changes in water quality consist mainly of flora & fauna within the project area, including mangrove and shorebirds. Based on the proposed spatial layout plan (Figure 2.5), the environmental scoring for the residual impacts for each impact component (after accounting for the recommended mitigation measures) according to the RIAM was Slight Negative to No Impact.

An analysis of the impact of the placement of the proposed wet infrastructure on the hydrodynamics around the Mandai Mangrove and Mudflat Park shows no or very limited effects. The piles of the look-out platforms and the backfills generate negligible disturbances in the system. Differences in current magnitude and wave heights are only expected within a few meters of the piles or along the new backfill. Hence, No Impact is anticipated on floating fish farms located in the western side of Johor Strait which are almost 1km away from the project area.

Considering the above findings, no mitigation measures are required. Table 7.2 summarises the impacts with their corresponding Environmental Scores.

7.4.1 Predicted Impacts

RIAM Environmental Scoring for the Predicted Impacts

Table 7.2. Predicted coastal hydraulics impacts from proposed works at project area

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="4">Kranji Reservoir Park</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space
• Temporary working space</td><td>• Vegetation clearance</td><td>No predicted Impact</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Bird sanctuary/Coastal Forest
• Heron rookery
• Lookout shelter
• Pedestrian bridge
• Pedestrian path
• Nature-based Solutions
– Interlocking rings
– Intertidal terrace
– Rain garden</td><td rowspan="2">• Vegetation clearance
• Land-based development with piling
• Revetment
• Shoreline stabilisation
• Restoration of mangrove edge
• Reforestation of coastal forest</td><td>Impact on water level due to proposed new wet infrastructure</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Impact on current speed due to proposed new wet infrastructure</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Operation</td><td>• Bird sanctuary/ Coastal Forest
• Heron rookery
• Lookout shelter
• Pedestrian bridge
• Pedestrian path
• Nature-based Solutions
– Interlocking rings
– Intertidal terrace
– Rain garden</td><td>• Recreational visitorship
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Impact on floating fish farms due to proposed new wet infrastructure</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Water level	2	-1	1	1	1	-6	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Current speed	2	-1	1	1	1	-6	No Impact
				Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms due to proposed new wet infrastructure	2	-1	1	1	1	-6	No Impact
Sungei Pang Sua Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation Clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="5">Public Trail (Profile B -2, Option 2)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space</td><td>• Vegetation clearance</td><td>No predicted Impact</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Earth trail
• Nature-based Solutions
– Geo bags</td><td rowspan="2">• Vegetation clearance
• Earthworks
• Revetment and placement of geo bags
• Land and intertidal based development</td><td>Water level</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Current speed</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td rowspan="2">Operation</td><td rowspan="2">• Earth trail
• Nature-based Solutions
– Geo bags</td><td rowspan="2">• Recreational visitorship
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Routine maintenance</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Impact on floating fish farms</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td rowspan="5">Public Trail (Profile C)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space</td><td>• Vegetation clearance
• Earthworks</td><td>No predicted Impact</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Elevated Boardwalk</td><td rowspan="2">• Vegetation clearance
• Earthworks
• Land and intertidal based development</td><td>Water level</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Current speed</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td rowspan="2">Operation</td><td rowspan="2">• Elevated Boardwalk</td><td rowspan="2">• Recreational visitorship
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Routine maintenance</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Impact on floating fish farms</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Constructio n	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	No predicted Impact	-	-	-	-	-	-	-
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Water level	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Hoarding installation	No predicted Impact	-	-	-	-	-	-	-
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Water level	2	-1	1	1	1	-6	No Impact
				Current speed	2	-1	1	1	1	-6	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Routine maintenance	2	-1	1	1	1	-6	No Impact
				Impact on floating fish farms	2	-1	1	1	1	-6	No Impact

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to location.

The predicted impacts are expected to be mainly Slight Negative across all locations, except for locations with heavy construction and in sensitive areas (i.e., mangroves and intertidal habitats).

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc.) are expected. The predicted impacts from these works would mostly be the sea level rise and current speed. As the pre-construction works are mainly vegetation clearance, we do not predict the occurrence of further impacts.

During the construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas along the coastline (i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion). The main coastal hydraulic concerns arising from these works are the impact on the floating farm. Based on our modelled scenarios, the construction impacts would not reach the areas around the fish farm, and No Impacts are predicted.

As no construction works will be carried out during the operation phase, the impacts would be generally in the No Impact range. As the impacts are No Impact, there were no proposed mitigation measures.

7.4.2 Mitigation Measures

As the predicted impacts fall within the No Impact range, no mitigation measures are required.

Table 7.3. Coastal hydraulics impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	No predicted Impact	• None required
Construction	Water level	• None required
	Current speed	• None required
Operation	Routine maintenance	• None required
	Impact on floating fish farms	• None required

7.4.3 Residual Impacts

During pre-construction phase, there are No Impacts predicted. Thus, there is no mitigation measures proposed. There are No Impacts anticipated as well.

During construction phase, predicted impacts across the locations include changes in water level and current speed. As the area of impact is rather small, the impacts predicted lies in the No Impact range. Similarly, no mitigation measures are proposed.

During operation phase, predicted impacts across the locations include routine maintenance and impact on the floating fish farms nearby. As the area of impact is rather small, the impacts predicted lies in the No Impact range. Similarly, no mitigation measures are proposed.

RIAM Environmental Scoring for the Residual Impacts

Table 7.4. Environmental Scores of the predicted and residual impacts on site's coastal hydraulics after implementation of mitigation measures listed in Table 7.3

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		– Interlocking rings – Intertidal terrace – Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Co nst ruc	• Earth trail	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Biodegradable coir fibre logs	Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working spac	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Op era tion	• Public Trail	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		Boardwalk	Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Co nst ruc	• Earth trail	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions − Geo bags	Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions − Geo bags	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Elevated Boardwalk	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation		Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guided Trail (Profile D Option 2)	Pre-construction		Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Guided Trail (Profile D Option 2)	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Guided Trail (Profile D Option 2)	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Guided Trail (Profile D Option 2)	Operation		Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• At-grade pedestrian connection	Water level	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Current speed	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• At-grade pedestrian connection	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Soil Erosions and Surface Runoff	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Sediment runoff and siltation	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Accidental spillage of oil & fuel and waste disposal	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Routine maintenance	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Impact on floating fish farms	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

8 SEDIMENT QUALITY AND DYNAMICS

8.1 Baseline methodology

In order to document the baseline sediment quality within the project area, grab sampling was undertaken at 8 representative locations for sediment grading and toxicity testing (SD1-SD8), The sampling locations for sediment quality analyses are presented in Figure 8-1.

Figure 8-1. Sediment sampling locations

Seabed samples were collected using a Van Veen Grab Sampler and kept in plastic bags duly annotated. The grain size distribution of the samples was analysed. Positioning of the sample for the sediment sampling was done by DGPS (Figure 8-2). Subsequently, the sediment samples were sent to SINGLAS-accredited laboratory to analyse the soil parameters for toxicity profile. Figure 8-3 shows the photographs of sediment sampling activity.

Figure 8-2. Example of DGPS

Figure 8-3. Photographs of sediment sampling activities

Table 8.1. Summary of sediment quality parameters analysed for the purpose of environmental baseline study.

In-Situ Parameters	Ex-Situ Parameters	
	Parameter	Units
Visual characterisation	Arsenic	mg/kg dry wt.
	Cadmium	mg/kg dry wt.
	Chromium	mg/kg dry wt.
	Copper	mg/kg dry wt.
	Lead	mg/kg dry wt.
	Mercury	mg/kg dry wt.
	Nickel	mg/kg dry wt.
	Zinc	mg/kg dry wt.
	Total Petroleum Hydrocarbons	mg/kg dry wt.

8.2 Baseline Results and Discussion

There are no local Singapore standards or criteria available to compare the levels for soil toxicity parameters, soil bulk density, soil organic matter, and total petroleum hydrocarbons in the sediments. The regional standards were researched to find an appropriate criterion for comparison purposes. Hong Kong Sediment Quality (HKSQ) Criteria for Management of Dredged /Excavation Sediment were utilised to compare the study results regarding soil toxicity parameters.

The baseline results for the sediment sampling can be seen below in Table 8.2. The full report can be found in **Appendix G**. As noted from the Table 8.2, a few exceedances above LCEL (Lower Chemical Exceedance Level) and UCEL (Upper Chemical Exceedance Level) of the HKSQ Criteria are observed in the collected samples. The Arsenic content of seven samples (SD1-SD7) exceeds the LCEL. The Copper content of sample SD3, SD5 and SD6 exceeds the LCEL whereas other sample results are within the criteria. The Zinc content in sample SD2, SD3, SD5, SD6 marginally exceeds the LCEL and three Zinc samples SD3, SD5, SD6 also exceeds UCEL.

Table 8.2. Sediment baseline results

Test Parameter	unit	Test Method	SD1	SD2	SD3	SD4	SDS5	SD6	SD7	SD8	Hong Kong Sediment Quality Criteria[15]	
											LCEL*	UCEL*
Bulk Density	Mg/m3	BS EN ISO 17892-2 : 2014 Section 5.1	1.59	1.42	1.29	1.48	1.22	1.23	1.38	1.43	-	-
Organic Matter as LOI	%	as 13.77: part 32018	6.25	1	5.92	5.39	11.3	9	6.61	1.68	-	-
Cadmium as Cd	mg/kg	APHA 3120B	0.48	0.45	0.49	0.39	0.95	0.75	0.53	0.04	1.5	4
Chromium as Cr	mg/kg	APHA 3120B	14.1	23.8	35.9	22.8	46.5	37.5	25.9	3.99	80	160
Mercury as Hg	mg/kg	usEPA 245.1 (FINIS) (1994)	0.11	0.18	0.2	0.13	0.26	0.19	0.12	0.021	0.5	1
Nickel as Ni	mg/kg	APHA 3120B	7.48	12	15.6	10.3	15.9	14.8	12.3	2.09	40	40
Zinc as Zn	mg/kg	APHA 3120B	197	**210**	**335**	178	**494**	**368**	0.222	28.8	200	270
Copper as Cu	mg/kg	APHA 31.20B	26.1	44.9	**69.7**	39.2	**83.2**	**72.6**	46.3	4.09	65	110
Lead as Pb	mg/kg	APHA 3120B	18	25.8	31.3	21	56	57.1	33.4	5.78	75	110
Arsenic as As	mg/kg	APHA 3120B	**15.7**	**24.5**	**28.8**	**16.1**	**40.2**	**26.5**	**18.1**	2.54	12	42
Total Petroleum Hydrocarbons (by FTIR)	mg/kg	USEPA 8440 (1996)	383	399	444	515	1,124	795	651	ND		

*Lower Chemical Exceedance Level (LCEL)
*Upper Chemical Exceedance Level (UCEL)

[15] Hong Kong Sediment Criteria website:
https://www.epd.gov.hk/eia/register/report/eiareport/eia_1722009/html/Section%207%20(Sediment)/Section%207%20(Sediment).htm

8.3 Sediment Dynamics & Morphology

The sediment dynamics and morphology at and around Mandai Mangrove and Mudflat were simulated to study the baseline conditions and to assess the impacts of the new park features on sediment dynamics and morphology. This includes suspended sediment concentrations (SSC) and erosion and deposition patterns at the scale of the full model domain (Johor Strait). In contrast to previous feasibility study for Mandai by TAC (2020), where only sediment plume modelling as a consequence of the construction works was included, here the (background) system dynamics are considered.

To assess the environmental impact of the design layout on sediment dynamics and morphology, model scenarios before and after implementation of the new wet infrastructure are compared. This new wet infrastructure is located in the higher parts of the intertidal areas that are only wet during highwater or more extreme high tide and squall events. As shown in Chapter 7, the current magnitudes and wave heights, which drive the sediment dynamics in the area, are low at Mandai Mangrove and Mudflat. Moreover, the changes in currents and waves due to the planned wet infrastructure are very limited and only in the direct vicinity of the infrastructure. Therefore, the impact of the wet infrastructure implementation on sediment dynamics and morphology are expected to be minor.

The setup and results of the sediment dynamics and morphology modelling for a number of environmental scenarios are presented in this Chapter. The aim is to show the impact of the planned wet infrastructure under both present-day and future predicted sea level rise on sediment dynamics and morphology.

8.3.1 Model input and scenarios

The approach of simulating the (background) sediment dynamics and morphology in the project area is different from the previous feasibility study for Mandai in 2019, where sediment plumes were modelled. For sediment and morphology modelling, the Delft3D modelling software was applied. The same computational grid, (initial) depth schematisation, meteorological forcing, wave forcing, and schematisation of the new wet infrastructure were applied as for the Delft3D hydrodynamic model presented in Chapter 7. Therefore, the (initial) resulting water level, current and wave fields are the same (but may differ after bed level changes). The sediment and morphology modelling was done in 2D depth-averaged mode, as the Johor Strait is relatively well-mixed and 3D effects are expected to be negligible. Depth-averaged settings were also utilized by (Willemsen, 2016). (Willemsen, 2016) demonstrated (Sun et al., 2017) results to the 3D model, as previously noted by (Hu et al., 2009) and (Horstman et al., 2015). Moreover (Sun et al., 2017) notes that "the spring tide is the first-order factor for the water vertical mixing in the WJS, the wind is also very important for the vertical mixing especially in neap tide condition."

This section first describes the concepts of the applied sedimentation and erosion modelling, the parameterisation of sediment characteristics and morphology, and the scenarios representing different morphological responses to sea level rise.

8.3.2 *Conceptual model description*

The sedimentation and erosion processes in the Delft3D model originate from the Partheniades-Krone formulations (Partheniades, 1965), with modifications made by (Van Kessel et al., 2011) that allow for buffering of fine sediment in the seabed. For the sediment model, two cohesive sediment fractions are included with one cohesive fraction representative for poorly flocculated mud particles and the other fraction for flocculated cohesive particles. Sediment parameter settings are determined based on assessment of properties of the sediment samples and expert judgement.

The bed is schematized using a two-layer model (Van Kessel et al., 2011): an easily erodible, mobile upper layer that contains fresh deposits of unconsolidated mud (layer S1) and a less mobile underlayer with consolidated mud (layer S2). The upper layer represents a thin layer of fine sediment resting temporarily on the bed (prior to consolidating), while the underlayer represents the subsoil, comprising of a mix of sand and less-erodible (consolidated) mud. Erosion rates of the upper layer depend on the amount of sediment available in this layer. Erosion rates increase along with the available amount of sediment until a critical mass is reached, after which erosion rates are independent of the amount of sediment present in the mobile upper layer. A schematization of this two-layer bed model is provided in Figure 8-4.

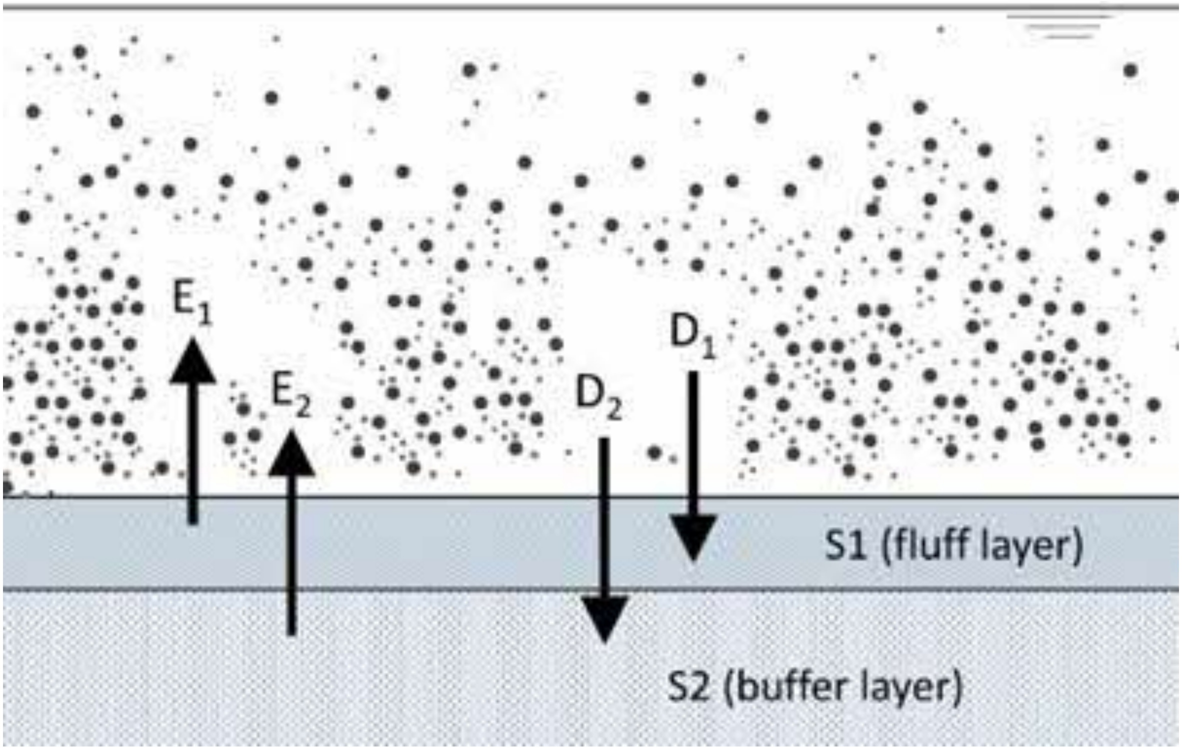


Figure 8-4. Representation of the two-layer bed schematization in Delft3D with suspended sediment particles in the water column on top of bed layers S1 (thin fluff layer) and layer S2 (buffer layer). $D_{1,2}$ = deposition flux towards layer S1,S2; $E_{1,2}$=erosion flux from layer S1,S2.

8.3.3 *Sediment characteristics & Morphology parameters*

Field measurements of median grain size in the project area were collected at the site as shown in Figure 8-5. The results are tabulated as in Table 8.3. These measurements were performed by Marchwood Laboratory Services.

Figure 8-5. Sediment sample locations

Table 8.3. Sediment bulk density and median grain size.

Location	Bulk density (kg/m^3)	D50 (µm)
SD1	1590	10
SD2	1420	9
SD3	1290	2
SD4	1480	2
SD5	1220	2
SD6	1230	2.5
SD7	1380	2.5
SD8	1430	3

Settling velocities for sediment particles are based on the Stokes equation, see Equation 8.1 Here, w_s denotes the settling velocity, ρ_s the density of dry sediment (2600 kg/m^3), ρ_f the density of the fluid (1000 kg/m^3), g the accelation constant (m/s^2), $D50$ the median grainsize (m) and η the viscosity of water (1000 Pa/s). We assumed spherical particles.

Equation 8.1. Stokes for settling velocity, adopted from on Ferguson and Church (2004).

$$w_s = \frac{2}{9}\frac{\left(\rho_s - \rho_f g(D50/2)^2\right)}{\eta}$$

Based on this assessment (see Figure 8-6) two fractions were modelled 1) fraction 1 with larger flocs with a settling velocity of 10^{-4} m/s, and 2) fraction 2 with smaller flocs with a settling velocity of 10^{-5} m/s. These values are in agreement with the model set-up by Willemsen et al. (2016).

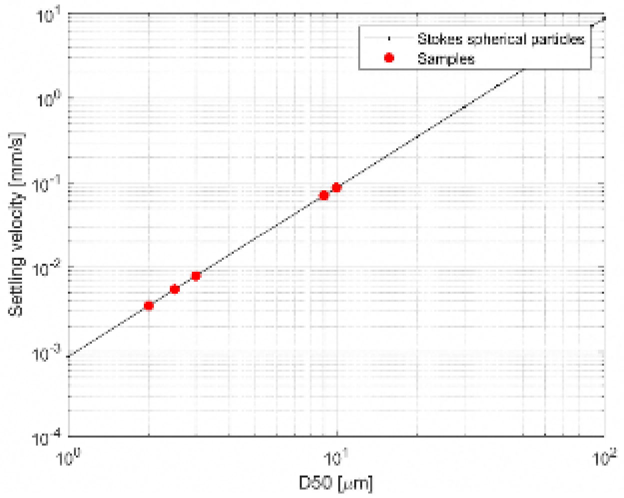


Figure 8-6. Settling velocity as a function of median grainsize using the Stokes formulation **(Ferguson & Church, 2004)**.

Initial conditions and boundary conditions

Initial conditions for sediment thickness in the bed are 0.9 m fine sediment fraction 1 and 10 cm fine sediment fraction 2; all applied uniformly over the model domain. Initial conditions for suspended sediment concentrations are zero for all sediment fractions. As no data is available on the sediment concentration conditions at the upstream boundaries, the sediment concentrations are based on data presented in Van Maren et al. (2014): an average of 150 mg/L east of the Strait of Johor. The sediment concentration boundary conditions result in nearly equal sediment influx and outflux (to prevent net sediment export out of the model domain by the flood currents). For all boundaries the distribution in SSC of the incoming flow between the fine sediment fractions is 50% fraction 1 and 50% fraction 2.

Sediment characteristics of the model domain are portrayed in Table 8.4. The same locations were also modelled by Willemsen et al. (2016). Therefore, sediment characteristics of the model approach of that study are also indicated in Table 8.4. It can be seen that the model approach of this study is largely in line with Willemsen et al. (2016).

In absence of detailed observations, the sediment characteristics are assumed to apply over the entire model domain, see Table 8.4. Suitable representative values for the critical shear stress for erosion could range between 0.5 and 3.0 Pa, based on the the range of bulk densities reported in Table 8.4. A sensitivity run was made with 3.0 Pa which showed less perturbations in suspended sediment concentrations and morphological change than when using 0.5 Pa. Therefore 0.5 Pa was applied in the scenario simulations as conservative approach.

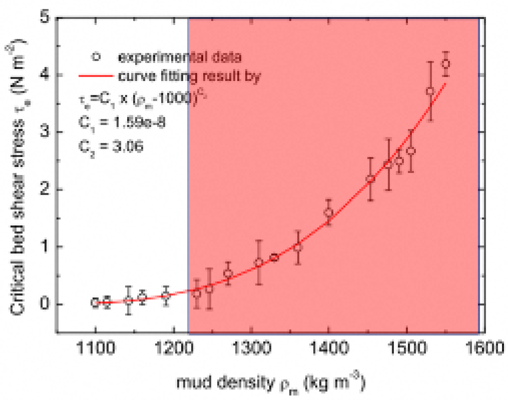


Figure 8-7: Critical bed shear stress as function of bulk density of mud. The red square indicates the range of bulk densities reported in Table **8.3** and the critical bed shear stresses we can expect. Based on Xu et al. **(2015)**.

Table 8.4. Uniform values for sediment characteristics over the model domain.

Variable	**Value in current model**	**Value in Willemsen et al. (2016)**
Critical bed shear stress for erosion (Pa)	0.5	0.5 1.0 for sensitivity analysis
Critical bed shear stress for erosion of fluff layer (Pa)	0.1	-
Erosion parameter (kg m^{-2} s^{-1})	1.10^{-4}	1.10^{-4}
Settling velocity large flocs of fraction 1 (m/s)	1.10^{-4}	1.10^{-4}
Settling velocity small flocs of fraction 2 (m/s)	1.10^{-5}	-
Layer thickness fraction 1 (m)	0.9	Not specified
Layer thickness fraction 2 (m)	0.1	Not specified

Three varying wind conditions and their effect on suspended sediment concentration (SSC) (g/L), available mass of sediment (kg/m^2) and morphological change (m) were modelled:

1. Extreme squall event
2. NE monsoon conditions
3. SW monsoon conditions

To evaluate the systems response under SLR after implementation of the Experiential Walk, three sea levels rise scenarios with SW monsoon wind conditions were modelled:

1. SW monsoon with 10 cm SLR
2. SW monsoon with 32 cm SLR
3. SW monsoon with 102 cm SLR

For all models the simulation period lasted from the 27th of May until the 10th of June to keep the same tidal conditions over the different scenarios. However, wind data that generate the local waves will vary between the runs (i.e., representing different wind conditions), as described in Chapter 7.

8.3.4 Response to sea level rise

To assess the impact of sea level rise on the sediment transport and morphology in the project area, simulations with water level projections for 2030, 2050, and 2100 were applied, as described in earlier sections. In these simulations, the water level is increased homogeneously throughout the domain (i.e., no changes in tidal boundary conditions, meteorological forcing or sediment availability) and no morphological response of the Mandai Mangrove and Mudflat to sea level rise was assumed, although the seabed of tidal basins and estuaries typically rises (partially) with sea level rise due to increased accommodation space. To study the impact of sea level rise projections with morphological response, situations where the bed was assumed to grow fully or only partly with sea level rise based on the SLR model scenarios listed were assessed. In this indicative assessment it is assumed that the morphological response would be uniform within the (wet) domain, implying that full growth with sea level rise would create an identical situation to a scenario without sea level rise. No additional model scenarios were executed for this.

For the scenario where the bed grows only partly with sea level rise, it was assumed that the bed grows with 50% of the sea level rise. Some literature (Van der Wegen, 2013 ; Wegen and Roelvink, 2008; Lodder, et al., 2019; Van Maanen et al., 2013) indicates that bed level does not always keep up with SLR, but often lags behind. Precise growth rates are unknown; therefore, scenarios are used:

- 100% growth with SLR, 50% growth with SLR and 0% growth with SLR).
- 100% growth is identical to a simulation without SLR (no relative SLR, since spatially uniform).
- 50% growth reported in Deltares report.
- 0% growth is also reported in Deltares report.

This creates a (spatially-uniform) relative sea level rise of 5 cm (in 2030), 16 cm (in 2050) and 51 cm (in 2100). Additional model scenarios were not included. The impact was indicatively assessed based on the existing SLR scenarios for 10 cm, 32 cm and 102 cm below. For example, the scenario with 51 cm SLR (representative for RCP8.5 projection in 2100 and partial growth with SLR), the results will be in between the scenario of 32 cm and 102 cm.

8.4 Morphodynamic modelling results

In this section the results of the mean suspended sediment concentration (SSC) (g/L) and morphological change (m) under the three varying wind conditions (extreme squall event, NE monsoon conditions and SW monsoon conditions) are presented. The available mass of sediment (kg/m^2) for these scenarios can be found in **Appendix F**.

The variables were analysed in the situation after implementation of the Experiential Walk under these conditions together with difference maps. The difference maps are computed as results of simulation with intervention minus results of simulation without intervention. So, positive values indicate an increase in the reported variable after construction of the Experiential Walk and excavation.

The results for the extreme scenario of 102 cm SLR scenario are presented in this section. The results for the scenarios with seabed rise of 10 cm and 32 cm are included in **Appendix F**. These scenarios include implementation of the boardwalk and are compared with the current SW monsoon scenario, which includes implementation of the Experiential Walk and excavation, by means of difference maps. These difference maps are computed as follows:

Difference map = output of SW monsoon with SLR scenario including experiential walk - output of SW monsoon under current conditions including experiential walk

Therefore, positive values indicate a decrease of the reported variable with respect to the present. In this section, all reported scenarios are modelled with high mobility of the bed with a critical bed shear stress of 0.5Pa to analyse maximum variation in the sediment variable values.

8.4.1 Monsoon conditions

Figure 8-8 and Figure 8-10 show that time-averaged SSC during NE conditions are higher than during SW monsoon conditions, surpassing 0.5 g/L close to the intertidal mudflats. However, the construction of the Experiential Walk and excavation induced only a local change in SSC. As a consequence of the excavation and Experiential Walk construction, both during NE and SW monsoon conditions SSC is increased within the excavation with a maximum of 0.05 g/L and decreased with a maximum of 0.05 g/L in the direct vicinity of the excavation, see Figure 8-9 and Figure 8-11. During NE monsoon conditions the affected area is slightly larger compared to SW monsoon conditions because of construction.

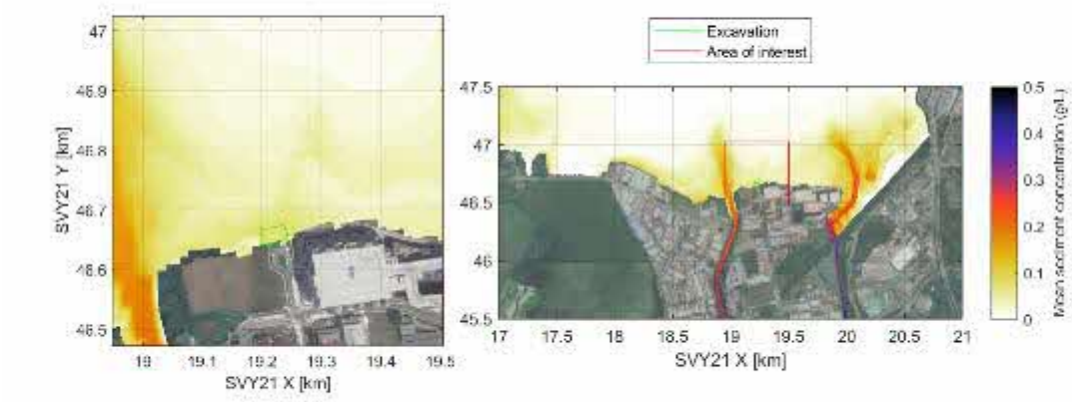


Figure 8-8. Time-averaged suspended sediment concentration (g/L) of the SW monsoon scenario including Experiential Walk. Left: Region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

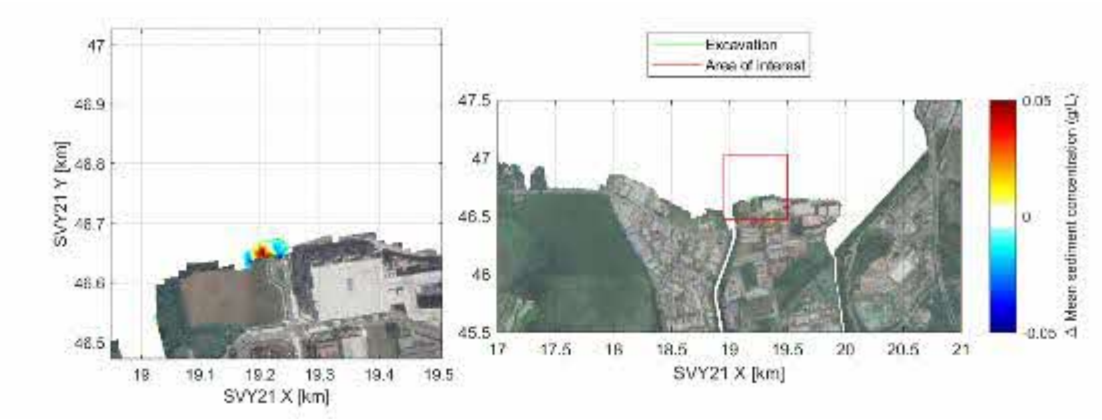


Figure 8-9. Change of the time-averaged suspended sediment concentration (g/L) of the SW monsoon scenario including Experiential Walk. Positive values indicate an increase of the time-averaged suspended sediment concentration after the construction of the Experiential Walk and excavation. Left: Region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

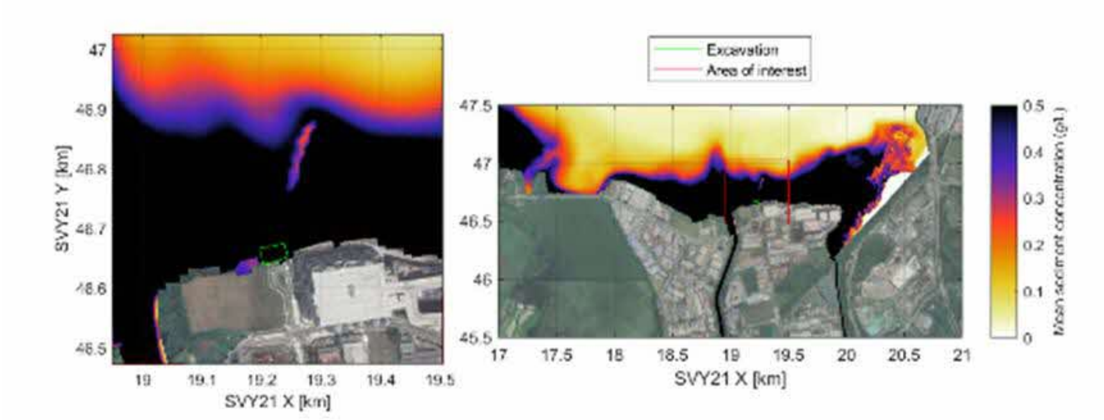


Figure 8-10. Time-averaged suspended sediment concentration (g/L) of the NE monsoon scenario including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

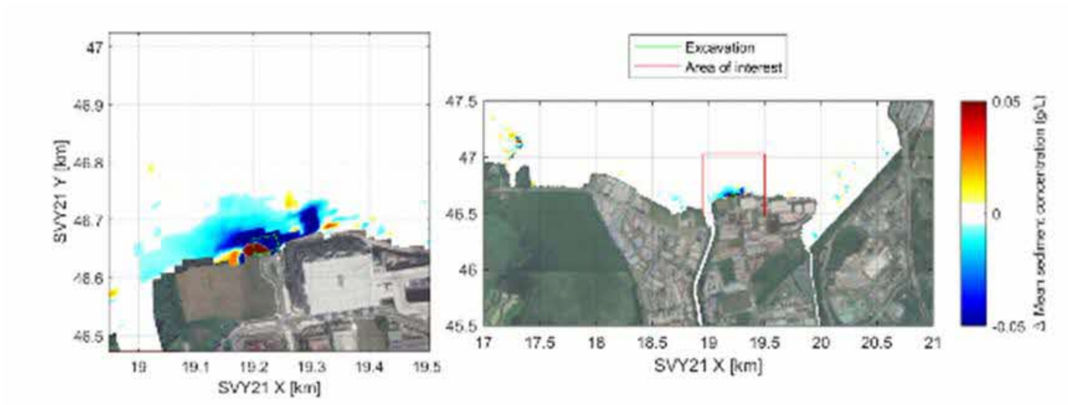


Figure 8-11. Change of the time-averaged suspended sediment concentration (g/L) of the NE monsoon scenario including Experiential Walk. Positive values indicate an increase of the time-averaged suspended sediment concentration after the construction of the Experiential Walk and excavation. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

More pronounced morphological change is visible in the NE monsoon scenario compared with the SW monsoon, see Figure 8-12 and Figure 8-13. Yet, the erosion in the NE scenario is minor with cumulative erosion up to 5 cm during the first spring-neap cycle in the shallow areas close to the coast. There is no morphological change observed in the SW scenario.

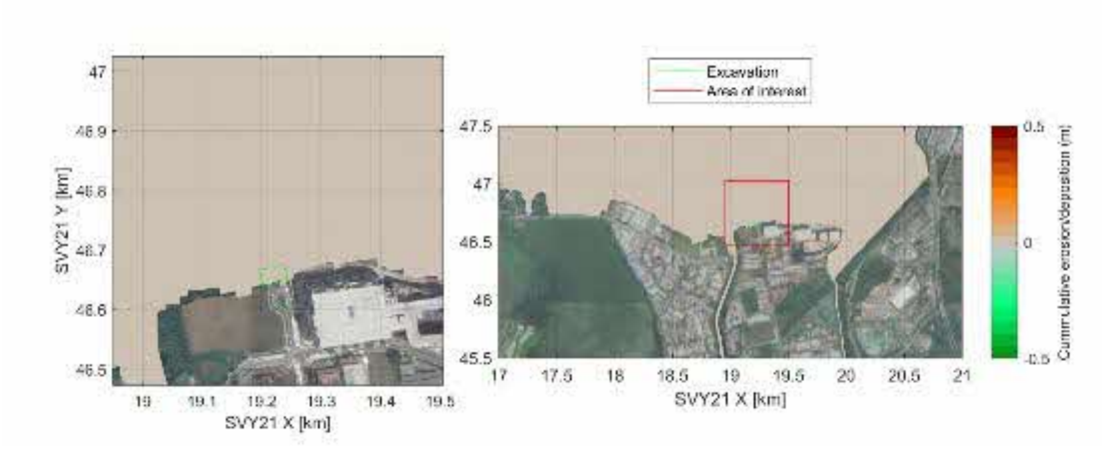


Figure 8-12. Cumulative erosion/deposition (m) at the last time step of the SW monsoon scenario including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

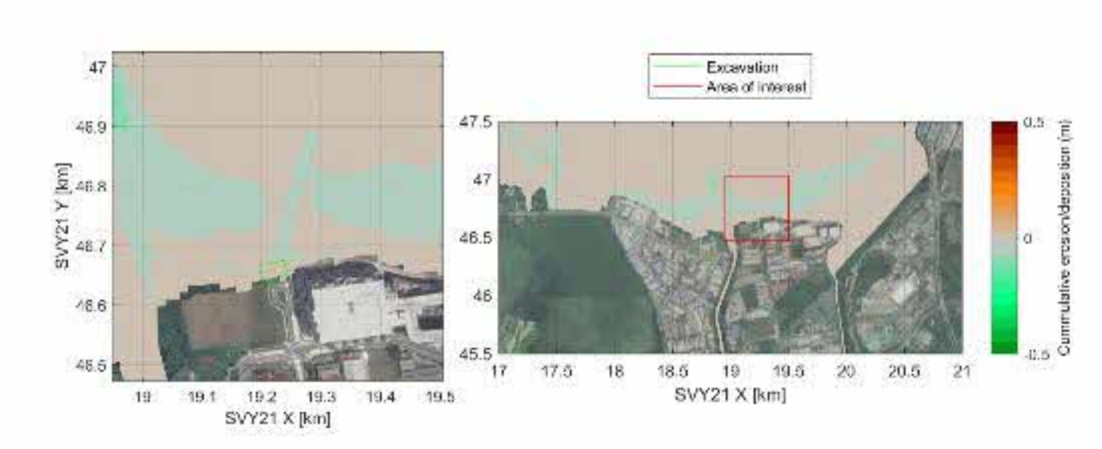


Figure 8-13. Cumulative erosion/deposition (m) at the last time step of the NE monsoon scenario including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

The construction of the Experiential Walk only leads to limited deposition (1-5 cm during the first spring-neap cycle) within the excavated area in the NE scenarios, while there is no effect of the Experiential Walk on morphological change in the SW scenario, see Figure 8-14 and Figure 8-15. However, this is a very local effect, since a control point directly next to the Experiential Walk and excavation indicates no change between model result with and without experiential walk, see
Figure 8-16.

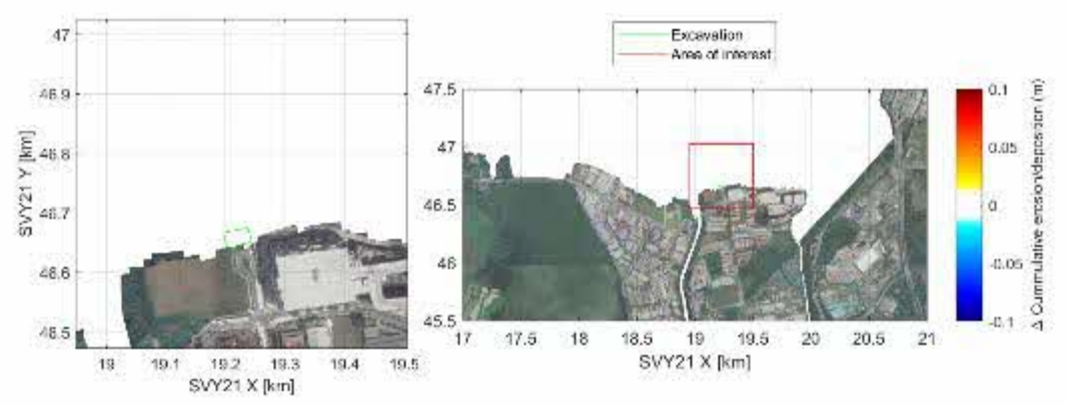


Figure 8-14. Change of the cumulative erosion/deposition (m) of the SW monsoon scenario including Experiential Walk. Positive values indicate more deposition or less erosion after the construction of the Experiential Walk and excavation. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

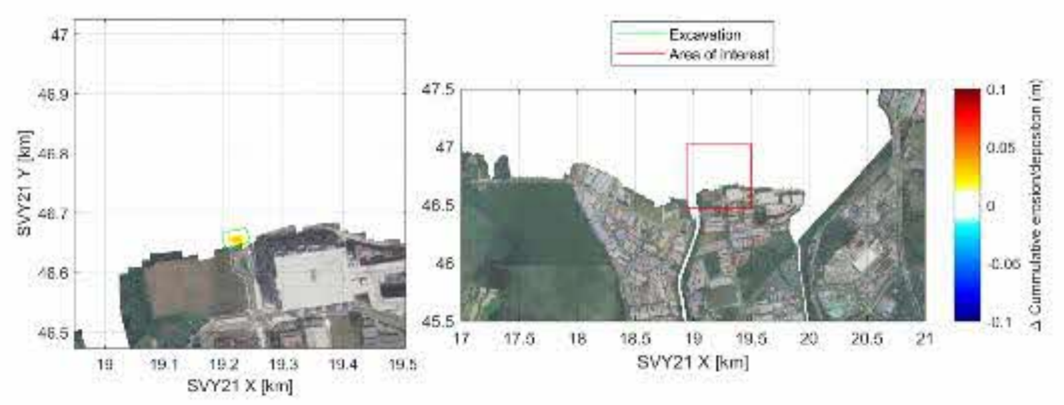


Figure 8-15. Change of the cumulative erosion/deposition (m) of the NE monsoon scenario including Experiential Walk. Positive values indicate more deposition or less erosion after the construction of the Experiential Walk and excavation. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

Figure 8-16. Time versus sediment bed level during NE monsoon conditions at a control point directly next to the Experiential Walk.

8.4.2 Extreme squall event

Results of the extreme squall event scenario are comparable with the NE monsoon scenario. However, during an extreme squall event most of the change in SSC and morphology enfolds during a relatively short time interval with energetic conditions (the 6th of June), while observed change for the NE monsoon condition is the consequence of intermediately energetic conditions over a longer timespan (27th of May until the 10th of June). During the extreme squall event, a peak in NW wind conditions at 06:00pm on 6th of June generates significant wave heights up to 0.8 m at the Experiential Walk. This erodes the shallow areas facing the northwest with 0.5 to 1 cm, see Figure 8-20. Therefore, more sediment is brought into suspension reaching SSC values up to 5 g/L, see Figure 8-19. The impact of the Experiential Walk on the water column is primarily very local Figure 8-18. The impact in the sediment bed level is negligible (Figure 8-21 and Figure 8-22): the excavation and Experiential Walk will experience 1-2 cm more deposition with respect to the reference (Figure 8-20).

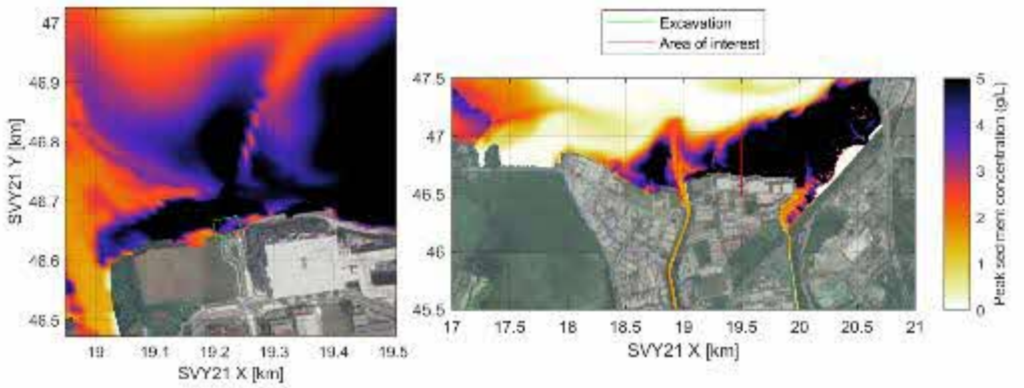


Figure 8-17. Suspended sediment concentration (g/L) during the peak of the squall scenario (at 06:00 p.m. on June 6, 2019) including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

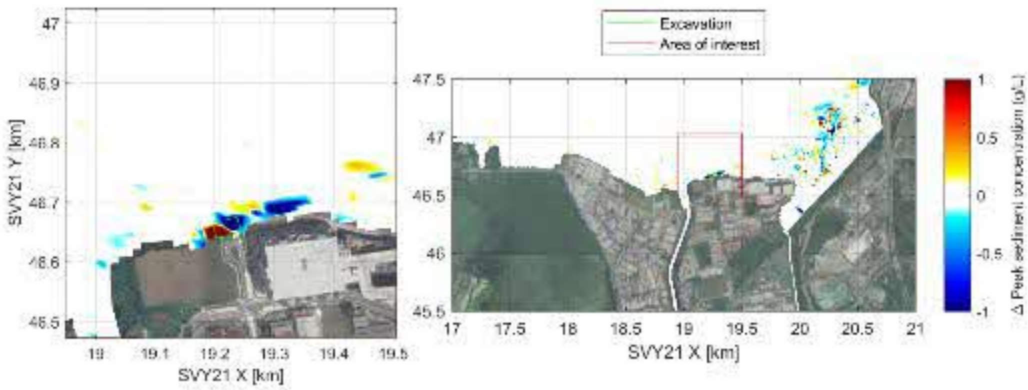


Figure 8-18. Change of the suspended sediment concentration (g/L) during the peak of the squall scenario (at 06:00 p.m. on June 6, 2019) due to the Experiential Walk. Positive values indicate an increase of the time-averaged suspended sediment concentration after the construction of the

Experiential Walk and excavation. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

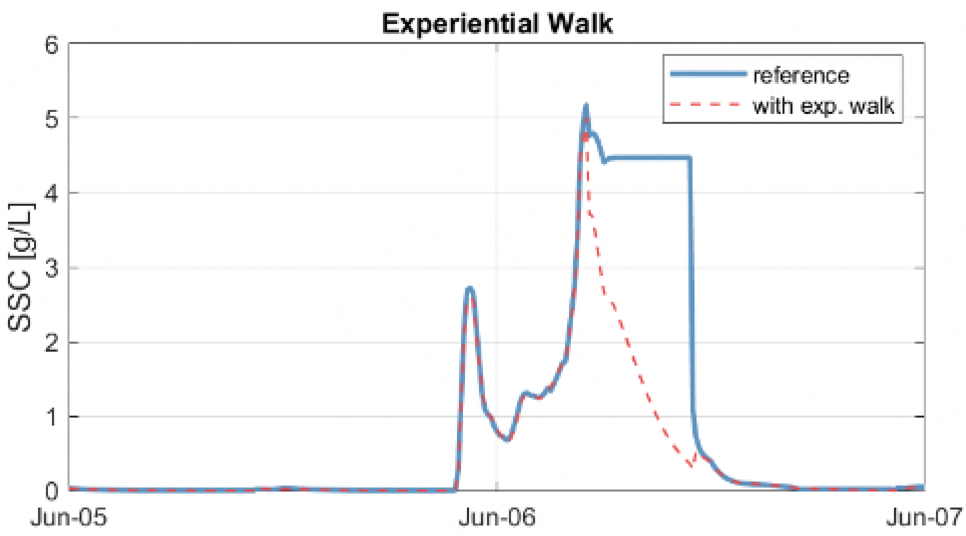


Figure 8-19. SSC over time during the extreme squall event at a control point directly next to the Experiential Walk. SSC values for the reference after the peak remain constant for some hours on June 6 as this control point was not inundated.

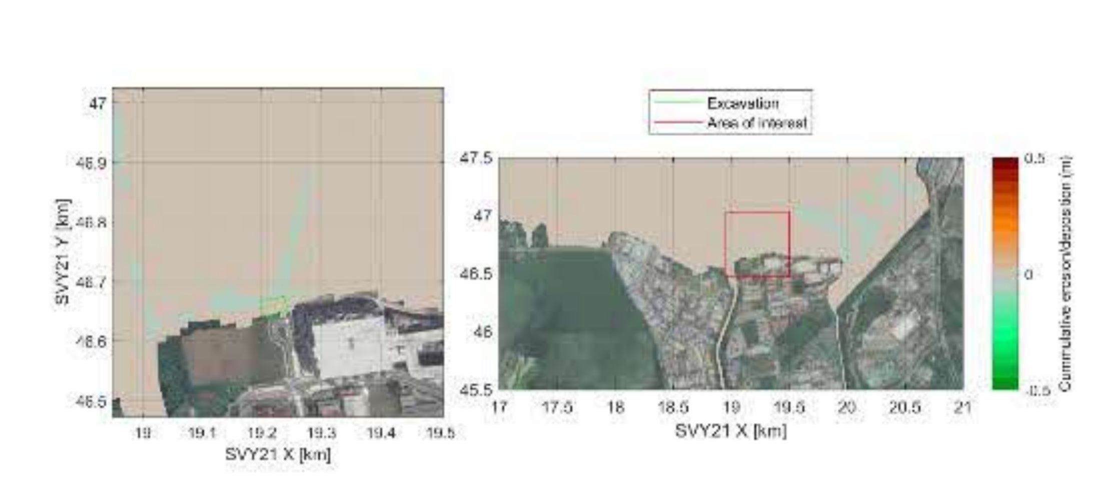


Figure 8-20. Cumulative erosion/deposition (m) at the last time step of the squall scenario including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

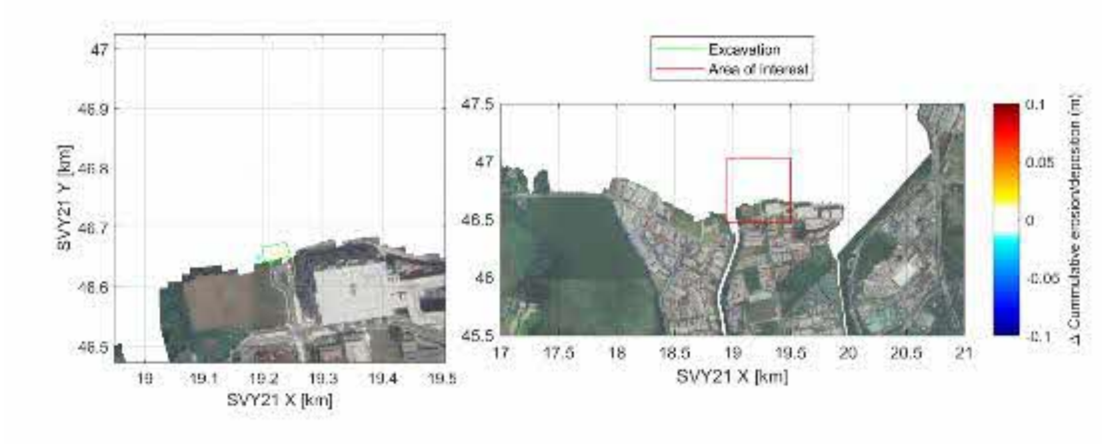


Figure 8-21. Change of the cumulative erosion/deposition (m) of the squall scenario including Experiential Walk. Positive values indicate an increase of the cumulative erosion/deposition after the construction of the Experiential Walk and excavation. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

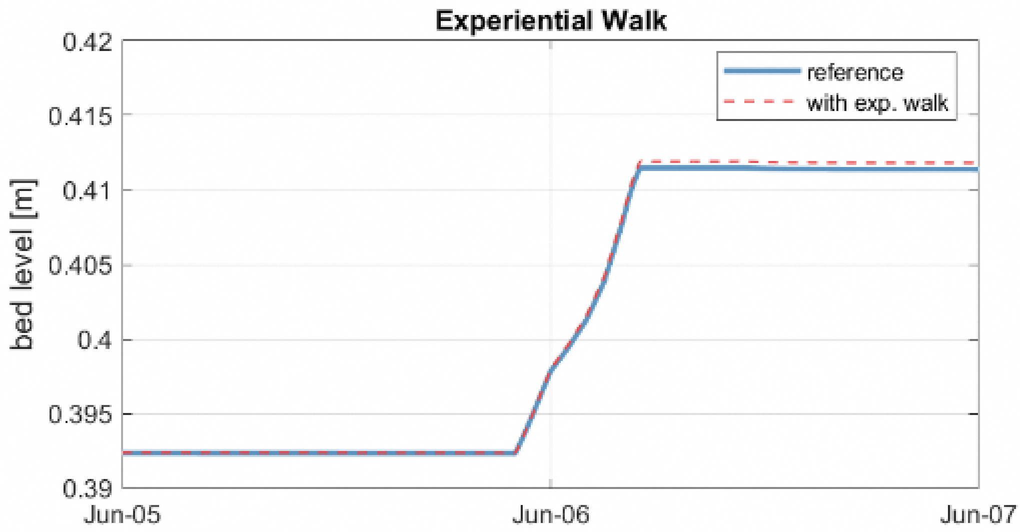


Figure 8-22: Sediment bed level over time during the extreme squall event.

8.4.3 Effects of future sea level rise on the sediment dynamics and morphology at Mandai Mangrove and Mudflat

In this section the model results of sea level rise (SLR) representative for the RCP8.5 projection in 2100 are presented, without increase in bed elevation (most conservative scenario). This scenario consists of 102 cm SLR. The scenarios with 10 cm (RCP8.5 in 2030) and 32 cm (RCP8.5 in 2050) SLR can be found in **Appendix F**. All SLR model results indicate a decrease in the time-averaged SSC of more than 0.05 g/L in the shallow areas with respect to the present, see Figure 8-23 and Figure 8-24. However, this is not consequence of enhanced deposition with respect to the present, since morphological change is similar to present SW monsoon conditions, see Figure 8-25 and Figure 8-26.

To study the impact of sea level rise projections with morphological response, we assess situations where the bed would grow fully or only partly with sea level rise based on the SLR model scenarios described above. Assuming full seabed growth with sea level rise ('keeping pace') would create an identical situation to a scenario without sea level rise (see Sections 8.4.1 and section 8.4.2). So, no changes in hydrodynamics or sediment dynamics due to the present situation are anticipated if the seabed keeps pace with SLR.

The impact of a SLR scenario where the seabed grows with 50% of the sea level rise ("partially keeping pace"), the impact is indicatively assessed based on the existing SLR scenarios for 10 cm, 32 cm and 102 cm. In 2100 a SLR of 102 cm and a seabed rise of 51 cm would result in a relative SLR of 51 cm. The changes in hydrodynamics and sediment dynamics will be in between the scenario of 32 cm and 102 cm, i.e. the time-averaged SSC would decrease in the shallow areas compared to the current situation. No significant morphological changes are expected within the timeframe of a spring-neap cycle.

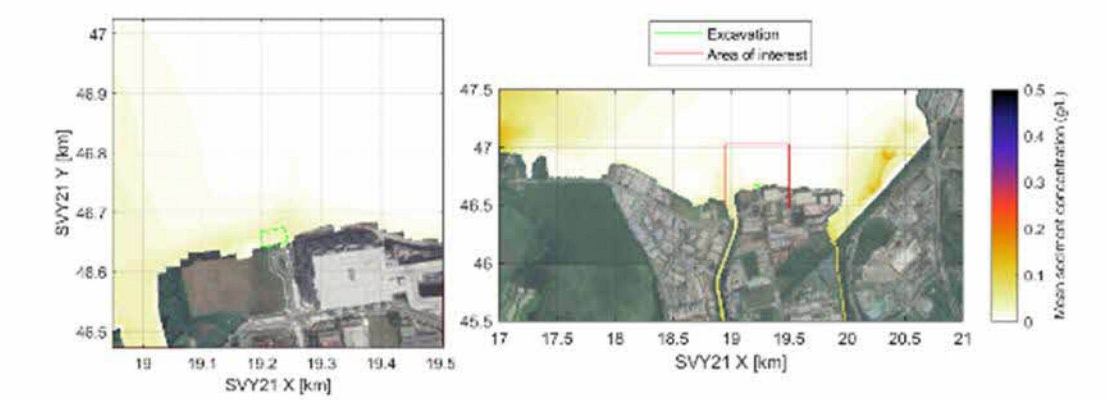


Figure 8-23. Time-averaged suspended sediment concentration (g/L) of the 'SLR under SW Monsoon, 102 cm'-scenario including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

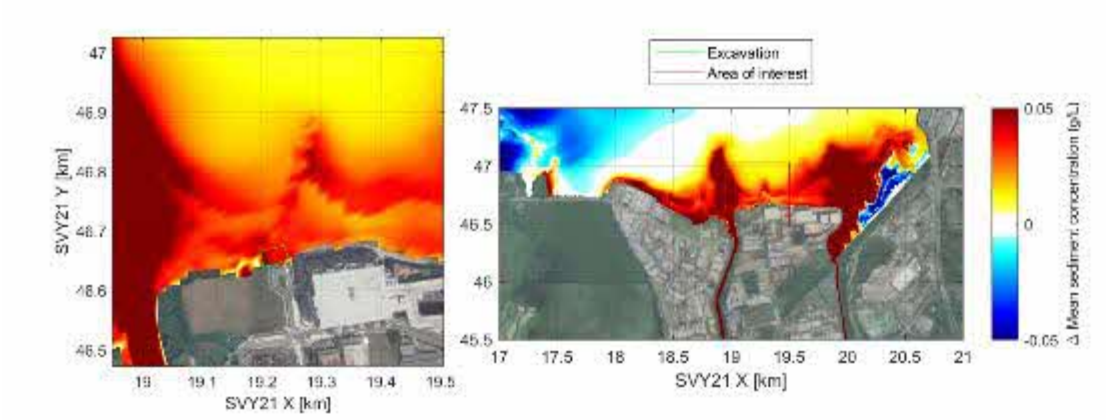


Figure 8-24. Change of the time-averaged suspended sediment concentration (g/L) of the 'SLR under SW Monsoon, 102 cm'-scenario including Experiential Walk. Here, the output of the model of current SW monsoon conditions is subtracted from the output of the model under this sea level rise scenario. Positive values indicate a decrease of the time-averaged suspended sediment

concentration with respect to the present. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

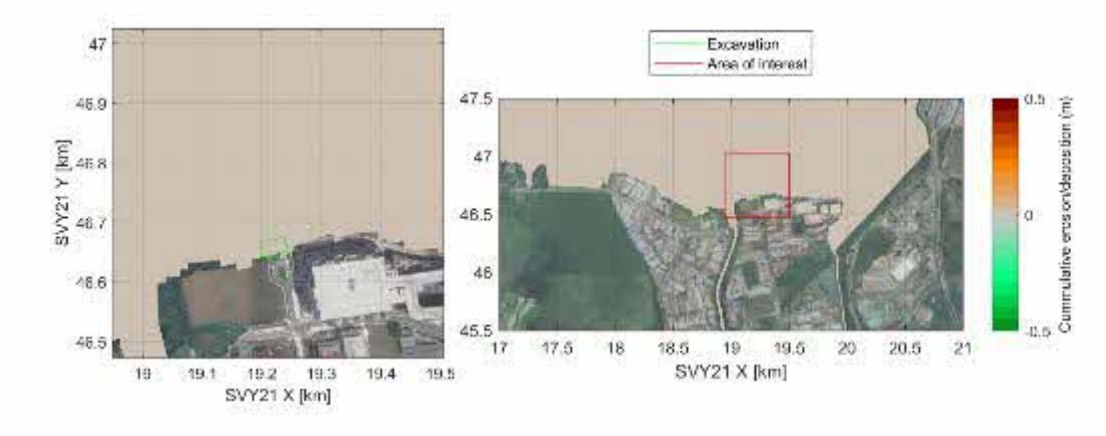


Figure 8-25. Cumulative erosion/deposition (m) at the last time step of the 'SLR under SW Monsoon, 102 cm'-scenario including Experiential Walk. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated

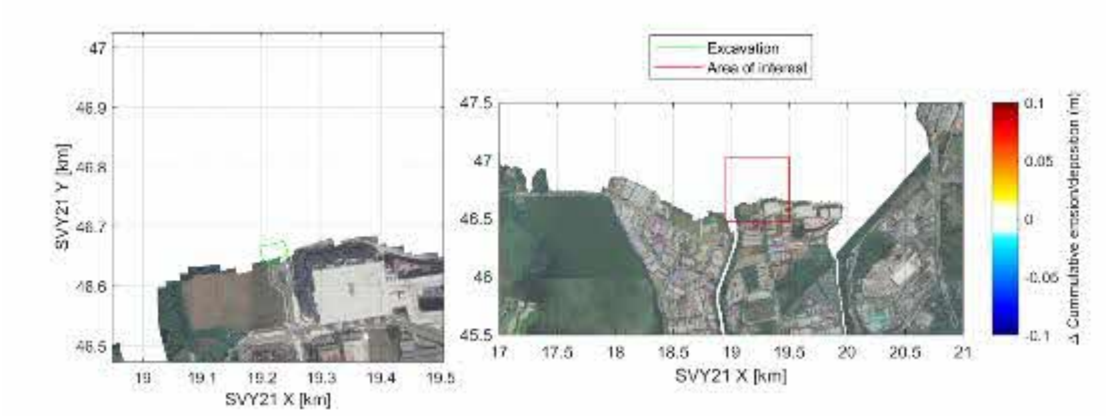


Figure 8-26. Change of the cumulative erosion/deposition (m) of the 'SLR under SW Monsoon, 102 cm'-scenario including Experiential Walk. Here, the output of the model of current SW monsoon conditions is subtracted from the output of the model under this sea level rise scenario. Positive values indicate a decrease of the cumulative erosion/deposition with respect to the present. Left: region of interest. Right: Surrounding area of region of interest in which the extent of the region of interest is indicated.

8.5 Impact Assessment

8.5.1 Predicted Impacts

Due to the nature of the construction works it is anticipated that no local or transboundary impacts will be arising from sediment dispersion from the construction works of proposed Nature Park infrastructure.

The residual impacts were evaluated using the RIAM method (Table 8.5) with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in the band of Minor to Slight Negative.

RIAM Environmental Scoring for the Predicted Impacts

Table 8.5. Predicted sediment quality impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre-construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="5">Sungei Kranji Pavilion</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space
• Hoarding</td><td>• Vegetation clearance</td><td>Sediment runoff and siltation</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-36</td><td>Slight Negative</td></tr>
<tr><td rowspan="3">Construction</td><td rowspan="3">• 2-storey pavilion
• Public amenities
• Viewing gallery
• Parking lots
• Coach drop-off</td><td rowspan="3">• Earthworks
• Land-based development with piling
• Vegetation clearance
• Demolition of existing building</td><td>Sediment runoff and siltation</td><td>3</td><td>-3</td><td>2</td><td>2</td><td>3</td><td>-63</td><td>Minor Negative</td></tr>
<tr><td>Impact on floating fish farms due to sediment dispersion</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Transboundary impact due to sediment dispersion beyond national boundary</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Operation</td><td>• 2-storey pavilion
• Public amenities
• Viewing gallery
• Parking lots
• Coach drop-off</td><td>• Recreational visitorship
• Public vehicle access
• Small vehicle deployment for maintenance works
• Artificial light at night
• Enhancement planting</td><td>No predicted Impact</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">Sungei Pang Sua Pavilion</td><td>Pre- construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space
• Hoarding</td><td>• Vegetation Clearance</td><td>Sediment runoff and siltation</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-28</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Lookout viewing tower.
• Interpretive Gallery with office
• Public amenities
• Experiential walk trail</td><td rowspan="2">• Earthworks
• Land-based development with piling
• Demolition of existing</td><td>Sediment runoff and siltation</td><td>3</td><td>-3</td><td>2</td><td>2</td><td>3</td><td>-63</td><td>Minor Negative</td></tr>
<tr><td>Impact on floating fish farms due to sediment dispersion</td><td>2</td><td>-1</td><td>1</td><td>1</td><td>1</td><td>-6</td><td>No Impact</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Intertidal terrace	building	Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	No predicted Impact	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative
Kranji Reservoir Dam (Profile E)	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
Kranji Reservoir Dam (Profile E)	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation	Sediment runoff and siltation	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative
				Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact
				Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted Impact	-	-	-	-	-	-	-

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

The predicted impacts are expected to range from Minor to Slight Negative across all locations, except for locations with heavy construction and/or in sensitive areas (i.e., mangroves and intertidal habitats).

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc) are expected. The predicted impacts from these works would mostly be the sediment runoff and siltation. Based on our modelled scenarios, the area of impacts is minimal and there will be limited to no changes in baseline conditions. Thus, it is assessed that there are no trans-boundary impacts and No Impact to the nearby floating fish farms.

During the construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas along the coastline (i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion). The main coastal hydraulic concerns arising from these works are the impacts on the floating farm. Based on our modelled scenarios, the effects from the construction are unlikely to reach the fish farm areas. Thus, there will be limited to no changes in baseline conditions and the predicated impacts are No Impacts.

During the operation phase, no works will be carried out. As such, there will be no predicted impact.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

8.5.2 Mitigation Measures

Mitigation measures are to be implemented wherever negative impacts are predicted, in order to reduce the impacts of the works on the environment. A majority of sediment quality mitigation measures are covered in this Chapter.

Table 8.6. Sediment quality impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Sediment runoff and siltation	• Implementation of ECM. • Construction activities to be limited to the smallest footprint areas possible. • Storage and stockpiles areas to be identified and approved by NParks. • Construction to be carried out during low tide period as far as possible. • All machinery and equipment to be located on dry land as far as possible. • No heavy construction machinery should be located on intertidal areas.
Construction	Sediment runoff and siltation	• Implementation of ECM. • Construction activities to be limited to the smallest footprint areas possible. • Storage and stockpiles areas to be identified and approved by NParks. • Construction to be carried out during low tide period as far as possible. • All machinery and equipment to be located on dry land as far as possible. • No heavy construction machinery should be located on intertidal areas.
	Sediment dispersion	• None required
	Transboundary impact	• None required
Operation	No predicted Impact	• None required

Pre-Construction / Construction Phase

The following measures are recommended to manage the identified impacts.

Earth Control Measures (ECM)

An appropriate ECM plan is to be prepared and endorsed by a Qualified Erosion Control Professional (QECP) before the commencement of the construction works. The ECM plan should include:

- Earth control measures are to be implemented by the contractor according to the QECP endorsed plans before starting the work.
- Proper sediment control measures designed to capture and retain silt are to be implemented which may include perimeter cut-off drains, perimeter silt fence, silt traps and silt treatment systems.
- QECP to review ECM plan implementation regularly during construction to ensure that the measures put in place remain effective.
- Regular monitoring of ECM treatment plant performance is to be carried out by Environmental Control Officer (ECO).
- Regular maintenance of ECM is to be carried out.
- After rain events, earth control measures in the field to be inspected and maintained over the course of construction.

Specific Mitigation Measures for Construction within Intertidal Area

- To avoid heavy (noisy) construction work during peak migratory bird season i.e., August to April.
- To limit construction activities to one area at a time to minimise disturbance to shorebirds.
- Construction activities shall be limited to the smallest footprint areas possible.
- Construction to be carried out during low tide period as far as possible to prevent sediment transport.
- All machinery and equipment to be located on dry land as far as possible.
- No heavy construction machinery should be located on intertidal areas.
- All construction personnel should be educated about the sensitive ecological nature of work areas before commencing the work and regular briefing during work should be carried out.
- Earth control measures such as installation of floating silt boom along the coastline should be implemented where necessary.

Other Best Construction Practices

The following best practices should be adopted throughout the construction site:

- Storage and stockpiles areas to be identified and approved by NParks.
- To locate stockpiles as far away as possible from waterways & mudflat areas.
- Excess loose soil and rock to be contained prior to the commencement of the works.

With the adoption of these necessary mitigation measures, the potential impacts on sediment quality during construction activities are considered to be negligible.

Operation Phase

As the Operation phase impacts were assessed to be insignificant, no mitigation measures are proposed. Should major maintenance be undertaken during the operation phase, mitigation measures proposed for the construction phase should apply.

8.5.3 Residual Impacts

RIAM Environmental Scoring for the Residual Impacts

Table 8.7. Environmental Scores of the predicted and residual impacts on site's sediment quality after implementation of mitigation measures listed in Table 8.6

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		– Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	2	-2	2	2	3	-28	Slight Negative	3	-1	2	2	3	-21	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Experiential walk trail • Nature-based Solutions – Intertidal terrace	Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Public Trail Boardwalk	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile B -2, <u>Option 1</u>)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	Sediment runoff and siltation	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• At-grade pedestrian connection	Sediment runoff and siltation	3	-3	2	2	3	-63	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• At-grade pedestrian connection	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Sediment runoff and siltation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Sediment runoff and siltation	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Impact on floating fish farms due to sediment dispersion	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
			Transboundary impact due to sediment dispersion beyond national boundary	2	-1	1	1	1	-6	No Impact	2	-1	1	1	1	-6	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	No predicted Impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

9 NOISE

9.1 Introduction

The main sources of noise in the project area comes from the traffic along Kranji Way road, with relatively constant sources being the activities conducted in the Kranji Industrial Estate (the project area receives fairly high levels of noise disturbance).

Noise can lead to annoyance due to interference with communication and pose disturbance to sensitive receptors (i.e., people working on site, fauna). There is no extensive research done on how noise emissions affect fauna. However, some studies showed that chronic and frequent noise such as traffic noise interferes with animals' abilities to detect important sounds, whereas intermittent and unpredictable noise such as piling, honking from vehicles and machinery and shouting is often perceived as a threat (Francis & Barber, 2013). These disturbances can potentially alter species' behaviour and impair their ability to forage and avoid predation, leading to decreased survivability. Fauna species present within project area were identified as sensitive receptors and disturbance to shorebirds was identified as potential main impact during construction.

Section 9.2 describes the relevant standards for the ambient noise that are applicable to the Project activities, the methodology and results for the baseline noise study. It also described potential noise impacts from construction works, and recommendation for mitigation measures. A quantitative impact assessment approach is being used for assessment of impacts.

9.2 Relevant Environmental Legislation, Guidelines and Standards

The applicable noise limits follow Environmental Protection and Management (Control of Noise at Construction Sites) Regulation 2008 which prescribes the maximum noise levels permissible at construction sites for different periods and types of premises affected. The permissible levels are listed in Table 9.1.

Table 9.1. Maximum permissible noise levels from construction sites (source: SSO)

<table>
<tr><th>Types of affected buildings</th><th>Leq</th><th>7 am – 7 pm</th><th>7–10 pm</th><th>10 pm – 7 am</th></tr>
<tr><td colspan="5">Mondays–Saturdays</td></tr>
<tr><td rowspan="2">(a) Hospitals, schools, institutions of higher learning, homes for aged sick, etc.</td><td>Leq 12 hrs</td><td>60 dB(A)</td><td colspan="2">50 dB(A)</td></tr>
<tr><td>Leq 5 mins</td><td>75 dB(A)</td><td colspan="2">55 dB(A)</td></tr>
<tr><td rowspan="3">(b) Residential buildings located less than 150 m from the construction site</td><td>Leq 12 hrs</td><td>75 dB(A)</td><td colspan="2">-</td></tr>
<tr><td>Leq 1 hr</td><td>-</td><td>65 dB(A)</td><td>55 dB(A)</td></tr>
<tr><td>Leq 5 mins</td><td>90 dB(A)</td><td>70 dB(A)</td><td>55 dB(A)</td></tr>
<tr><td rowspan="2">(c) Buildings other than those in (a) and (b) above</td><td>Leq 12 hrs</td><td>75 dB(A)</td><td colspan="2">65 dB(A)</td></tr>
<tr><td>Leq 5 mins</td><td>90 dB(A)</td><td colspan="2">70 dB(A)</td></tr>
<tr><td colspan="5">Sundays and Public Holidays</td></tr>
<tr><td rowspan="2">(a) Hospitals, schools, institutions of higher learning, homes for aged sick, etc.</td><td>Leq 12 hrs</td><td>60 dB(A)</td><td colspan="2">50 dB(A)</td></tr>
<tr><td>Leq 5 mins</td><td>75 dB(A)</td><td colspan="2">55 dB(A)</td></tr>
<tr><td rowspan="2">(b) Residential buildings located less than 150m from the construction site</td><td>Leq 12 hrs</td><td>75 dB(A)</td><td colspan="2">-</td></tr>
<tr><td>Leq 5 mins</td><td>75 dB(A)</td><td colspan="2">55 dB(A)</td></tr>
</table>

Types of affected buildings	Leq	7 am – 7 pm	7–10 pm	10 pm – 7 am
(c) Buildings other than those in (a) and (b) above	Leq 12 hrs	75 dB(A)	65 dB(A)	
	Leq 5 mins	90 dB(A)	70 dB(A)	

9.3 Baseline Methodology

9.3.1 Sensitive Receptors Identification

Noise can lead to annoyance due to interference with communication or disturbance to receptors involved in leisure activities, as well as sleep disturbance. The effects of noise may vary with the individual receptor and is dependent on many factors such as the activity that the receptor is engaged in, as well as the duration of noise exposure.

The criteria applied for identification of Noise Sensitive Receptor (NSR) are based on EPM (Control of Noise at Construction Sites) Regulation 2008 which are listed below:

a) Hospitals, schools, institutions of higher learning, homes for aged sick, etc.
b) Residential buildings located less than 150 m from the construction site
c) Buildings other than those in (a) and (b) above

The sensitive receptor potentially affected by the proposed project have been identified (Table 9.2) through a combination of desktop study and visual surveys at the project areas.

Table 9.2. List of identified noise-sensitive receptors

ID	Type	Description	Approximate Distance*
NSR1	Workers	People working on the site (e.g., construction workers, consultants)	Within Project Area
NSR2	Flora and Fauna	Flora and fauna living within project area	Within Project Area

*Approximate distance from the nearest project work area

9.4 Baseline Field Survey

Baseline ambient noise levels were monitored at four locations for a week (24 hours x 7 days) duration. Monitoring locations were chosen based on the factors such as sensitive receptor, relevance to construction activity, site access and equipment security. Type 1 noise level meter Rion NL-52 was installed at each location to record the sound pressure level (Leq) with 5-minute sampling intervals for seven consecutive days, yielding the data of Leq 12 hrs, Leq 1 hr, and Leq 5 mins.

Figure 9-1 shows the photographs of on-site monitoring equipment setup and Figure 9-2 the location map of the noise monitoring stations. Table 9.3 summarises the coordinates of monitoring stations, applicable noise limit that corresponds to the receptors the station represents, and short description of the location of each station.

The baseline noise monitoring data are available as **Appendix H** of this report.

Figure 9-1. Photos of the on-site baseline noise monitoring equipment

Table 9.3. Location of baseline noise monitoring stations

Station ID	Monitoring Period	Latitude	Longitude	Noise Limit Type	Description of Location
N1	31 Aug 2022 – 7 Sep 2022	1.438249	103.754646	(c)	Behind Old Kranji Post PCG gate, at the roundabout beside Timmac building
N2	31 Aug 2022 – 7 Sep 2022	1.439121	103.742984	(c)	At the open field beside Kranji Carpark A
N3	8 Sep 2022 – 15 Sep 2022	1.439357	103.737725	(c)	At the open field within Kranji Reservoir Park B, near the Kranji Beach Battle Historic Marker

Figure 9-2. Locations of the baseline noise monitoring stations within project area

9.5 Baseline Results and Discussion

Table 9.4 and Figure 9-3 show the baseline noise level monitored by Station N1, all of which fell within the noise limit of type (c). The full data set can be found in **Appendix H.**

Table 9.4. Summary of the baseline Leq 5 mins noise monitoring results at Station N1

Date	Monitoring Period	Monitored Noise Level (dBA)			Type (c) Noise Limit Leq 5 mins (dB(A))
		Min. Leq 5 mins	Median Leq 5 mins	Max. Leq 5 mins	
Wed, 31/08/2022	7 am – 7 pm	50.7	54.7	75.7	90
	7 pm – 7 am (+1)	44.9	49.2	66.6	70
Thu, 01/09/2022	7 am – 7 pm	44.9	49.2	66.6	90
	7 pm – 7 am (+1)	48.9	51.1	57.8	70
Fri, 02/09/2022	7 am – 7 pm	52.9	56.6	59.5	90
	7 pm – 7 am (+1)	47.5	50.9	61.4	70
Sat, 03/09/2022	7 am – 7 pm	53.3	56.1	59.5	90
	7 pm – 7 am (+1	48.7	50.9	58.6	70
Sun, 04/09/2022	7 am – 7 pm	49.3	53.8	58.3	90
	7 pm – 7 am (+1)	46.8	50.2	60.3	70
Mon, 05/09/2022	7 am – 7 pm	53.5	56.8	81.9	90
	7 pm – 7 am (+1)	48.2	51.2	69.8	70
Tue, 06/09/2022	7 am – 7 pm	53.8	57.0	67.9	90
	7 pm – 7 am (+1)	49.1	51.5	68.4	70

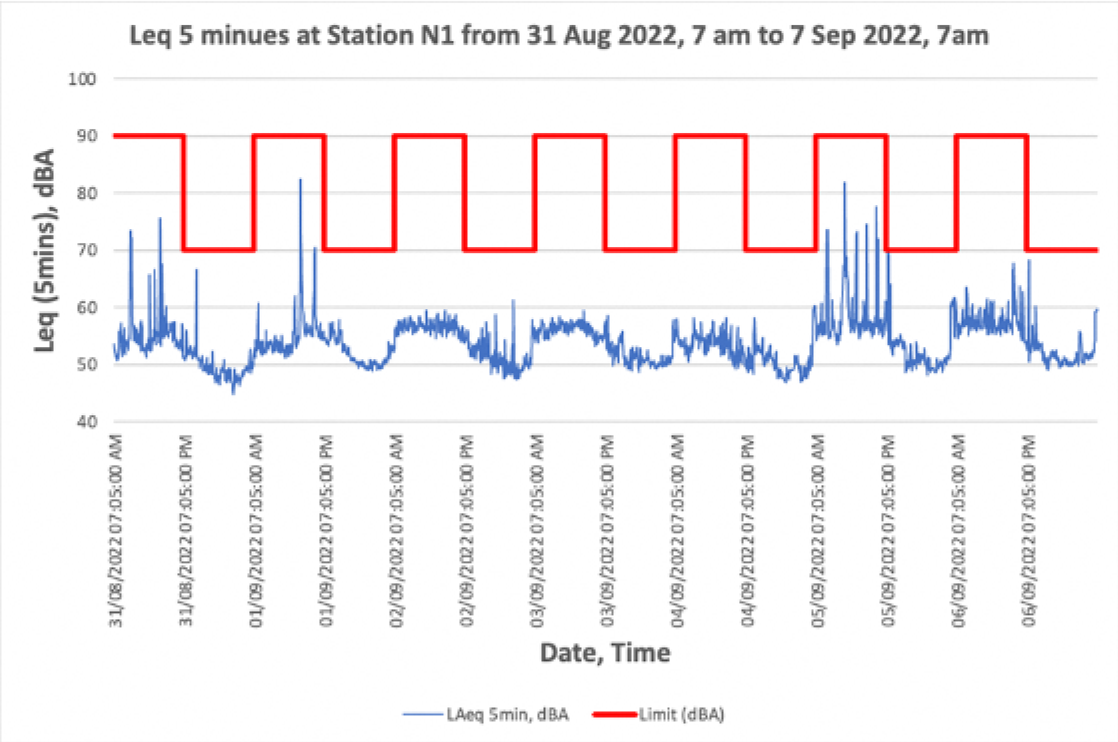


Figure 9-3. Baseline Leq 5 mins monitoring results at Station N1 over one-week period

Table 9.5 and Figure 9-4 show the baseline noise level monitored at Station N2. While the day-time noise levels mostly complied with the noise limit for type (c) aside from 2 instances, which showed minor exceedance during its night-time noise limit. Such records may be attributed to traffic noise along Kranji way during the peak hours.

Table 9.5. Summary of the baseline Leq 5 mins noise monitoring results at Station N2

Date	Monitoring Period	Noise Level (dBA)			Type (a) Noise Limit Leq 5 mins (dBA)
		Min. Leq 5 mins	Median Leq 5 mins	Max. Leq 5 mins	
Wed, 31/08/2022	7 am – 7 pm	53.2	56.2	78.6	90
	7 pm – 7 am (+1)	44.8	48.1	61.0	70
Thu, 01/09/2022	7 am – 7 pm	52.1	55.6	83.9	90
	7 pm – 7 am (+1)	47.2	49.8	61.0	70
Fri, 02/09/2022	7 am – 7 pm	53.4	56.4	59.7	90
	7 pm – 7 am (+1)	46.3	50.1	61.8	70
Sat, 03/09/2022	7 am – 7 pm	52.7	55.9	59.6	90
	7 pm – 7 am (+1	47.6	50.1	58.6	70
Sun, 04/09/2022	7 am – 7 pm	48.3	53.3	58.3	90
	7 pm – 7 am (+1)	45.6	49.3	60.5	70
Mon, 05/09/2022	7 am – 7 pm	53.0	56.6	84.5	90
	7 pm – 7 am (+1)	47.1	50.4	**71.1**	70
Tue, 06/09/2022	7 am – 7 pm	53.4	56.9	68.9	90
	7 pm – 7 am (+1)	48.1	50.7	69.5	70

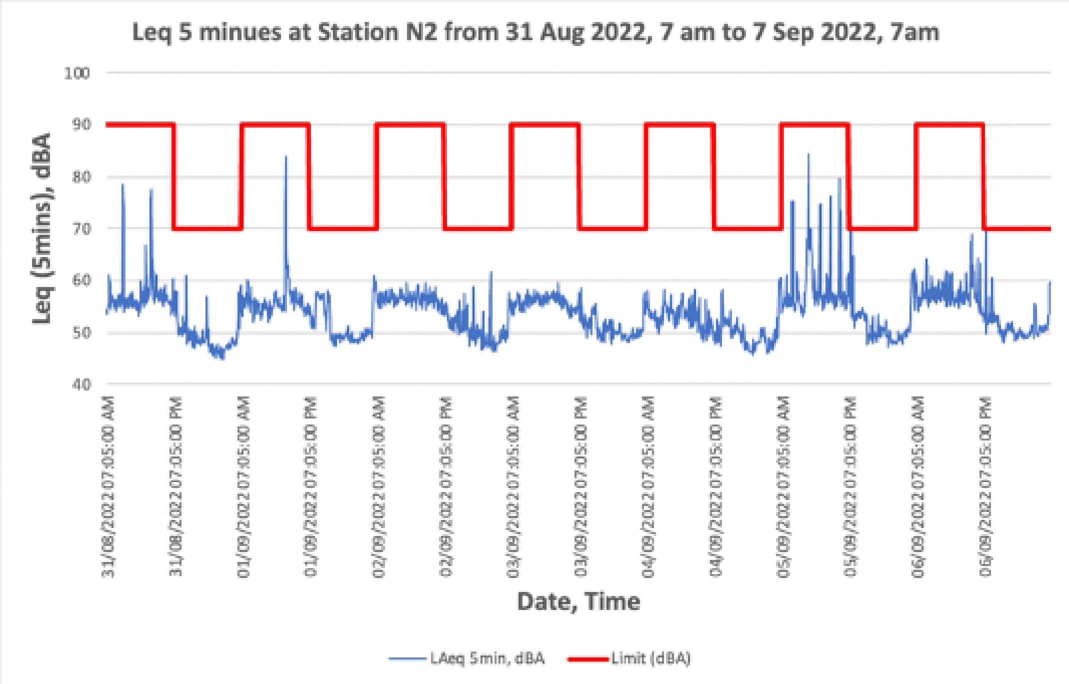


Figure 9-4. Baseline Leq 5 mins monitoring results at Station N2 over one-week period

Table 9.6 and Figure 9-5 show the baseline noise level monitored by Station N3, all of which fell within the noise limit of type (c), aside from occasional spikes, which showed exceedance during its night-time noise limit. Such records may be attributed to traffic noise along Kranji way during the peak hours.

Table 9.6. Summary of the baseline Leq 5 mins noise monitoring results at Station N3

Date	Monitoring Period	Monitored Noise Level (dBA)			Type (c) Noise Limit Leq 5 mins (dBA)
		Min. Leq 5 mins	Median Leq 5 mins	Max. Leq 5 mins	
Thu, 08/09/2022	7 am – 7 pm	47.0	51.0	58.5	90
	7 pm – 7 am (+1)	48.0	51.8	61.4	70
Fri, 09/09/2022	7 am – 7 pm	48.1	52.0	78.4	90
	7 pm – 7 am (+1)	47.8	52.4	59.4	70
Sat, 10/09//2022	7 am – 7 pm	46.6	50.2	53.9	90
	7 pm – 7 am (+1)	46.9	51.6	59.8	70
Sun, 11/09/2022	7 am – 7 pm	45.7	49.8	76.5	90
	7 pm – 7 am (+1	47.0	53.2	60.8	70
Mon, 12/09/2022	7 am – 7 pm	46.6	50.5	80.5	90
	7 pm – 7 am (+1)	45.5	51.0	**78.4**	70
Tue, 13/09/2022	7 am – 7 pm	48.0	51.9	81.5	90
	7 pm – 7 am (+1)	46.7	49.6	**78.9**	70
Wed, 14/09/2022	7 am – 7 pm	50.1	52.8	77.1	90
	7 pm – 7 am (+1)	47.2	49.3	**79.5**	70

Note: Bold shows exceedance

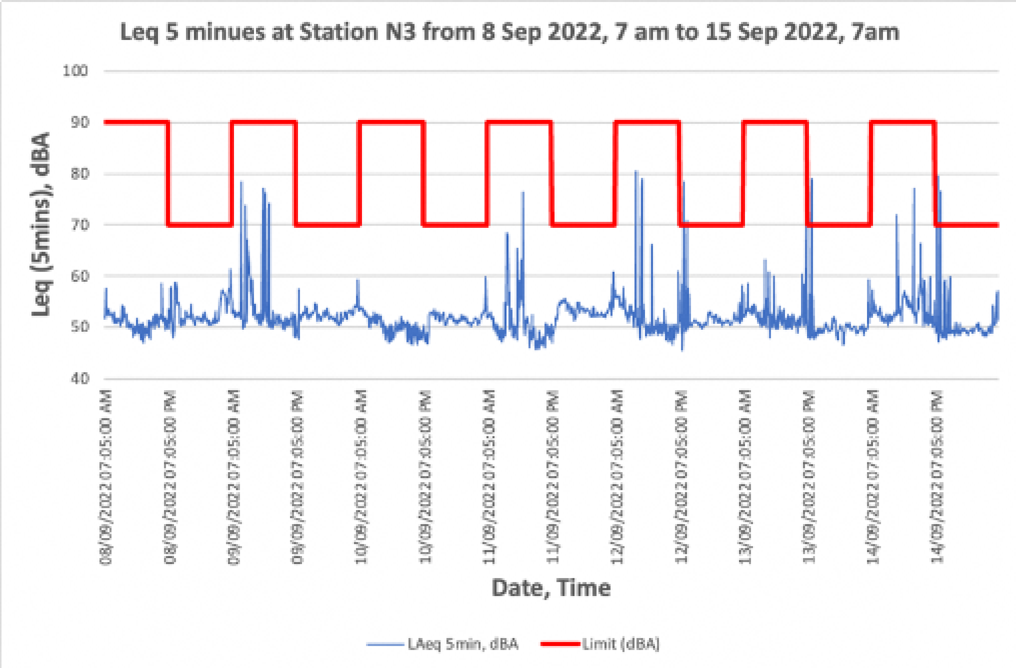


Figure 9-5. Baseline Leq 5 mins monitoring results at Station N3 over one-week period

While most of the noise levels were below the noise limits, it was noted that construction noise was heard at night during fauna surveys. The project area is inhabited by fauna species which may be sensitive to noise. Some of these species, particularly nocturnal species such as bats and frogs, rely on their hearing for movement, communication, and foraging. These species are likely to be impacted by increased noise levels.

The effects of noise on fauna are poorly understood since both stimuli and responses can vary. Nonetheless, Francis and Barber (2013) have found that chronic and frequent noise such as traffic noise interferes with animals' abilities to detect important sounds, and intermittent and unpredictable noise such as piling, honking from vehicles and machinery and shouting is often perceived as a threat. This can alter species' behaviour and impair their ability to forage and avoid predation, leading to decreased survivability.

9.6 Impact Assessment

A construction site can introduce significant new noise sources which must be managed as a minimum to comply with NEA Control of Noise at Construction Sites limits, and potentially at lower limits if sensitive receptors such as migratory shorebirds are nearby. As the design of proposed Nature Park is guided by low-impact design principle as described in Section 2.3.3, the numbers of new site features are kept minimum which will help in keeping the noise impacts localized.

There are no residential communities within the project area. The land adjacent to the proposed Nature Park is managed by JTC and is earmarked for industrial development. These are areas used or intended to be general industry, warehouse, and other public installations. Hence, it is considered that no sensitive human receptors are situated within the project area.

Other than human receptors, the site is also inhabited by many fauna species (see

Chapter 5) which may be sensitive to noise. Specifically, Mandai Mangrove and Mudflat serves as an important site for migratory birds that lies within the East Asian-Australasian Flyway (EAAF). This site is also home to several globally and locally threatened fauna species (**Appendix C**). These habitats are critical feeding and roosting sites for migratory and resident shorebirds as well as other threatened fauna species. Hence, shorebirds and other threatened species are identified as critical noise sensitive receptors. The effects of noise on fauna are poorly understood since both stimuli and responses can vary.

9.6.1 *Predicted Impacts*

RIAM Environmental Scoring for the Predicted Impacts

Table 9.7. Predicted noise impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		– Interlocking rings – Intertidal terrace – Rain garden									
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td></td><td>Operation</td><td>• Public earth trail
• Nature-based Solutions
– Biodegradable coir fibre logs</td><td>• Recreational visitorship
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Disturbance to shorebirds and other fauna species in and around the project area</td><td>5</td><td>-2</td><td>3</td><td>2</td><td>2</td><td>-70</td><td>Minor Negative</td></tr>
<tr><td rowspan="6">Public Trail (Profile B -1)</td><td rowspan="2">Pre-construction</td><td rowspan="2">• Construction site access
• Construction site boundary
• Storage space and working space</td><td rowspan="2">• Vegetation clearance</td><td>Disturbance to shorebirds and threatened fauna species</td><td>5</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-60</td><td>Minor Negative</td></tr>
<tr><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td rowspan="3">Construction</td><td rowspan="3">• Boardwalk (using existing PCG fence footing as foundation)</td><td rowspan="3">• Earthworks - Slope cut at gradient of 1:5
• Land and intertidal based development</td><td>Disturbance to shorebirds and threatened fauna species</td><td>5</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-70</td><td>Minor Negative</td></tr>
<tr><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-28</td><td>Slight Negative</td></tr>
<tr><td>Disturbance to construction workers due to exposure to high noise levels of construction activities</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-14</td><td>Slight Negative</td></tr>
<tr><td>Operation</td><td>• Public Trail Boardwalk</td><td>• Recreational visits
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Disturbance to shorebirds and other fauna species in and around the project area</td><td>5</td><td>-2</td><td>3</td><td>2</td><td>2</td><td>-70</td><td>Minor Negative</td></tr>
<tr><td rowspan="2">Public Trail (Profile B -2, <u>Option 1)</u></td><td rowspan="2">Pre-construction</td><td rowspan="2">• Construction site access
• Construction site boundary
• Storage space and working space</td><td rowspan="2">• Earthworks
• Vegetation clearance</td><td>Disturbance to shorebirds and threatened fauna species</td><td>5</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-60</td><td>Minor Negative</td></tr>
<tr><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Guided Trail (Profile	Pre-constr	• Construction site access	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="6"></td><td></td><td>• Construction site boundary
• Storage space and working space</td><td></td><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td rowspan="3">Construction</td><td rowspan="3">• Earth Trail (1.5m wide) at edge of back mangrove</td><td rowspan="3">• Vegetation clearance
• Earthworks-backfilling
• Land and intertidal based development</td><td>Disturbance to shorebirds and threatened fauna species</td><td>5</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-70</td><td>Minor Negative</td></tr>
<tr><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-28</td><td>Slight Negative</td></tr>
<tr><td>Disturbance to construction workers due to exposure to high noise levels of construction activities</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-14</td><td>Slight Negative</td></tr>
<tr><td>Operation</td><td>• Earth Trail (1.5m wide) at edge of back mangrove</td><td>• Recreational visits
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Disturbance to shorebirds and other fauna species in and around the project area</td><td>5</td><td>-2</td><td>3</td><td>2</td><td>2</td><td>-70</td><td>Minor Negative</td></tr>
<tr></tr>
<tr><td rowspan="5">Guided Trail (Profile D, Option 2)</td><td rowspan="2">Pre-construction</td><td rowspan="2">• Construction site access
• Construction site boundary
• Storage space and working space</td><td rowspan="2">• Vegetation clearance</td><td>Disturbance to shorebirds and threatened fauna species</td><td>5</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-60</td><td>Minor Negative</td></tr>
<tr><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td rowspan="3">Construction</td><td rowspan="3">• Elevated Boardwalk (1.5m wide) in back mangrove zones</td><td rowspan="3">• Vegetation clearance
• Earthworks-backfilling
• Land and intertidal based development</td><td>Disturbance to shorebirds and threatened fauna species</td><td>5</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-70</td><td>Minor Negative</td></tr>
<tr><td>Disturbance to other fauna species</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-28</td><td>Slight Negative</td></tr>
<tr><td>Disturbance to construction workers due to exposure to high noise levels of construction activities</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-14</td><td>Slight Negative</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation	Disturbance to threatened fauna species	3	-2	2	2	2	-36	Slight Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Disturbance to threatened fauna species	3	-2	2	2	3	-42	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative
				Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Disturbance to fauna species in and around the project area	3	-2	3	2	2	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Boundary markers	Pre-construction	• Markers made up of rows of Bakau poles	• Boundary marker installation	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative
				Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	• Maintenance works	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	2	2	2	-60	Minor Negative

Pre-construction / Construction Phase

The baseline noise surveys showed that ambient noise levels in the project area is within NEA limits for construction site. However, usage of construction equipment during construction phase is likely to increase noise levels within project area which can affect critical noise sensitive receptors i.e. shorebirds and threatened fauna species.

Airborne noise levels generated by construction equipment will vary depending on the type of equipment (i.e. excavator, piling rig), condition of equipment, and duration of operation (i.e. long term or intermittent). The noise levels will also be affected by noise characteristics such as continuous or intermittent noise as well as by distance, locations (i.e. stationary or mobile sources) and variations in the power of the equipment.

The following routine construction activities are identified as potential sources of noise during the pre-construction and construction phases of proposed Nature Park:

- Site clearing, earth-moving/earthworks, and general construction activities (e.g. clearing and preparation, excavation, backfill, compaction, spoil handling and transport, building of permanent structures);
- Materials handling (delivery, unloading and use of construction aggregates etc.);
- Vehicle movements for the equipment, materials, and personnel movement in and out of construction work areas; and
- Use of stationary and mobile equipment such as pile drivers, excavators etc. leading to variable and sporadic noise levels, typically repeating over time.

Main sources of noise emissions during construction activities associated with different project components and assessment of likely noise impacts are presented in Table 9.8 and described below.

Table 9.8. Identification of potential noise impacts of proposed Infrastructure development at project area

<table>
<tr><th>Location</th><th>Planned Infrastructure</th><th>Planned Activities</th><th>Potential Noise Sources</th><th>Potential Impact</th></tr>
<tr><td rowspan="3">Key Nodes</td><td>Kranji Reservoir Park</td><td rowspan="2">Site clearance, Excavation, Piling, Structure work, Nature-based solutions</td><td rowspan="3">• Mini Excavator
• Compactor
• Generator
• Lorry crane
• Haul truck
• Piling rig</td><td rowspan="3">Disturbance to Shorebirds and threatened fauna species</td></tr>
<tr><td>Sungei Pang Sua Pavilion</td></tr>
<tr><td>Sungei Kranji Pavilion</td><td>Site clearance, Excavation, Piling, Structure work</td></tr>
<tr><td rowspan="3">Coastal trails</td><td>Public Trail</td><td rowspan="3">Site clearance, Excavation, Earthworks and Trail construction</td><td rowspan="3">• Compactor
• Generator
• Mini Excavator</td><td rowspan="3">Disturbance to shorebirds and other animals</td></tr>
<tr><td>Guided Trail</td></tr>
<tr><td>Sungei Pang Sua Trail</td></tr>
</table>

As assessed above, the potential sources of noise impact would likely be from usage of powered mechanical equipment, heavy machinery, and vehicles during the construction

of the key nodes. No significant noise impact is expected from construction of the coastal trails along mudflat area due to limited scale of construction work.
The increase in noise levels during construction phase may impact the species inhabiting the project area and surrounding environment i.e. specifically mudflats along guided trail. The frequency and loudness of noise produced by pre-construction and construction works (i.e. mainly piling work for lookout decks) may interfere with the communication calls of certain animal groups, particularly birds. A large number of birds use calls to communicate between members for the purposes of territory marking, courtship, mating, and predator alarms. Increased environmental noise may mask the birds' song and impact their courting (Swaddle & Page, 2007). Also, birds use auditory signals in species distinction, advertisement of food sources, and flock cohesion. As noted earlier in section 5.6, number of piles is expected to be minimal per structure.

Arthropod abundance may also be impacted by the noise pollution due to cascading effects within the ecological network, as well as direct impacts for insects such as crickets that rely on audio signals for mating. This could also result in indirect negative impacts on plants that rely on these organisms for pollination or seed dispersal or have prey-predator relationships with other impacted species (Bunkley et al., 2017).

Particular attention needs to be paid to nocturnal animals given that this group is habituated to even lower noise levels than diurnal animals. Many nocturnal animals rely more on other senses besides sight to navigate, and increased noise levels may impact their movement and other activities. For example, insectivorous bats rely on sound to locate and catch their prey. This process might be affected by night-time construction noise, which could fall within the spectrum of their auditory signals (Bunkley et al., 2017). However, it is anticipated that no night-time construction activity will take place which is likely to keep this impact at minimum.

On the other hand, the noise from on-site construction works may also impact construction personnel on site. Prolonged exposure to high noise levels is known to be detrimental to human health and well-being, with short-term deafness as one of the possible impacts. However, these can be easily mitigated by proper mitigation measures.

As can be seen from above Table 9.8, disturbance to shorebird from noise generated by construction activity is identified as the main critical impact. However, achieving applicable maximum permissible noise level for construction work solely based on regulatory requirements may not be adequate to address impact on shorebirds. Hence, literature research is carried out to suggest conservative noise limits as described below which can be considered for construction phase activities.

Various studies have put forward recommended guidelines stating that continuous construction noise levels should be kept below 60-70 dB(A), as birds may be able to get accustomed to ambient noise below these levels (Cutts & Allen, 1999; Dooling & Popper, 2007). In order to prevent their vocal signals from being masked by ambient noise, birds may employ short term behavioural strategies, such as scanning (head turning), raising vocal output and changing singing location, which can increase vocal signal level of about 10 dB (Dooling & Popper, 2007).

Studies also suggest that sudden irregular noise above 50 dB(A) should be avoided as it causes maximum disturbance to birds, which includes them flying away and leaving the area altogether (Cutts & Allen, 1999). In order to protect roosting birds, disturbance events should be restricted at and around high tide as birds begin to roost, as roosting birds have shown to be more sensitive to disturbance (Cutts & Allen, 1999).

Many studies have shown a lower range of thresholds levels for noise, from 45-56 dB(A), whereby above this threshold of noise, bird densities decline (Rejinen, Foppen, & Meeuwsen, 1996; Hirvonen, 2001; Waterman et al., 2004; Reijnen & Foppen, 2006; Patón et al., 2012; Bottalico et al., 2015). Since bird species rely heavily on vocal cues to attract mates and defend territories, the presence of noise could result in stress and disruption of vocal communication, ultimately contributing to low reproduction and high emigration rates (Reijnen & Foppen, 2006).

It has also been suggested that the threshold which marks the difference between rare and common bird species is around 50 dB, with rare species appearing below the threshold and common species appearing above the threshold (Patón et al., 2012). This is especially relevant here, as the Mandai Mangrove and Mudflat serve as an important feeding ground for both locally and globally threatened bird species, as well as both resident breeders and passage migrants/winter visitors. Furthermore, several studies have shown lower threshold levels for noise in wader birds (Hirvonen, 2001; Waterman et al., 2004) further emphasizing a need for conservative noise limits at the mudflats. Considering all research findings, the distance of planned construction activities from mudflat feeding grounds, and practicality of achieving the limit during construction, average noise levels should be maintained below 60 dB(A) for the protection of shorebirds.

Further, to reduce impact on migratory birds, the heavy construction activities (i.e., piling) should be avoided during peak migratory season (i.e. August to April) to prevent disturbances to these species.

The noise emissions from the development of JTC industrial areas, which run parallel to Nature Park site, may cause cumulative negative impacts to the ambient noise levels, if that constructions happen simultaneously with Nature Park development.

Based on the above assessment, the potential impacts on the noise levels of the site are deemed to be moderate, localised, and temporary. Considering the presence of critical habitats within the project area, appropriate mitigation measures are required to further mitigate these impacts.

Operation Phase

Operation phase activities of Nature Park will include recreational & educational use of the Nature Park by the general public and periodic maintenance of the visitor facilities, such as the Pang Sua entrance, lookout decks, trails, and bird hides. The increased human presence due to the development of the Nature Park within the project area can be controlled to prevent any disturbance to migratory birds. NParks typically includes signboards in their parks to educate visitors of the Do’s and Don’ts within the parks. Such signboards could be placed in the proposed park to remind visitors to keep their noise levels low so that wildlife will not be impacted. It is expected that these reminders will help to educate visitors and assist in reducing any impact on the overall biodiversity of the project area. As such, these operation phase activities are not expected to generate significant noise impacts.

If there is major maintenance work required for park infrastructure which may create the possibility of short-term operation phase impacts. However, it is expected that such impacts will only last for the duration of the maintenance works and would be limited in scope. As such, usage of heavy machinery should be avoided as far as possible. Overall, the potential for long term operation phase impacts is negligible, assuming that the necessary precautions have been undertaken to prevent such impacts.

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

Overall, the predicted impacts are expected to be mainly Minor Negative across all locations except for locations with heavy construction and/or in sensitive areas (i.e., mangroves and intertidal habitats). This is especially so during the pre-construction and construction phases. Whereas, during the operation phase the predicted impacts are Slight Negative.

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc.) are expected. The predicted impacts from these works would mostly be the disturbances that would occur to fauna in the area and the workers who are on site. Most of the planned activities would not cause much noise disturbance when compared to the baseline, except for the piling activities. The areas with the piling activities would then have a higher score that would be in the Minor Negative range while the remaining would be in the Slight Negative range.

During construction phase, heavy construction works (i.e., piling, demolition and hacking and removing of remnant concrete structures) will be carried out especially in the planned infrastructure areas i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion along the coastline. The main noise concerns arising from these works are the disturbance to the fauna in the area. The construction activities would make use of machinery that would produce lots of noise, especially during excavation and piling. Both of which would influence the noise levels negatively due to the high noise levels. This would then have a score that would be in the Minor Negative range.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

9.6.2 Mitigation Measures

Table 9.9. Noise impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Disturbance to shorebirds and threatened fauna species	• Avoid the peak migratory bird season (i.e. August to April) for heavy or noisy construction works • The construction work is to be carried out during daytime only (i.e. 8AM to 6PM). Night works are to be avoided as far as possible. • Installation of at least 4 m high noise barrier between the noise sources and the mudflats. • Where a noise barrier is no longer practical, a noise blanket screen can be used to reduce the noise travelling to the mudflats.
	Disturbance to other fauna species	• Contractor to comply with "SS 602 – Code of Practice for Noise Control on Construction and Demolition Sites". • Contractor to prepare a Noise Management Plan • Erection and maintenance of noise barriers around construction work areas • Quieter equipment and vehicles with low noise levels to be used • All pile driving shall be carried out by a recognized noise reducing system. • Restriction of vehicular speed on-site
Construction	Disturbance to shorebirds and threatened fauna species	• Avoid the peak migratory bird season (i.e. August to April) for heavy or noisy construction works • The construction work is to be carried out during daytime only (i.e. 8AM to 6PM). Night works are to be avoided as far as possible. • Installation of at least 4 m high noise barrier between the noise sources and the mudflats. • Continuous noise monitoring is to be carried out at construction areas as close as possible to the mudflats to determine if generated noise is within the suggested noise limit (i.e. 65 dBA) for shorebirds. • To stop work if the monitored noise levels from work areas along the mudflats exceeds the suggested noise limit to review if further controls are needed.
	Disturbance to other fauna species	• Contractor to comply with "SS 602 – Code of Practice for Noise Control on Construction and Demolition Sites". • Contractor to prepare a Noise Management Plan • Erection and maintenance of noise barriers around construction work areas • Quieter equipment and vehicles with low noise levels to be used • All pile driving shall be carried out by a recognized noise reducing system.

Phase	Impact Component	Recommended Mitigation Measures
		• Restriction of vehicular speed on-site
	Disturbance to construction workers due to exposure to high noise levels of construction activities	• Personnel are to wear appropriate Personal Protective Equipment (PPE) at all times while in the construction site • Quieter equipment and vehicles with low noise levels to be used
Operation	Disturbance to shorebirds and other fauna species in and around the project area	• Implementation of NParks visitors' rules & regulations to educate visitors

Pre-construction / Construction Phase

Specific Mitigation Measures

These mitigation measures are specifically proposed to reduce noise impact on migratory and resident shorebirds & other threatened fauna inhabiting the Mandai Mangrove and Mudflat and mangrove area.

- Avoid heavy or noisy construction work (i.e., Piling) during the peak migratory bird season (i.e. August to April) along the areas (i.e. shorebird trail) facing the mudflats.
- The construction work is to be carried out during daytime only (i.e., 8AM to 6PM). Night works are to be avoided.
- Prior to commencement of construction works, install an at least 4 m high noise barrier between the work areas and the sensitive habitats (i.e., mudflats and mangroves).
- For construction works approaching or involving the intertidal zone (i.e., mainly backfill areas and coastal protection revetment work), where a noise barrier is no longer practical, a noise blanket screen can be used to reduce the noise travelling to the mudflats.
- Continuous noise monitoring is to be carried out at construction areas as close as possible to the mudflats to determine if generated noise is within the suggested noise limit (i.e., 65 dBA) for shorebirds.
- If the monitored noise levels from work areas along the mudflats exceeds the suggested noise limit, then construction activities should stop to review if further controls are needed.
- All construction personnel should be educated about the sensitive ecological nature of work areas before commencing the work and regular briefing during work to be carried out.

General Best Practices

Good site practices and noise management can be expected to considerably reduce the pre-construction and construction noise impact on the sensitive receptors.

- The Contractor shall comply with "SS 602 – Code of Practice for Noise Control on Construction and Demolition Sites".
- The Contractor should prepare a Noise Management Plan covering site utilisation plan, sequence of work and construction methods involved, indicating anticipated noise levels accompanying each type of activity and scheduling of works demonstrating consideration of noisy activities.
- All compressors, generators, welding sets shall be of sound reduced models fitted with properly lined and sealed acoustic covers which shall be kept closed whenever the machines are in use and all ancillary pneumatic percussive tools shall be fitted with mufflers or silencers of the type recommended by the manufacturer.
- Where alternatives are available, only equipment and vehicles that emit lower noise levels are to be used.
- All pile driving shall be carried out by a recognised noise reducing system.
- Hacking works to be localised as much as possible.
- Care shall be taken when loading or unloading vehicles, dismantling scaffolding

or moving materials to reduce impact noise.

- Intermittently used vehicles and machinery are to be shut down between work periods or be throttled down to a minimum noise level emission.
- Generators are to be placed away from coastal edge.
- Where possible, vehicles and machinery known to emit high levels of noise in one direction are to be orientated away from sensitive receptors and scheduled for operation during the least sensitive parts of the day (i.e., late morning to late afternoon).
- Only well-maintained machineries should be operated on-site and should be serviced regularly during construction.
- Restriction of vehicular speed on-site.
- Noise level monitoring throughout all phases to ensure that the construction noises remain within acceptable limits.

The following measure is to be implemented specifically for human receptors:

- Personnel are to wear appropriate Personal Protective Equipment (PPE) all the time while on the construction site.

Effective implementation of these mitigation measures should be able to reduce the noise impacts from project on sensitive receptors to acceptable levels.

Operation Phase

With NParks' signboards reminding visitors of proper behaviour in a Nature Park, the direct impacts were assessed to be insignificant, and therefore, no mitigation measures are proposed. Should major repairs be undertaken during the operation phase, mitigation measures proposed for the construction phase will apply.

9.6.3 Residual Impacts

The residual impacts were evaluated using the RIAM method with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in the band of Slight Negative.

During pre-construction phase, the main concern across most locations is disturbance to shorebirds and threatened fauna species. Mitigation measure such as avoiding construction works during peak migratory bird season and to only carry out works in the daytime will help to reduce the magnitude of disturbance to shorebirds, thus reducing the environment score from Minor Negative to Slight Negative range band.

During construction phase, on top of disturbance to shorebirds, other predicted impacts across many locations include disturbance to construction workers due to exposure to high noise levels of construction activities. Following mitigation measures detailed in Section 9.6.2, the environment score of these predicted impacts can be reduced from Minor Negative to Slight Negative range. For example, while the environment score of disturbance to shorebirds and threatened fauna species was assessed to be in Minor Negative range prior to mitigation, mitigation measures such as installation of high noise barriers and to stop work along mudflats if it exceeds the suggested noise limits can reduce the magnitude of impact of disturbance to shorebirds and threatened fauna species such that the final residual environment score are reduced to Slight Negative range.

Similar to the pre-construction and construction phase, during operation phase, the main concern across most locations is the disturbance to shorebirds and other fauna species. Mitigation measures such as educational signs, implementation of visitors' rules and regulations can help reduce the magnitude of impact such that the residual environment score are reduced from Minor Negative to Slight Negative range.

RIAM Environmental Scoring for the Residual Impacts

Table 9.10. Environmental Scores of the predicted and residual impacts on site's noise after implementation of mitigation measures listed in Table 9.9

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Public Trail Boardwalk	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Geo bags	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile C)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Elevated Boardwalk	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Guided Trail (Profile D, Option 1)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• At-grade pedestrian connection	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	3	-70	Minor Negative	5	-1	2	2	3	-35	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative
	Operation	• At-grade pedestrian connection	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	3	2	2	-70	Minor Negative	5	-1	3	2	2	-35	Slight Negative
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to threatened fauna species	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Disturbance to threatened fauna species	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	3	-28	Slight Negative	2	-1	2	2	3	-14	Slight Negative
			Disturbance to construction workers due to exposure to high noise levels of construction activities	1	-2	2	2	3	-14	Slight Negative	1	-1	2	2	3	-7	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Disturbance to fauna species in and around the project area	3	-2	3	2	2	-42	Minor Negative	3	-1	3	2	2	-21	Slight Negative
Boundary markers	Pre-construction	• Markers made up of rows of Bakau poles	Disturbance to shorebirds and threatened fauna species	5	-2	2	2	2	-60	Minor Negative	5	-1	2	2	2	-30	Slight Negative
			Disturbance to other fauna species	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	Disturbance to shorebirds and other fauna species in and around the project area	5	-2	2	2	2	-60	Minor Negative	5	-2	2	2	2	-30	Slight Negative

10 AMBIENT AIR QUALITY

10.1 Introduction

The main air pollution in Singapore comes from stationary sources (e.g., power stations, industries, and refineries) and mobile sources (e.g., motor vehicles and visiting marine vessels). The NEA monitors air quality in Singapore and publishes the 24-hour Pollutant Standards Index (PSI) reading that provides an indication of air quality at any point of time.

Deteriorated ambient air quality can pose negative impacts on sensitive receptors located near emission generating activities (i.e., construction workers) as well as biodiversity. For example, particulate matter settling on leaves may cause leaf injury thought abrasion or chemical interactions. Dust particles entering stomata may also reduce photosynthetic functions. Dust landing directly on soil may affect nutrient cycling processes (Grantz et al., 2003).

The existing literature on the effect of construction dust on birds in particular is limited, with most studies examining effects of air pollution on wildlife in general, rather than the effect of construction dust on birds specifically. Since the avian respiratory system, unlike the mammalian respiratory system, is characterized by unidirectional airflow and cross-current gas exchange, this makes them more susceptible to high concentrations of pollutants in the air. Studies have shown that birds exposed to urban air pollution may exhibit a build-up of cellular and mineral debris leading to characteristic conditions of pneumonia (Ejaz et al., 2014).

During the baseline surveys, there were no stationary sources of air pollution observed within the project area. The nearest source of air pollution outside project area includes movement of vehicles within the area and exhaust emissions from vehicular traffic along Kranji way, Kranji Loop and Kranji Road. The project area’s natural setting, and the presence of forested area contribute to the relatively good prevailing air quality of the area.

The Section 8.2 describes the relevant standard for the ambient air quality that are applicable to the Project activities, the methodology and results for the baseline ambient air quality study. It also described potential air quality impacts from construction works, and recommendation for mitigation measures. A qualitative impact assessment approach is being used for assessment of impacts.

10.2 Relevant Environmental Legislation, Guidelines and Standards

Singapore ambient air quality targets are provided in Table 10.1.

Table 10.1. Applicable Singapore Ambient Air Quality Targets **(NEA, 2021)**

	Long Term Targets (WHO Final)
Particulate Matter (PM_{10})	Annual mean: 20 µg/m^3 24-hour mean: 50 µg/m^3
Particulate Matter ($PM_{2.5}$)	Annual mean: 10 µg/m^3 24-hour mean: 25 µg/m^3
Sulphur Dioxide (SO_2)	24-hour mean: 20 µg/m^3
Carbon Monoxide (CO)	8-hour mean: 10 mg/m^3 1-hour mean: 30 mg/m^3
Ozone (O_3)	8-hour mean: 100 µg/m^3
Nitrogen Dioxide (NO_2)	Annual mean: 40 µg/m^3 1-hour mean: 200 µg/m^3

10.3 Baseline Methodology

10.3.1 Sensitive Receptors Identification

The Air Sensitive Receptor (ASR) potentially affected by the proposed project have been identified (Table 10.2) through a combination of desktop study and visual surveys within the project area.

Table 10.2. List of identified air-sensitive receptors

ID	Type	Description	Approximate Distance*
ASR1	Workers	People working on the site (e.g., construction workers, consultants)	Within Project Area
ASR2	Flora and Fauna	Flora and fauna living within project area	Within Project Area
ASR3	Recreation	People visiting Kranji Recreation Centre	120m from Project Area
ASR4	Residential building	People at Kranji Lodge 1	6500m from Project Area

*Approximate distance from the nearest project work area

10.3.2 Baseline Field Survey

The baseline ambient air quality monitoring was carried out at three (3) locations for a week (24 hours x 7 days). The monitoring locations were chosen based on the factors such as location of sensitive receptors, relevance to project activity, site access and equipment security. Six (6) parameters were monitored: Particulate Matters with diameters of less than 10 and 2.5 microns (PM_{10} and $PM_{2.5}$), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Ozone (O_3).

The monitoring was conducted using the Oceanus OC-1000 Portable Multi Gas Detector. It is powered by rechargeable lithium battery with high capacity and equipped with an internal sampling pump fitted with six sensors to detect the gas composite concentration. The baseline data were recorded at 10-minute intervals, with their averages calculated and compared with respective values in the Singapore Ambient Air Quality Targets (NEA, 2021).

Table 10.3 lists down the coordinates of monitoring stations and short description of the location of each station while Table 10.1 summarises the applicable ambient air quality target values in Singapore (NEA, 2021). Figure 10-1 shows the location map of monitoring stations and Figure 10-2 shows photographs of the on-site monitoring equipment. The baseline ambient air quality monitoring data are available as **Appendix I.**

Table 10.3. Location of ambient air quality monitoring stations

Station	Monitoring Period	Latitude	Longitude	Description of Location
A1	31 Aug– 6 Sep 2022	1.438249	103.754646	Behind Old Kranji Post PCG gate, a the roundabout beside Timmac building
A2	31 Aug– 6 Sep 2022	1.439121	103.742984	At the open field beside Kranji Carpark A
A3	31 Aug– 6 Sep 2022	1.439357	103.737725	At the open field within Kranji Reservoir Park B, near the Kranji Beach Battle Historic Marker

Figure 10-1. Locations of baseline ambient air quality monitoring stations within project area

Figure 10-2. On-site baseline ambient air quality monitoring equipment

10.4 Baseline Results and Discussion

The baseline air quality monitoring results generally complied with Singapore Ambient Air Quality Targets (NEA, 2021), except some readings for 24-hour PM2.5 mean (µg/m^3) and one reading for the maximum hourly NO_2 mean (µg/m^3). Nonetheless, subsequent readings for the remainder of monitoring complied with the targets. The data is presented in the following sections.

10.4.1 Baseline Results at Station A1

At Station A1, the 24-hour PM2.5 mean (µg/m^3) exceeded the long-term target on four days of the week, of which the maximum was 40.6 µg/m^3. There was also one day (1st September 2022) in which the maximum hourly NO_2 mean had slightly exceeded the long-term target. The target is 200 µg/m^3 while the maximum hourly NO_2 mean was 205.54 µg/m^3. Such records may be attributed to heavy vehicle traffic along Kranji way during the peak hours.

Table 10.4. 24-hour mean of PM_{10}, $PM_{2.5}$, and SO_2 levels at Station A1

Monitoring Period	24-hour PM_{10} mean (µg/m^3)	24-hour $PM_{2.5}$ mean (µg/m^3)	24-hour SO_2 mean (µg/m^3)
Wednesday, 31/08/2022	26.2	21.3	0.45
Thursday, 01/09/2022	44.3	**37.5**	3.83
Friday, 02/09/2022	47.8	**38.5**	1.24
Saturday, 03/09/2022	22.9	17.2	0.06
Sunday, 04/09/2022	28.2	23.8	0.05
Monday, 05/09/2022	44.5	**38.1**	2.30
Tuesday, 06/09/2022	47.9	**40.6**	4.61
Long Term Target (µg/m^3)	**50.00**	**25.00**	**20.00**

Note: **Bold** indicates exceedance

Table 10.5. 8-hour and maximum daily hourly mean of CO level at Station A1

Monitoring Period	Duration	8-hour CO mean (mg/m^3)	Max. hourly CO mean (mg/m^3)
Wednesday, 31/08/2022	00:00–08:00	0.37	0.78
	08:00–16:00	0.39	
	16:00–00:00	0.24	
Thursday, 01/09/2022	00:00–08:00	0.45	0.75
	08:00–16:00	0.28	
	16:00–00:00	0.44	
Friday, 02/09/2022	00:00–08:00	0.62	0.74
	08:00–16:00	0.28	
	16:00–00:00	0.21	
Saturday, 03/09/2022	00:00–08:00	0.23	0.58
	08:00–16:00	0.23	
	16:00–00:00	0.16	
Sunday, 04/09/2022	00:00–08:00	0.32	0.49
	08:00–16:00	0.29	
	16:00–00:00	0.28	
Monday, 05/09/2022	00:00–08:00	0.48	0.60
	08:00–16:00	0.36	
	16:00–00:00	0.42	
Tuesday, 06/09/2022	00:00–08:00	0.64	0.93
	08:00–16:00	0.49	
	16:00–00:00	0.41	
Long Term Target (mg/m^3)		**10.00**	**30.00**

Note: **Bold** indicates exceedance

Table 10.6. 8-hour average of O_3 and maximum daily hourly average of NO_2 at Station A1

Monitoring Period	Duration	8-hour O_3 mean ($\mu g/m^3$)	Max. hourly NO_2 mean ($\mu g/m^3$)
Wednesday, 31/08/2022	00:00–08:00	4.76	92.71
	08:00–16:00	22.41	
	16:00–00:00	32.51	
Thursday, 01/09/2022	00:00–08:00	3.20	**205.54**
	08:00–16:00	21.47	
	16:00–00:00	7.54	
Friday, 02/09/2022	00:00–08:00	2.78	105.16
	08:00–16:00	13.06	
	16:00–00:00	6.79	
Saturday, 03/09/2022	00:00–08:00	5.40	83.83
	08:00–16:00	22.97	
	16:00–00:00	28.01	
Sunday, 04/09/2022	00:00–08:00	8.29	89.31
	08:00–16:00	10.80	
	16:00–00:00	6.88	
	00:00–08:00	1.91	156.14

Monitoring Period	Duration	8-hour O_3 mean ($\mu g/m^3$)	Max. hourly NO_2 mean ($\mu g/m^3$)
Monday, 05/09/2022	08:00–16:00	10.12	
	16:00–00:00	4.85	
Tuesday, 06/09/2022	00:00–08:00	3.07	179.92
	08:00–16:00	20.40	
	16:00–00:00	27.02	
Long Term Target ($\mu g/m^3$)		**100.00**	**200.00**

Note: **Bold** indicates exceedance

10.4.2 Baseline Results at Station A2

At Station A2, the 24-hour $PM_{2.5}$ mean (µg/m3) exceeded the long-term target on four days of the week, of which the maximum was 35.2 $\mu g/m^3$. It is noted that the four days on which there was exceedance at Station A2 are the same four days as at Station A1. All other parameters measured at Station A2 were below the long-term targets.

Table 10.7. 24-hour mean of PM_{10}, $PM_{2.5}$, and SO_2 levels at Station A2

Monitoring Period	24-hour PM_{10} mean ($\mu g/m^3$)	24-hour $PM_{2.5}$ mean ($\mu g/m^3$)	24-hour SO_2 mean ($\mu g/m^3$)
Wednesday, 31/08/2022	22.5	18.6	1.75
Thursday, 01/09/2022	25.0	**29.5**	3.30
Friday, 02/09/2022	37.7	**32.2**	2.23
Saturday, 03/09/2022	14.9	11.1	0.22
Sunday, 04/09/2022	26.7	21.8	0.18
Monday, 05/09/2022	37.8	**31.5**	1.51
Tuesday, 06/09/2022	42.1	**35.2**	10.26
Long Term Target ($\mu g/m^3$)	**50.00**	**25.00**	**20.00**

Note: **Bold** indicates exceedance

Table 10.8. 8-hour and maximum daily hourly mean of CO level at Station A2

Monitoring Period	Duration	8-hour CO mean (mg/m^3)	Max. hourly CO mean (mg/m^3)
Wednesday, 31/08/2022	00:00–08:00	0.37	0.81
	08:00–16:00	0.39	
	16:00–00:00	0.25	
Thursday, 01/09/2022	00:00–08:00	0.42	0.71
	08:00–16:00	0.31	
	16:00–00:00	0.40	
Friday, 02/09/2022	00:00–08:00	0.60	0.81
	08:00–16:00	0.25	
	16:00–00:00	0.20	
Saturday, 03/09/2022	00:00–08:00	0.22	0.28
	08:00–16:00	0.15	
	16:00–00:00	0.17	
	00:00–08:00	0.40	0.60

Monitoring Period	Duration	8-hour CO mean (mg/m³)	Max. hourly CO mean (mg/m³)
Sunday, 04/09/2022	08:00–16:00	0.33	
	16:00–00:00	0.27	
Monday, 05/09/2022	00:00–08:00	0.46	0.63
	08:00–16:00	0.36	
	16:00–00:00	0.42	
Tuesday, 06/09/2022	00:00–08:00	0.67	1.01
	08:00–16:00	0.37	
	16:00–00:00	0.38	
Long Term Target (mg/m³)		**10.00**	**30**

Table 10.9. 8-hour average of O_3 and maximum daily hourly mean of NO_2 at Station A2

Monitoring Period	Duration	8-hour O_3 mean (µg/m³)	Max. hourly NO_2 mean (µg/m³)
Wednesday, 31/08/2022	00:00–08:00	3.95	101.76
	08:00–16:00	24.06	
	16:00–00:00	29.52	
Thursday, 01/09/2022	00:00–08:00	4.06	128.00
	08:00–16:00	20.89	
	16:00–00:00	17.46	
Friday, 02/09/2022	00:00–08:00	3.29	74.56
	08:00–16:00	15.00	
	16:00–00:00	13.90	
Saturday, 03/09/2022	00:00–08:00	2.04	73.82
	08:00–16:00	21.58	
	16:00–00:00	25.49	
Sunday, 04/09/2022	00:00–08:00	5.29	72.95
	08:00–16:00	12.64	
	16:00–00:00	18.20	
Monday, 05/09/2022	00:00–08:00	3.19	82.69
	08:00–16:00	12.63	
	16:00–00:00	8.68	
Tuesday, 06/09/2022	00:00–08:00	3.04	119.85
	08:00–16:00	32.57	
	16:00–00:00	31.71	
Long Term Target (µg/m³)		**100.00**	**200.00**

10.4.3 Baseline Results at Station A3

At Station A3, the 24-hour $PM_{2.5}$ mean (µg/m3) exceeded the long-term target on two days of the week, of which the maximum was 28.8 µg/m³. All other parameters measured at Station A3 were below the long-term targets.

Table 10.10. 24-hour mean of PM_{10}, $PM_{2.5}$, and SO_2 levels at Station A3

Monitoring Period	24-hour PM_{10} mean (µg/m^3)	24-hour $PM_{2.5}$ mean (µg/m^3)	24-hour SO_2 mean (µg/m^3)
Wednesday, 31/08/2022	17.0	16.6	10.59
Thursday, 01/09/2022	26.0	**25.8**	8.93
Friday, 02/09/2022	24.0	24.4	5.72
Saturday, 03/09/2022	11.1	10.6	0.59
Sunday, 04/09/2022	19.8	19.5	3.30
Monday, 05/09/2022	24.3	24.0	7.13
Tuesday, 06/09/2022	29.2	**28.8**	18.23
Long Term Target (µg/m^3)	**50.00**	**25.00**	**20.00**

Note: **Bold** indicates exceedance

Table 10.11. 8-hour and maximum daily hourly mean of CO level at Station A3

Monitoring Period	Duration	8-hour CO mean (mg/m^3)	Max. hourly CO mean (mg/m^3)
Wednesday, 31/08/2022	00:00–08:00	0.52	1.08
	08:00–16:00	0.52	
	16:00–00:00	0.40	
Thursday, 01/09/2022	00:00–08:00	0.60	0.89
	08:00–16:00	0.41	
	16:00–00:00	0.56	
Friday, 02/09/2022	00:00–08:00	0.93	1.09
	08:00–16:00	0.38	
	16:00–00:00	0.32	
Saturday, 03/09/2022	00:00–08:00	0.35	0.44
	08:00–16:00	0.27	
	16:00–00:00	0.30	
Sunday, 04/09/2022	00:00–08:00	0.62	0.87
	08:00–16:00	0.49	
	16:00–00:00	0.38	
Monday, 05/09/2022	00:00–08:00	0.63	0.81
	08:00–16:00	0.50	
	16:00–00:00	0.61	
Tuesday, 06/09/2022	00:00–08:00	0.94	1.55
	08:00–16:00	0.51	
	16:00–00:00	0.56	
Long Term Target (mg/m^3)		**10.00**	**30.00**

Table 10.12. 8-hour average of O_3 and maximum daily hourly mean of NO_2 at Station A3

Monitoring Period	Duration	8-hour O_3 mean ($\mu g/m^3$)	Max. hourly NO_2 mean ($\mu g/m^3$)
Wednesday, 31/08/2022	00:00–08:00	11.14	10.59
	08:00–16:00	30.60	
	16:00–00:00	59.15	
Thursday, 01/09/2022	00:00–08:00	13.18	139.80
	08:00–16:00	25.52	
	16:00–00:00	45.28	
Friday, 02/09/2022	00:00–08:00	8.78	83.65
	08:00–16:00	22.00	
	16:00–00:00	28.48	
Saturday, 03/09/2022	00:00–08:00	7.81	70.69
	08:00–16:00	18.56	
	16:00–00:00	43.72	
Sunday, 04/09/2022	00:00–08:00	13.26	87.13
	08:00–16:00	22.39	
	16:00–00:00	37.26	
Monday, 05/09/2022	00:00–08:00	9.57	112.91
	08:00–16:00	23.67	
	16:00–00:00	21.77	
Tuesday, 06/09/2022	00:00–08:00	6.36	125.26
	08:00–16:00	44.83	
	16:00–00:00	65.85	
Long Term Target ($\mu g/m^3$)		**100.00**	**200.00**

10.5 Impact Assessment

10.5.1 Predicted Impacts

RIAM Environmental Scoring for the Predicted Impacts

Table 10.13. Predicted ambient air quality impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre-construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions − Interlocking rings − Intertidal terrace − Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		– Interlocking rings – Intertidal terrace – Rain garden									
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-2	3	2	2	-14	Slight Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-2	2	2	2	-12	Slight Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="5">Public Trail (Profile B -2, Option 1)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space</td><td>• Earthworks
• Vegetation clearance</td><td>Fugitive dust</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td rowspan="3">Construction</td><td rowspan="3">• Earth trail
• Nature-based Solutions
– Interlocking rings</td><td rowspan="3">• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation.
• Earthworks
• Backfilling
• Revetment and placement of interlocking rings
• Land and intertidal based development</td><td>Fugitive dust</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Exhaust emissions in vehicles</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Noxious vapours from oils, glues, thinners, paints</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Operation</td><td>• Earth trail
• Nature-based Solutions
– Interlocking rings</td><td>• Recreational visits
• Small vehicle deployment for maintenance works</td><td>Vehicle emissions from maintenance vehicles</td><td>1</td><td>-1</td><td>2</td><td>2</td><td>2</td><td>-6</td><td>No Impact</td></tr>
<tr><td>Public Trail (Profile B -2, Option 2)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space</td><td>• Vegetation clearance</td><td>Fugitive dust</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile C)	Pre-constructi	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Landscape enhancement	Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Fugitive dust	1	-2	2	2	2	-12	Slight Negative
				Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative
				Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact

Pre-construction / Construction Phase

Project activities in the site include vegetation clearance, earthworks, construction of drains and sewers, and infrastructure works. Based on these activities, the following potential impacts on ambient air quality are identified:

Fugitive Dust Emissions from Construction Works

The following construction works are expected to create dust emission:

- Site clearance
- Soil investigation work
- Soil filling and earthworks for the platform level
- Temporary stacking of excavated soil within project area
- Erection of temporary (e.g., site office) structures
- Earthworks for pile cap
- Backfill, soil mixing and compaction
- Cutting and grinding work for pile head
- Construction of the new infrastructures
- Vehicle movements on access roads

Fugitive dust emissions from construction activities are unavoidable to be generated during soil excavation, backfilling activities, and vehicle movements within the project area on unpaved surfaces. These fugitive dust emissions are expected to have a Slight Negative and direct impact on local air quality and affect air sensitive receptor located near dust generating construction activities (e.g., construction workers).

Additionally, deteriorated ambient air quality also has negative impacts on biodiversity. For example, particulate matter settling on leaves may cause leaf injury though abrasion or chemical interactions. Dust particles entering stomata may also reduce photosynthetic functions. Dust landing directly on soil may affect nutrient cycling processes (Grantz et al., 2003).

The existing literature on the effect of construction dust on birds is limited, with most studies examining the effects of air pollution on wildlife in general, rather than the effect of construction dust on birds specifically. Since the avian respiratory system, unlike the mammalian respiratory system, is characterized by unidirectional airflow and cross-current gas exchange, this makes them more susceptible to high concentrations of pollutants in the air. Studies have shown that birds exposed to urban air pollution may exhibit a build-up of cellular and mineral debris leading to characteristic conditions of pneumonia (Ejaz et al., 2014).

The impact duration of fugitive emissions of construction dust is anticipated to be short-term and expected to vary significantly from day to day depending upon the duration of dust-generating construction activities within the project area. Actual fugitive dust emissions concentrations from construction site will depend on effectiveness of control measures, length of operation, and ambient weather condition (e.g., rainfall, wind speed, and wind direction). The extent of fugitive emissions is local, within the project as the vegetated area around the project area will act as a barrier for further dispersion. Also, the impacts are reversible when dust-generating construction activities stop.

Exhaust Emissions from Construction Machinery and Heavy Vehicles

Project activities are anticipated to use fuel-burning (i.e., mainly diesel) machinery such as road roller machines, generator sets, and other heavy vehicles such as grader, dozer, excavator, front-end loader, and haul truck that may cause exhaust emission. These exhaust emissions can cause direct and negative effects on local air quality by potentially increasing the concentrations of CO, NO_2, SO_2, O_3, PM_{10} and $PM_{2.5}$. This could cause the local air quality to deteriorate.

The impact is expected to be short-term depending on the duration of operation of machinery and heavy vehicles. The geographical extent of exhaust emissions is considered to be local, within the project area, even its dispersion will be affected by a number of factors such as ambient weather and wind direction. Ambient air quality impacts due to exhaust emissions of fuel burning machinery and vehicles are reversible when they stop operating.

Odour Emissions

During construction works, it is anticipated that odours generated at the project area would be minimal. The potential impact is anticipated to be short term, indirect and insignificant as it would be assumed to be managed by suitable waste management mitigation measures discussed in Chapter 11.

Overall, potential air quality impacts on ASR are expected to be of Slight Negative in nature, direct, and local. Duration is anticipated to be short term and reversible as the impact will cease upon completion of the air pollution generating construction activities. As such, mitigation measures are recommended to further reduce the potential impacts.

Operation Phase

An impact that would be generated during the Operational phase would be the vehicular emissions by visitors. Nonetheless, it is important to note that this EIA is meant to address impacts from the earthworks and infrastructure works phase of the development and is not meant to address the operation phase of the development. TAC recommends that the impacts from the operational phase of this project be assessed separately.

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

Overall, the predicted impacts are expected to be mainly Slight Negative across all locations during the pre-construction and construction phases. Whereas the predicted impacts are No Impact during the operation phase.

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc) are expected. The predicted impacts from these works would mostly be the disturbances that would occur to fauna in the area and the workers who are on site. Most of the planned activities would not cause much air disturbance when compared to the baseline, except for the earthwork activities. The activities that would release dust or emissions from exhausts would then have a higher score that would be in the Slight Negative range.

During the construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas along the coastline (i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion). The main air quality concerns arising from these works are the disturbance to the fauna in the area. The construction activities may make use of machinery that would produce toxic gases, influencing the air quality negatively. However, since the Mandai area is an industrial area by default, and experiences air emissions from various existing industries such as manufacturing facilities, the air would not be largely affected. This would then have a score that would be in the Minor Negative range.

During the operation phase, no works will be carried out. Regardless, it should be noted that the increase of vehicles in the area due to visitorship would cause minor disturbances in terms of air compared to the baseline conditions. This is especially so since the area would be publicly accessible compared to the present conditions whereby there are not many areas for vehicles to park. In addition, it is expected that there would be tour groups visiting the area, increasing the number of vehicles and thus would have impact on the air quality. Since there will be little to No Impacts in terms of the air quality, the assessment is generally in the No Impact range.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

10.5.2 Mitigation Measures

Mitigation measures are to be implemented wherever negative impacts are predicted, in order to reduce the impacts of the works on the environment. A majority of air quality impact mitigation measures are covered in this Chapter.

Table 10.14. Air quality impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Fugitive dust	• To implement dust suppression plan • Use of hoarding at project boundary to minimise dust generation by attenuating wind forces. • To avoid stockpiles of soil and dusty materials at project area within forested area as far as possible. • Use of regular watering to reduce dust emissions from exposed site surface
Construction	Fugitive dust	• To implement dust suppression plan • Use of hoarding at project boundary to minimise dust generation by attenuating wind forces. • To avoid stockpiles of soil and dusty materials at project area within forested area as far as possible. • Stockpiles of dusty material should be properly stored, covered entirely with impervious sheeting, or dampened with water • Use of regular watering to reduce dust emissions from exposed site surface • Personal protective equipment i.e., face mask to be worn during dust exposure • Intermittently used vehicles and machinery are to be shut down between work periods
	Exhaust emissions in vehicles	• Contractor to prepare a dust suppression Plan • Erection and maintenance of noise barriers around construction work areas • Restriction of vehicular speed on-site • Alternative fuels such as methanol, natural gas or electricity should be used whenever possible
	Noxious vapours from oils, glues, thinners, paints	• No opening burning of waste materials • Proper storage of building materials, chemicals and fuels • Conduct periodic checks to prevent accumulating unnecessary chemicals • Ensure that lids and caps on all chemical containers are tightly closed to prevent evaporation of contents. A Teflon of PVC cap liner may be used to provide a better seal.
Operation	Vehicle emissions from maintenance vehicles	• Implementation of NParks visitors' rules & regulations to educate visitors

Pre-construction / Construction Phase

The combined mitigation measures are proposed covering the project area:

For site dust control, the contractor shall prepare and implement the dust control plan covering the following dust suppression measures:

- Use of hoarding at project boundary within work areas to minimise dust generation by attenuating wind forces.
- To avoid stockpiles of soil and dusty materials at project area within work areas as far as possible.
- If unavoidable, stockpiles of soil should be located away as far as possible from sensitive receptors (i.e., adjacent flora and fauna).
- Provide additional dust screen at project boundary near sensitive receptors (i.e., flora and fauna).
- Any soil or stockpiles of dusty material should be properly stored, covered entirely with impervious sheeting, or dampened with water to maintain entire surface wet by contractor.
- Soil stockpiles shall not be higher than 0.6 times the nearest hoarding height.
- Excavations should be backfilled or reinstated as soon as practicable following completion of the construction work.
- Material transport of inert solids (excavated materials) should be enclosed using impervious sheeting, minimising the visual dust impacts as well.
- Use of regular watering to reduce dust emissions from exposed site surfaces, particularly during dry weather on open areas.
- Open burning of construction and other wastes are not allowed at the worksite as this is an offence under the Environmental Pollution Control regulation.
- Personal protective equipment such as masks shall be worn during the severe air pollution and/or dust exposure periods by construction personnel.
- Avoid soil disturbing works during dry and/or windy conditions.
- Stabilize/cover all stockpiled materials for longer than one month by turfing, erosion blanketing or other method.
- Vehicle on-site speed restrictions should be imposed to prevent dust being stirred up by vehicle movements.

Other mitigation measures that need to be taken by the contractor include:

- Provide vehicle washing facilities before the construction site exit.
- Pave the area between the construction site exit and the vehicle washing facilities.
- Maintain road surface in the construction site wet (e.g., using sprinkler).
- Proper maintenance of construction vehicles and fuel burning equipment.
- Intermittently used vehicles and machinery are to be shut down between work periods to minimum exhaust emission.

The recommended measures above, when implemented effectively, are expected to mitigate the potential impacts on the ambient air quality of the site to acceptable levels.

Operation Phase

No Impacts on ambient air quality are expected to be generated during the Operational phase of the project. Hence, no further recommendations for air quality are given.

10.5.3 Residual Impacts

The residual impacts were evaluated using the RIAM method (Table 10.15) with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in a band of No Impact and considered acceptable.

During pre-construction phase, the main concern across most locations is the fugitive dust generated. Mitigation measures such implementation of dust suppression plans and regular watering of site surface can help in reducing the environment score from Slight Negative to No Impact range band.

During construction phase, on top of fugitive dust generation, other predicted impacts across many locations include exhaust emissions in vehicles and noxious vapours generated. Following mitigation measures detailed in Section 10.5.2, the environment score of these predicted impacts can be reduced from Slight Negative to No Impact range. For example, while the environment score of fugitive dust generation was assessed to be in Slight Negative range prior to mitigation, mitigation measures such as proper storage of building materials and conducting periodic checks to prevent accumulation of unnecessary chemicals can reduce the magnitude of impacts identified such that the final residual environment score are reduced to No Impact range.

During operation phase, the main concern across most locations are vehicle emissions from visitor cars or maintenance vehicles. Mitigation measures such as educational signs, implementation of visitors' rules and regulations can help reduce the magnitude of impact such that the residual environment score are reduced from Slight Negative to No Impact range.

RIAM Environmental Scoring for the Residual Impacts

Table 10.15. Environmental Scores of the predicted and residual impacts on site's air quality after implementation of mitigation measures listed in Table 10.14

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path	Vehicle emissions from visitor cars or maintenance vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Vehicle emissions from visitor cars or maintenance vehicles	1	-2	3	2	2	-14	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Vehicle emissions from visitor cars or maintenance vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Public Trail Boardwalk	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact
Kranji Reservoir Dam (Profile E)	Pre-constructi	• Construction site boundary • Storage space and working space	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• At-grade pedestrian connection	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• At-grade pedestrian connection	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Fugitive dust	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Exhaust emissions in vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Noxious vapours from oils, glues, thinners, paints	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	1	2	2	-6	No Impact

11 GROUND-BORNE VIBRATION

11.1 Introduction

This Section describes the relevant standard for the ground-borne vibration that are applicable to the Project activities, the methodology and results for the baseline ground vibration study. It also described potential ground vibration impacts from construction works, and recommendation for ground vibration mitigation measures. A qualitative impact assessment approach is being used for assessment of impacts.

11.2 Relevant Environmental Legislation, Guidelines and Standards

As there are no specific laws and standard in Singapore presently that describe the assessment criteria for ground vibration, the following international standards are used as reference for ground vibration assessment criteria associated with human annoyance.

1. BS 5228-2 Code of Practice for Noise and Vibration Control on Construction and Open Sites.
2. United States Federal Transit Authority (FTA) Transit Noise and Vibration Impact Assessment Manual.

The baseline ground vibration data obtained are compared with the ground-borne vibration limits stated in the BS 5228-2 Code of Practice for Noise and Vibration Control on Construction and Open Sites (Table 11.1).

Table 11.1. BS 5228 Part 2 Guidance on Human Response to Vibration Levels

Sr No.	Vibration Level	Effect	Description
1	0.14 mm/s	Threshold of Perception	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
2	0.3 mm/s	Just Perceptible	Vibration might be just perceptible in residential environment.
3	1.0 mm/s	Likely Complaint	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if warning and explanation is given to residents
4	10 mm/s	Likely Intolerable	Vibration is likely to be intolerable for any more than a brief exposure at this level

According to BS 5228-2, human beings are known to be very sensitive to vibration, the threshold of perception being typically in the PPV range of 0.14 $mm \cdot s^{-1}$ to 0.3 $mm \cdot s^{-1}$. Vibrations above these values can disturb, startle, cause annoyance or interfere with work activities. At higher levels they can be described as unpleasant or even painful. In residential accommodation, vibrations can promote anxiety lest some structural mishap might occur.

11.3 Baseline Methodology

11.3.1 Sensitive Receptors Identification

The sensitive receptor identification criteria are based on the United States Federal Transit Authority (FTA) Transit Noise and Vibration Impact Assessment Manual. The criteria are listed below:

- Category 1 (High Sensitivity) covers manufacturing as well as vibration-sensitive research, hospitals with vibration-sensitive equipment, and university research operations.
- Category 2 (Residential) covers residential land uses and any buildings where people sleep, such as hotels and hospitals.
- Category 3 (Institutional) covers institutional land uses with primarily daytime use e.g., schools, churches, other institutions, and quiet offices that do not have vibration-sensitive equipment, but still have the potential for activity interference.
- Special Buildings: This category includes concert halls, TV studios, recording studios, auditoriums, and theatres.

The Vibration Sensitive Receptors (VSRs) potentially affected by the proposed project have been identified (Table 11.2) through a combination of desktop study and visual surveys within the project area.

Table 11.2. List of identified vibration sensitive receptors.

ID	Type	Description	Approximate Distance*
VSR1	Workers	People working on the site (e.g., construction workers, consultants)	Within Project Area
VSR2	Flora and Fauna	Flora and fauna living within project area	Within Project Area
VSR3	Recreation	People visiting Kranji Recreation Centre	120m from Project Area
VSR4	Residential building	People at Kranji Lodge 1	6500m from Project Area

*Approximate distance from the nearest project work area

The impacts of anthropogenic-derived vibration on fauna are poorly understood. However, some animals, particularly amphibians, are sensitive to vibrations, as increased vibrations may affect their ability to communicate, and may reduce their reproductive success (Caorsi, et al., 2019).

11.3.2 Baseline Field Survey

The ground-borne vibration level monitoring is conducted for approximately one week (7 x 24 hours) to generate baseline condition. The monitoring locations were chosen based on factors such as presence of sensitive receptors, relevance to project activity, site access, and equipment security. Ground-borne vibration level was monitored using three (3) units of Minimate Plus manufactured by Instantel Inc., with a trigger level of approximately 0.13 mm/s (i.e., vibration levels as low as 0.13 mm/s will be recorded). The monitoring locations are described in Table 11.3.

Table 11.3. Location of vibration monitoring stations

Station	Monitoring Period	Latitude	Longitude	Description of Location
V1	31 Aug – 7 Sep 2022	1.438249	103.754646	Behind Old Kranji Post PCG gate, at the roundabout beside Timmac building
V2	31 Aug – 7 Sep 2022	1.439121	103.742984	At the open field beside Kranji Carpark A
V3	31 Aug – 7 Sep 2022	1.439357	103.737725	At the open field within Kranji Reservoir Park B, near the Kranji Beach Battle Historic Marker

Figure 11-1 shows the location map of monitoring stations and Figure 11-2 shows the photographs of the on-site monitoring equipment setup. The baseline vibration monitoring report is available as **Appendix J.**

Figure 11-1. Locations of ambient vibration monitoring stations within project area

Figure 11-2. Pictures of the on-site baseline ground-borne vibration monitoring equipment

11.4 Baseline Results and Discussion

Table 11.4 summarises the baseline vibration levels recorded at the project area. In general, the baseline ground-borne vibration level did not go beyond 10 mm/s aside from one occurrence at Station V1 (i.e., 10.6 mm/s on 7 September 2022 at 13:57:33), two occurrences at Station V2 (i.e., 12.18 mm/s on 30 August at 11:03:09 and 75.95 mm/s on 7 September at 14:14:58) and two occurrences at Station V3 (i.e., 10.74 mm/s on 7 September at 14:20:23 and 20.52 mm/s on 30 August at 11:51:45).

Table 11.4. Baseline ground-borne vibration level at the project area at station V1, V,2 and V3

Station	No. of Recorded Occurrences	90^{th} Percentile (mm/s)	99^{th} Percentile (mm/s)	Maximum (mm/s)	Date & Time of Maximum Level Recorded
V1	107	1.1436	3.69308	10.6	7/9/2022, 1:57 PM
V2	46	3.02	47.25	75.95	7/9/2022, 2:14 PM
V3	20	9.7131	18.6618	20.52	30/8/2022, 11:51 AM

Stations V2 and V3 are located near a busy Kranji Way road with a busy traffic, which could explain the relatively higher levels of vibration.

As can be observed from the table above, Station V2 and Station V3 recorded a substantially higher number of vibration occurrences compared to V1, indicating that there are more frequent vibration sources at V2 and V3. This difference in the number of recorded occurrences was expected, since Station V2 and V3 are located next to Kranji Way road constantly utilised by vehicular traffic while Stations V1 is not near any major road.

11.5 Impact Assessment

11.5.1 Predicted Impacts

RIAM Environmental Scoring for the Predicted Impacts

Table 11.5. Predicted vibration impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden									
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Sungei Pang Sua Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	36	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Constructi on	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative
				Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact

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• Construction site boundary
• Storage space and working space</td><td>• Vegetation clearance</td><td>Disturbance to the fauna due to vibration from construction activities</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-36</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Elevated Boardwalk (1.5m wide) in back mangrove zones</td><td rowspan="2">• Vegetation clearance
• Earthworks-backfilling
• Land and intertidal based development</td><td>Disturbance to the fauna due to vibration from construction activities</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
<tr><td>Disturbance/ annoyance to the VSR due vibration from construction activities</td><td>2</td><td>-3</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
<tr><td>Operation</td><td>• Elevated Boardwalk (1.5m wide) in back mangrove zones</td><td>• Recreational visits
• Small vehicle deployment for maintenance works
• Generation of litter
• Enhancement planting</td><td>Vehicle emissions from visitor cars or maintenance vehicles</td><td>1</td><td>-1</td><td>2</td><td>2</td><td>2</td><td>-6</td><td>No Impact</td></tr>
<tr><td rowspan="3">Kranji Reservoir Dam (Profile E)</td><td>Pre-constructio</td><td>• Construction site boundary
• Storage space and working space</td><td>• Vegetation clearance</td><td>Disturbance to the fauna due to vibration from construction activities</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-36</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• At-grade pedestrian connection</td><td rowspan="2">• Clearance of existing path
• Exotic vegetation clearance
• Landscape enhancement</td><td>Disturbance to the fauna due to vibration from construction activities</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
<tr><td>Disturbance/ annoyance to the VSR due vibration from construction activities</td><td>2</td><td>-3</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
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<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td></td><td>Operation</td><td>• At-grade pedestrian connection</td><td>• Recreational visitorship
• Small vehicle deployment for maintenance works
• Generation of litter
• Enhancement planting</td><td>Vehicle emissions from visitor cars or maintenance vehicles</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td rowspan="4">Sungei Pang Sua Trail (Profile F)</td><td>Pre-construction</td><td>• Construction site access
• Construction site boundary
• Storage space and working space
• Hoarding</td><td>• Vegetation clearance
• Hoarding installation</td><td>Disturbance to the fauna due to vibration from construction activities</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-36</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">• Trail (1.5m wide) 2 - 6m from back mangrove</td><td rowspan="2">• Vegetation clearance
• Land based development</td><td>Disturbance to the fauna due to vibration from construction activities</td><td>3</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
<tr><td>Disturbance/ annoyance to the VSR due vibration from construction activities</td><td>2</td><td>-3</td><td>2</td><td>2</td><td>3</td><td>-42</td><td>Minor Negative</td></tr>
<tr><td>Operation</td><td>• Trail (1.5m wide) 2 - 6m from back mangrove</td><td>• Recreational visits
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Vehicle emissions from visitor cars or maintenance vehicles</td><td>1</td><td>-1</td><td>2</td><td>2</td><td>2</td><td>-6</td><td>No Impact</td></tr>
</table>

Pre-construction / Construction Phase

Construction activities can result in ground-borne vibration, depending on the various type of construction methods and equipment employed. Use of construction equipment could cause ground-borne vibration which spread through the ground and diminish in strength with distance. The ground vibrations generated during construction may create annoyance to people and detrimentally affect structures and sensitive devices. The focus on this vibration impact assessment during construction phase is on the nearest VSRs (i.e., workers and flora and fauna within project area).

The preliminary construction approach that would be used for this project is given in Chapter 2. Detailed information on the construction methodologies, specific equipment that will be used at each construction stage and their approximate quantity are not available at the time of this report preparation.

Main sources of ground vibration emissions during construction works at the project area are:

- Bored piling rigs to be used to pre-bore the ground for casting of the piles
- Excavators for earth handling and tree-clearance
- Shaft construction and Micro Tunnel Boring Machine (MTBM) during pipe jacking method

There are currently no Singapore standards that provide methodology to predict levels of ground vibration from construction activities. As such, to control the impact of vibration during site activities, limits relating to the perceptibility of vibration are typically used (see Section 10.2). BS 5228-2 provides the distances (based on historical field measurements) as to which activities could give rise to a just perceptible level of ground vibration. These distances are provided in Table 11.6.

Table 11.6. Perceptible vibration levels as per BS 5228-2

Construction Activities	Distance from Activity when Ground Vibration May Just be Perceptible (m)
Heavy vehicles	5 - 10
Rotary bored piling	20 - 30
Vibro hammer	25 – 35
Driven sheet piling	30 – 35

The construction activities will be conducted within the project area. It is likely that any vibration impacts generated will be experienced by the nearest VSRs (i.e., workers and flora and fauna).

The closest distance between the project worksite and nearest human related VSRs (i.e., onsite workers) is within the project area. As the work activities would involve only the equipment used at ground level (e.g., mobile crane, excavator), they were considered as potential vibration sources. Other construction activities such as vehicle movements, soil compaction, lifting using mobile cranes are unlikely to generate significant ground-vibration.

Therefore, it is anticipated that human VSRs would not encounter vibration effect above the perceptible level for construction works and unlikely to be affected. However, it is recognized that the work activities are in close proximity of VSR3 (i.e., people visiting Kranji area for recreation) hence Contractor shall implement recommended vibration mitigation measures/best practices for these worksites to minimise the vibration impacts.

While there is no extensive research done on how vibration emissions affect fauna, it is understood that vibration from anthropogenic sources affects communication ability of some fauna, for example amphibians, to communicate resulting in reduction of reproductive success. (Caorsi, et al., 2019) . Though there are limited studies on the impacts from vibration has on fauna, the few studies have shown that it can vibration behaviour physiology and mortality of fauna (Cross, et al., 2021) Hence, fauna located near any construction vibration sources are likely to be affected by the development. It is to be noted that vibration within the project area is likely a result of vehicular traffic along Kranji Way road. Additionally, heavy construction activities are expected to be restricted to daytime. It is anticipated that lower vibration generating construction methods will be used whenever possible, which will reduce much of the major impacts from vibration to sensitive receptors.

Overall, potential vibration impacts on VSR are expected to be of a Slight Negative nature, direct, and local. Duration is anticipated to be short term and reversible as the impact will cease upon completion of the vibration generating construction activities. Furthermore, this impact is to be managed through the mitigation measures/best practices recommended in next section.

Operation Phase

No Impacts on ground-borne vibration are expected to be generated during the operation phase of the project.

RIAM Environmental Scoring for the Residual Impacts
Table 11.8 summarises the impacts covering of all three areas with their corresponding Environmental Scores before and after the implementation of mitigation measures, which are elaborated in the following section.

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

Overall, the predicted impacts are expected to be mainly Slight Negative across all locations during the pre-construction and construction phases. Whereas the predicted impacts are ‘No Impact during the operation phase.

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc) are expected. The predicted impacts from these works would mostly be the disturbances that would occur to fauna in the area and the workers who are on site. Since the area of impact will be restricted to the boundary of the project footprint, as such there will be limited to no changes in baseline conditions and the predicated impacts are Slight Negative.

During construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion along the coastline. The main vibration concerns arising from these works are the disturbance to the fauna in the area. This would then have a higher score that would be in the Minor Negative range.

During the operation phase, no works will be carried out. Regardless, it should be noted that the increase of vehicles in the area due to visitorship would cause minor disturbances in terms of vibration compared to the baseline conditions. This is especially so since the area would be publicly accessible compared to the present conditions whereby there are not many areas for vehicles to park. In addition, it is expected that there would be tour groups visiting the area, increasing the number of vehicles and thus would have impact on the vibration in the area. Since there will be little to No Impacts in terms of the vibration levels, the assessment is generally in the No Impact range.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

11.5.2 Mitigation Measures

Table 11.7. Vibration impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Disturbance to the fauna due to vibration from construction activities	• Use of heavy equipment to be restricted to daytime only • Use of equipment or method which generate lower vibration levels • Route heavily loaded trucks away from the VSRs as far away as possible. • To plan and phase excavation, earth-moving, and ground piling activities in staggered manner • Control speed of vehicle movement at the worksite • Keep haul roads within project work site in good condition • Limit heavy construction activities to the pavilion construction area
Construction	Disturbance to the fauna due to vibration from construction activities	• Use of heavy equipment to be restricted to daytime only • Use of equipment or method which generate lower vibration levels • Route heavily loaded trucks away from the VSRs as far away as possible. • To plan and phase excavation, earth-moving, and ground piling activities in staggered manner • Control speed of vehicle movement at the worksite • Keep haul roads within project work site in good condition • Limit heavy construction activities to the pavilion construction area
	Disturbance/ annoyance to the VSR due vibration from construction activities	• Use of heavy equipment to be restricted to daytime only • Use of equipment or method which generate lower vibration levels • Route heavily loaded trucks away from the VSRs as far away as possible. • Control speed of vehicle movement at the worksite • To develop the vibration monitoring plan in consultation QP & to monitor throughout construction period • Notify nearby VSRs (residences) in advance of the construction activities
Operation	Vehicle emissions from visitor cars or maintenance vehicles	• Use of low-noise asphalt for prone areas (i.e. coach bays) during construction • Restrictions on number of large tour groups into the nature park to reduce number of large vehicles utilising the coach bay

Pre-construction / Construction Phase

The following mitigation measures / best practices are recommended to manage the impact to fauna surrounding project work areas. The Contractor shall be responsible to implement these measures.

- Construction works involving the use of heavy equipment should be restricted to daytime only (i.e., 8 am – 6 pm).
- Contractors shall be responsible to comply with all applicable regulatory and authority requirements and recommendation in this EIA report on ground-borne vibration.
- Vibrating equipment is to be placed on isolators such as spring coils.
- To monitor and assess the actual vibration levels while carrying out sheet piling work within that work area during construction phase.
- The drilling rig engine to be switched off when not in use to reduce vibration.
- Route heavily loaded trucks away from the VSRs as far away as possible.
- To plan and phase excavation, earthmoving, and ground piling activities in staggered manner where possible to minimize cumulative impact.
- Control speed of vehicle movement at the worksite to 10 km/hour.
- Notify nearby VSRs (e.g., residential buildings) in advance of the construction activities, particularly during pipe jacking works to allay potential concerns.
- To develop the vibration monitoring plan in consultation with Qualified Person (QP) and to monitor the vibration levels throughout construction period.
- Utilize a vibratory compactor that can adjust the impulse energy and frequency, compact soil with static method (no vibrations).
- Keep haul roads within the project work site in good condition to provide a smooth traveling surface.

Operation Phase

As no further impacts on ground-borne vibration are expected during Operation phase of the project, no recommendations for vibration reduction are proposed.

11.5.3 Residual Impacts

The residual impacts were evaluated using the RIAM method (Table 11.8) with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in the band of minor to Slight Negative.

During pre-construction phase, the main concern across most locations is disturbance to fauna. Mitigation measure such as restricting work areas and stagger work activities will help to reduce the magnitude of disturbance to shorebirds, thus reducing the environment score from Minor Negative to Slight Negative range band.

During construction phase, on top of disturbance to fauna, other predicted impacts across many locations include disturbance to VSR such as workers and nearby factories. Following mitigation measures detailed in Section 11.5.2, the environment score of these predicted impacts can be reduced from Minor Negative to Slight Negative range. For example, while the environment score of disturbance to fauna was assessed to be in Minor Negative range prior to mitigation, mitigation measures such as restricting heavy equipment usage can reduce the magnitude of impact of the disturbance such that the final residual environment score are reduced to Slight Negative range.

During operation phase, the main concern across most locations are the vehicle emissions from visitor cars or maintenance vehicles. However, there are No Impacts anticipated. Although there are No Impacts anticipated, the use of low-noise asphalt for prone areas has been suggested as it will also help in reducing the vibration experienced.

RIAM Environmental Scoring for the Residual Impacts

Table 11.8. Environmental Scores of the predicted and residual impacts on site's vibration after implementation of mitigation measures listed in Table 11.7

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	3	-21	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Public Trail Boardwalk	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	3	-21	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Geo bags	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	3	-21	Slight Negative
	Construction	• Elevated Boardwalk	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Elevated Boardwalk	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D, Option 1)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	3	-21	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D, Option 2)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
			Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	2	-18	Slight Negative
Guided Trail (Profile D Option 2)	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
Guided Trail (Profile D Option 2)	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
Guided Trail (Profile D Option 2)	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact
Kranji Reservoir Dam (Profile	Pre-construction	• Construction site boundary • Storage space and working space	Vehicle emissions from visitor cars or maintenance vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• At-grade pedestrian connection	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
	Construction	• At-grade pedestrian connection	Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
	Operation	• At- cars grade pedestrian connection	Vehicle emissions from visitor or maintenance vehicles	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	2	-36	Slight Negative	3	-1	2	2	3	-21	Slight Negative
Sungei Pang Sua Trail (Profile F)	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Disturbance to the fauna due to vibration from construction activities	3	-2	2	2	3	-42	Minor Negative	3	-1	2	2	3	-21	Slight Negative
Sungei Pang Sua Trail (Profile F)	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Disturbance/ annoyance to the VSR due vibration from construction activities	2	-3	2	2	3	-42	Minor Negative	2	-2	2	2	3	-28	Slight Negative
Sungei Pang Sua Trail (Profile F)	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Vehicle emissions from visitor cars or maintenance vehicles	1	-1	2	2	2	-6	No Impact	1	-1	2	2	2	-6	No Impact

12 LIGHT

12.1 Introduction

As a highly urbanised city-state, Singapore already has high levels of light pollution from buildings and streetlamps. While unavoidable in cities, such lighting often has adverse impacts on the natural environment. The alteration of natural cycles of day and night by artificial light sources can have negative impacts on animals and ecosystems or otherwise alter wildlife behaviour. Increased artificial light during the night disrupts circadian rhythms of animals and distorts the day-night cycle of plants. This may lead to increased predation pressure by diurnal carnivores on nocturnal animals, exhaustion from insects attracted to artificial light, and the alteration of breeding and sleeping cycles of various wildlife.

The distortion of day-night cycles in plants may also lead to altered growth rates and flowering cycles, thus affecting floristic communities. These effects of light on plants and animals derive from changes in orientation or disorientation, and attraction or repulsion from the altered light environment, which in turn may affect foraging, reproduction, migration and communication behaviour (Longcore & Rich, 2004).

Many groups of insects, such as moths, are attracted to lights as a result of their innate navigational behaviour. Visual communication within and between species can also be influenced by artificial lighting. Insects such as glow worms and fireflies communicate through bioluminescent signals, which can only be achieved in the absence of background light (Longcore & Rich, 2004). The cumulative effects of such behavioural changes induced by artificial night lighting can have the potential to disrupt key ecosystem functions (Longcore & Rich, 2004).

12.2 Impact Assessment

12.2.1 Predicted Impacts

RIAM Environmental Scoring for the Predicted Impacts

Table 12.1. Predicted light impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions − Interlocking rings − Intertidal terrace − Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Disturbance to the flora and fauna in coastal and forested area due to operational lights	1	-1	3	2	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden									
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Disturbance to the flora and fauna in coastal and forested area due to operational lights	1	-1	3	2	1	-6	No Impact
Sungei Pang Sua Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Disturbance to the flora and fauna in coastal and forested area due to operational lights	1	-1	3	2	1	-6	No Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	No predicted impact	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Guided Trail (Profile D Option 2)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	No predicted impact	-	-	-	-	-	-	-
Kranji Reservoir Dam (Profile E)	**Pre-constructi**	• Construction site boundary • Storage space and working space	• Vegetation clearance	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	No predicted impact	-	-	-	-	-	-	-

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance • Hoarding installation	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	No predicted impact	-	-	-	-	-	-	-

Impacts to flora and fauna from light pollution should be avoided particularly for sensitive or threatened species highlighted in Chapter 5. Alteration of natural cycles of light and dark by artificial light sources can negatively impact the ecosystem and its function (Katabaro et al., 2022). Increased artificial light during the night disrupts circadian cycles of animals and distorts the day-night cycle of plants. This may lead to increased predation pressure by diurnal carnivores on nocturnal animals, exhaustion from insects attracted to artificial light, disorientation, and disruption of foraging by birds, and the alteration of breeding and sleeping cycles of various animals. As a whole, these effects derive from changes in orientation or disorientation, and attraction or repulsion from the altered light environment, which in turn may affect foraging, reproduction, migration, and communication behaviour.

Artificial night lights have also shown to have an impact on migratory birds, a large proportion of which migrate at night. In general, the risk of bird collisions increases with increased light emissions (Ogden, 2002).

Many groups of insects, such as moths, are attracted to lights resulting from their innate navigational behaviour. Visual communication within and between species can also be influenced by artificial lighting. Insects such as fireflies communicate through bioluminescent signals, which can only be achieved in the absence of background light (Longcore & Rich, 2004). Foraging behaviours of animals such as fruit bats are altered by light pollution; fruit bats are less active and forage less in artificially illuminated areas. As fruit bats play the ecological role of seed dispersers and pollinators, their reduced foraging activities may result in the loss of pollinating and seed-dispersal services they provide (Lewanzik & Voigt, 2014). The cumulative effects of such behavioural changes induced by artificial night lighting can have the potential to disrupt key ecosystem functions (Longcore & Rich, 2004).

Pre-construction / Construction Phase

It is assumed that all construction activities will be limited to daytime, as such any light impacts during the construction phase are expected to be negligible.

Operation Phase

As the visitor facilities such as Kranji Pavilion, Sungei Pang Sua Pavilion and Public trails will only be open during the daytime from 0700 to 1900, No Impact is expected during the operation phase. Table 12.3 summarises the impacts covering all three areas with their corresponding Environmental Scores before and after the implementation of mitigation measures, which are elaborated in the following section.

12.2.2 Mitigation Measures

Table 12.2. Light impact components and their respective mitigation measures

<table>
<tr><th>Phase</th><th>Impact Component</th><th>Recommended Mitigation Measures</th></tr>
<tr><td>Pre-construction</td><td>Disturbance to the flora and fauna in coastal and forested area due to light from construction activities</td><td>• Construction lights shall be directed downwards and inwards, toward project area (i.e., directly away from forested areas)
• Construction to be kept to daytime working hours (8 am – 6 pm)
• All unnecessary lights should be turned off outside working hours
• Develop and implement LMP approved by NParks for the event of work exigencies</td></tr>
<tr><td rowspan="2">Construction</td><td>Disturbance to the flora and fauna due to construction lighting</td><td>• Permanent lighting for safety and emergency purposes should be minimised.
• Use lights with reduced or filtered out blue, ultraviolet, or violet wavelengths for permanent lighting.
• Direct or shield the lights away from the sensitive areas.</td></tr>
<tr><td>Disturbance to the flora and fauna in coastal and forested area due to light from construction activities</td><td>• Construction lights shall be directed downwards and inwards, toward project area (i.e., directly away from forested areas)
• Construction to be kept to daytime working hours (8 am – 6 pm)
• All unnecessary lights should be turned off outside working hours
• Develop and implement LMP approved by NParks for the event of work exigencies</td></tr>
<tr><td>Operation</td><td>No predicted impact</td><td>• None required</td></tr>
</table>

Where lighting is necessary for safety and security reasons for the proposed works within the EIA project area, mitigation measures can be taken to ensure minimal impact on sensitive wildlife.

Pre-construction / Construction Phase

During the construction phase, heavy construction activities within the EIA project area are to be limited to daylight hours (8 am – 6 pm). If necessary, only light nightworks are to be conducted outside of daylight hours. Light nightworks refer to works without the use of heavy machinery (e.g., no piling, no lights shining into the forested areas).

If light nightworks are necessary, construction lights should face downwards and away from forested areas. Such lights must be shielded, facing downwards and away from any forested areas. This will eliminate light spill, which is light that falls outside the area intended to be lit. Examples of ideal shielded lighting can be seen in Figure 12-1 below. All artificial lights should be turned off outside working hours except for safety & security reasons.

Figure 12-1. Example of light shielding

Additionally, a Lighting Management Plan (LMP) should be developed as part of the Construction EMMP in the case of work exigencies and for unavoidable nightwork, and the LMP is to be approved by NParks. The detailed requirement for LMP is covered in Section 15.5 The LMP should include minimally the following aspects:

- Objectives of Lighting Management Plan
- Purposes and categories of artificial lighting required
- Spatial layout of lighting utilised in project area
- Designs of lighting utilised – including height and shielding design
- Specifications of lighting utilised – lighting colour, spectrum, and brightness level
- Additional measures in place in the event that white or non-shielded lighting is required
- Implementation of monitoring plan

Operation Phase

Mitigation measures that should be implemented to minimise the impacts on sensitive receptors for the project area are as follows:

- All unnecessary lights in project area should be turned off
- Use the minimum number and intensity of lights if required for safety and security.
- Retain the hoarding along the edges of Sungei Pang Sua trails and Guided trails to prevent excess light from illuminating the forest.

12.2.3 Residual Impacts

The residual impacts were evaluated using the RIAM method (Table 12.3) with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in the band of Slight Negative.

During pre-construction and construction phase, the main concern across most locations is disturbance to flora and fauna due to construction activities. Following mitigation measures detailed in Section 12.2.2 such as directing lights away from sensitive areas and to keep construction works to daytime working hours, the environment score of these predicted impacts are likely to be in band of No Impact.

During operation phase, the main concern would be the disturbance to flora and fauna due to operational lights. Unlike the previous phases, the lights will be switched off in the night, allowing the impact to be No Impact in nature. Thus, no mitigation measures are required.

RIAM Environmental Scoring for the Residual Impacts

Table 12.3. Environmental Scores of the predicted and residual impacts on site's light levels after implementation of mitigation measures listed in Table 12.2

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace	Disturbance to the flora and fauna in coastal and forested area due to operational lights	1	-1	3	2	1	-6	No Impact	1	-1	3	2	1	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		− Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Disturbance to the flora and fauna in coastal and forested area due to operational lights	1	-1	3	2	1	-6	No Impact	1	-1	3	2	1	-6	No Impact
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Disturbance to the flora and fauna in coastal and forested area due to operational lights	1	-1	3	2	1	-6	No Impact	1	-1	3	2	1	-6	No Impact
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
Public Trail (Profile A)	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Public Trail Boardwalk	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D Option 2)	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
Guided Trail (Profile D Option 2)	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• At-grade pedestrian connection	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• At-grade pedestrian connection	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disturbance to the fauna due to vibration from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Disturbance to the flora and fauna in coastal and forested area due to light from construction activities	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	No predicted impact	-	-	-	-	-	-	-	-	-	-	-	-	-	-

13 WASTE MANAGEMENT

13.1 Introduction

The main impacts related to waste storage, handling, transport, and disposal include:

- Deterioration of the environment (e.g., visual, water quality, biodiversity impacts, increase vectors, contamination etc.); and
- Health and safety risks with regards to hazardous waste if they are not managed properly.

The main sources of potential impacts during the project activities are identified as the following:

- Waste management requirement for cut vegetation (e.g., from site clearance)
- Waste management requirement for excavated material
- Waste management requirement for general waste
- Waste management requirement for hazardous waste
- Waste management requirement for other construction waste

There are legislations implemented and enforced by the Singapore government for management of general and hazardous wastes which are discussed in next section. Table 13.1 provides anticipated types of waste likely to be generated during construction.

Table 13.1. Types of waste likely to be generated during construction phase

Solid Waste Type	Source Activity	Classification
Cut vegetation	Site clearance	Non-hazardous
Excavated material	Excavation	Non-hazardous
Plastic/wooden planks	Packaging material	Mixed
Hazardous waste	Maintenance activity	Hazardous
Scrap metal	Form/temporary work	Non-hazardous
General waste	Construction workers	Non-hazardous

13.2 Relevant Environmental Legislation, Guidelines and Standards

The Environmental Public Health (EPHA) Act, 2002 set up the regulatory framework for waste management through following regulations:

- Environmental Public Health (General Waste Collection) Regulations, 2000
- Environmental Public Health (Toxic Industrial Wastes) Regulations, 2000

The Environmental Public Health (General Waste Collection) Regulations set out the requirements for the management of non-hazardous general waste and the duties of generators and companies collecting such wastes. General waste must be managed in an environmentally sound manner and collected by an NEA-licensed general waste collector.

The Environmental Public Health (Toxic Industrial Wastes) Regulations set requirements for the generation, management, and disposal of wastes characterised as hazardous, such as oily sludge, solvents and asbestos containing materials. NEA has set out a list of specific wastes which are classified as Toxic Industrial Wastes (TIW) under the Schedule of this regulation. Special requirements apply to these TIWs with the key provisions includes appointment of a licensed TIW collection company to collect and treat the waste.

The Code of Practice for ECO stipulates the role of occupiers of construction sites and of the ECO, and their responsibilities pertaining to waste management at construction sites.

13.3 Impact Assessment

13.3.1 Predicted Impacts

RIAM Environmental Scoring for the Predicted Impacts

Table 13.2. Predicted waste management impacts from proposed infrastructure development and restoration works at project area

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="9">Kranji Reservoir Park</td><td rowspan="2">Pre- construction</td><td rowspan="2">• Construction site access
• Construction site boundary
• Storage space
• Temporary working space
• Hoarding</td><td rowspan="2">• Vegetation clearance</td><td>Disposal of vegetation</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td>Disposal of general waste material</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td rowspan="5">Construction</td><td rowspan="5">• Bird sanctuary/Coastal Forest
• Heron rookery
• Lookout shelter
• Pedestrian bridge
• Pedestrian path
• Nature-based Solutions
– Interlocking rings
– Intertidal terrace
– Rain garden</td><td rowspan="5">• Vegetation clearance
• Land-based development with piling
• Revetment
• Shoreline stabilisation
• Restoration of mangrove edge
• Reforestation of coastal forest</td><td>Disposal of vegetation</td><td>2</td><td>-1</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Disposal of excavated material</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td>Disposal of general waste material</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Disposal of hazardous waste</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Human-wildlife conflict</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Operation</td><td rowspan="2">• Bird sanctuary/ Coastal Forest
• Heron rookery
• Lookout shelter
• Pedestrian bridge
• Pedestrian path
• Nature-based Solutions</td><td rowspan="2">• Recreational visitorship
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Litter and plastic pollution</td><td>2</td><td>-2</td><td>3</td><td>2</td><td>3</td><td>-32</td><td>Slight Negative</td></tr>
<tr><td>Human-wildlife conflict</td><td>2</td><td>-3</td><td>3</td><td>2</td><td>1</td><td>-36</td><td>Slight Negative</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		– Interlocking rings – Intertidal terrace – Rain garden									
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative
				Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	1	-3	2	2	2	-18	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Illegal dumping	2	-3	2	2	3	-42	Minor Negative
				Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			• Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Human-wildlife conflict	2	-3	2	2	2	-30	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-3	2	2	3	-28	Minor Negative
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -2, Option 1)	Pre-Construction	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-3	2	2	1	-30	Minor Negative

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Phase</th><th rowspan="2">Proposed Infrastructure</th><th rowspan="2">Planned Activities</th><th rowspan="2">Predicted Impacts</th><th colspan="7">RIAM for Predicted Impacts</th></tr>
<tr><th>I</th><th>M</th><th>P</th><th>R</th><th>C</th><th>ES</th><th>ES Impact</th></tr>
<tr><td rowspan="10">Public Trail (Profile B -2, Option 2)</td><td rowspan="3">Pre-construction</td><td rowspan="3">• Construction site access
• Construction site boundary
• Storage space and working space</td><td rowspan="3">• Vegetation clearance</td><td>Disposal of woody vegetation</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td>Disposal of excavated material</td><td>2</td><td>-2</td><td>3</td><td>2</td><td>2</td><td>-28</td><td>Slight Negative</td></tr>
<tr><td>Disposal of general waste material</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td rowspan="5">Construction</td><td rowspan="5">• Earth trail
• Nature-based Solutions
– Geo bags</td><td rowspan="5">• Vegetation clearance
• Earthworks
• Revetment and placement of geo bags
• Land and intertidal based development</td><td>Disposal of woody vegetation</td><td>2</td><td>-1</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Disposal of excavated material</td><td>2</td><td>-1</td><td>3</td><td>2</td><td>2</td><td>-14</td><td>Slight Negative</td></tr>
<tr><td>Disposal of general waste material</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Disposal of hazardous waste</td><td>1</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-12</td><td>Slight Negative</td></tr>
<tr><td>Human-wildlife conflict</td><td>2</td><td>-3</td><td>2</td><td>2</td><td>2</td><td>-36</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Operation</td><td rowspan="2">• Earth trail
• Nature-based Solutions
– Geo bags</td><td rowspan="2">• Recreational visitorship
• Small vehicle deployment for maintenance works
• Enhancement planting</td><td>Litter and plastic pollution</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>3</td><td>-28</td><td>Slight Negative</td></tr>
<tr><td>Human-wildlife conflict</td><td>2</td><td>-3</td><td>2</td><td>2</td><td>2</td><td>-36</td><td>Slight Negative</td></tr>
<tr><td rowspan="2">Public Trail (Profile C)</td><td rowspan="2">Pre-construction</td><td rowspan="2">• Construction site access
• Construction site boundary
• Storage space and working space</td><td rowspan="2">• Vegetation clearance
• Earthworks</td><td>Disposal of woody vegetation</td><td>2</td><td>-2</td><td>2</td><td>2</td><td>2</td><td>-24</td><td>Slight Negative</td></tr>
<tr><td>Disposal of excavated material</td><td>2</td><td>-2</td><td>3</td><td>2</td><td>2</td><td>-28</td><td>Slight Negative</td></tr>
</table>

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	1	-3	2	2	2	-18	Slight Negative
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-2	2	2	2	-24	Slight Negative
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	1	-1	2	2	2	-6	No Impact
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Hoarding installation	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
				Disposal of excavated material	2	-2	3	2	2	-28	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative
				Disposal of excavated material	2	-1	3	2	2	-14	Slight Negative
				Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative
				Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Litter and plastic pollution	2	-2	2	2	3	-28	Slight Negative
				Human-wildlife conflict	2	-3	2	2	2	-36	Slight Negative
Boundary markers	Pre-construction	• Markers made up of rows of Bakau poles	• Vegetation clearance • Boundary marker installation	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	• Maintenance works	Litter and plastic pollution	2	-2	2	2	2	-24	Slight Negative

Pre-Construction and Construction Phase

Cut Vegetation

As discussed in Chapter 5 (Biodiversity), some trees will be potentially affected during the implementation of this project. Similarly, other vegetation, such as bushes and grassland will need to be cleared within the footprint of the project.

During vegetation clearance, the horticulture waste needs to be properly managed to prevent its unintended disposal to mudflat and mangrove area. The preferred disposal route for this type of material is for the extraction of timber for use in the wood industry where possible. Large stumps will require off-site transport for disposal at local disposal sites. The contractor shall not be permitted to dispose of cut vegetation by burning, as specified in the EPM (Prohibition on Use of Open Fires) Order.

Excavated Material

Due to the nature of construction work involved (i.e., limited excavation at locations where proposed Nature Park features such as trails, pavilions are planned) no significant volumes of spoil are expected to be generated from this project. Surplus excavated material can be used in reinstatement/restoration activities of slope within project area, otherwise it is to be collected by a licensed industrial waste collected for further treatment/ disposal.

Other Construction Waste

Other construction wastes will likely include:

- Broken rock or concrete
- Ferrous and non-ferrous scrap metal items
- Wooden planks, boards, pallets, formwork
- Packaging or wrapping materials such as plastic sheeting, corrugated
- Cardboard, paper
- Sacks and bags
- Metal or plastic containers and cans.

If not managed properly, the storage, handling, transport, and disposal of construction wastes has the potential to result in visual, water, dust, noise and general environmental deterioration. The disposal of construction waste may raise long-term concerns for mangroves and mudflats due to choking, smothering and microplastics. To minimize such impacts, any construction waste would need to be properly disposed, and it is good practice to segregate different categories of construction waste at source to facilitate recycling/disposal. It is expected that general refuse will be handled, stored, managed, and collected for appropriate disposal/treatment in accordance with the EPHA and the EPH (General Waste Collection) Regulations and there shall be no significant adverse impact to the environment.

General Waste

General waste will include debris, litter and wastes generated by the construction workers. The storage and handling of general refuse has the potential to give rise to a variety of adverse impacts. These include odour problems if the waste is not collected regularly (i.e., daily), windblown litter, water quality impacts if waste enters watercourses, visual impacts as well as the attraction of pests, disease vectors and scavenging animals (insects, rodents etc.) to the site if waste materials are incorrectly stored onsite. The number of workers on site and subsequently the estimated volume general refuse is unknown at this time. Quantities of general refuse produced by workers are typically in the range of 0.5 – 1 kg per person per day. It is expected that general refuse will be handled, stored, managed and collected for appropriate disposal/ treatment in accordance with the EPHA and EPH (General Waste Collection) Regulations and there shall be no adverse impact to the environment.

Hazardous Waste

Hazardous wastes include those listed in the EPHA and EPH (Toxic Industrial Wastes) Regulations. Hazardous waste is likely to arise principally as a result of maintenance activities for construction machinery and heavy vehicles at the construction site. Estimates of the quantities of hazardous waste are not available during preparation of this report. Types of hazardous construction waste generated include:

- Waste oils and used oil filters
- Paints and solvent residues
- Off-specification chemicals
- Oily water
- Drums, containers, packaging or wrapping materials, or soil contaminated with the TIW.

Hazardous construction wastes can pose serious environmental problems such as air, water, and land pollution unless they are handled, stored, transported, and disposed of in an appropriate manner. Potential hazards may include:

- Toxic / adverse health effects on the workforce
- Adverse effects on water quality/ surface water resources, soil, and groundwater in the event of spills and leaks
- Fire hazards

The generation of the hazardous construction wastes mentioned above is unavoidable. However, their environmental impact is not expected to raise long-term or irreversible negative effects as hazardous wastes are not routinely generated in big quantities by construction activities. In addition, hazardous waste will not be generated after the construction phase of the Project has been completed. Overall, potential waste management impacts are expected to be of Slight Negative nature, indirect, and local. Duration is anticipated to be short term and reversible as the impact will cease upon completion of the construction activities. As such, mitigation measures to address short-term impacts such as proper disposal of construction waste are recommended to further reduce the potential impacts.

Operation Phase

During its operational phase, the Nature Park should expect users to engage in leisurely strolls, exercise, cycling, birdwatching etc. General wastes such as plastic bottles, food and beverage packaging, tissue paper, brochures, etc. will be expected, and sufficient rubbish bins should be placed along strategic locations in the Nature Park to encourage responsible waste disposal and minimize littering. These bins should be animal proof to prevent animals from rummaging through bins.

Heavy construction vehicles are not anticipated to be used during the maintenance activities of Nature Park. As such, these operation phase activities are not anticipated to generate significant amounts of construction or hazardous waste.

RIAM Environmental Scoring for the Residual Impacts
Table 13.4. summarises the impacts covering of all three areas with their corresponding Environmental Scores before and after the implementation of mitigation measures, which are elaborated in the following section.

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

Overall, the predicted impacts are expected to be mainly Slight Negative across all locations.

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc) are expected. The predicted impacts from these works would be the disposal of woody vegetation from the clearance, excavated material and general waste material generated. Since the area of impact will be restricted to the boundary of the project footprint, as such there will be limited changes in baseline conditions, especially since some areas are already heavily littered in nature. Thus, the predicated impacts are Slight Negative.

During the construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas along the coastline (i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion). The main ecological concerns arising from these works are the disposal of hazardous waste material and human-wildlife conflict in addition to those mentioned before. Other predicted impact would include human-wildlife conflict which would be a derivative of improper management of food wastes. As a result, there would not be much waste impact to the surrounding area, causing the impacts to be Slight Negative in nature.

During the operation phase, no works will be carried out. Regardless, it should be noted that the occurrence of human-wildlife conflicts is expected to increase due to the increased opportunities of wildlife encounters following increased visitorship to the proposed nature park. Also, litter and plastic pollution is expected to be higher than during baseline conditions given that the area will be accessible to public. Since there will be little to No Impacts, the assessment is generally in the Slight Negative range.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

13.3.2 Mitigation Measures

Table 13.3. Waste management impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Disposal of woody vegetation	• To develop solid waste management plan • Timber/wood to be recovered for use in the wood industry as far as possible
	Disposal of excavated material	• To develop solid waste management plan • Surplus excavated material to be reused within project area as fill, landscaping, erosion control and restoration wherever practicable
	Disposal of general waste material	• Scrap metals to be recovered and sent for recycling as scrap • Inert general waste to be collected and disposed through licensed waste collector • All non-hazardous wastes to be handled and disposed of in accordance with EPH (General Waste Collection) Regulations
Construction	Disposal of woody vegetation	• To develop solid waste management plan • Timber/wood to be recovered for use in the wood industry as far as possible
	Disposal of excavated material	• To develop solid waste management plan • Surplus excavated material to be reused within project area as fill, landscaping, erosion control and restoration wherever practicable
	Disposal of general waste material	• Scrap metals to be recovered and sent for recycling as scrap • Inert general waste to be collected and disposed through licensed waste collector • All non-hazardous wastes to be handled and disposed of in accordance with EPH (General Waste Collection) Regulations
	Disposal of hazardous waste	• All hazardous wastes to be handled and disposed of in accordance with EPH (Toxic Industrial Wastes) Regulations • Disposal of hazardous waste to be conducted by a licensed waste collector for hazardous waste
	Human-wildlife conflict	• Establish designated areas for food and waste disposal • Conduct information sessions on what to do upon encountering wildlife • Implement proper use of Personal Protective Equipment (PPE) • Erect hoarding to prevent entry of animals (e.g., wild boars) into the project area • Wild pig management (e.g., trapping) prior to the commencement of tree felling

Phase	Impact Component	Recommended Mitigation Measures
Operation	Litter and plastic pollution	• Set up proper bin system • Incorporate signs including guidelines of proper park behaviour
	Human-wildlife conflict	• Incorporate signs including guidelines of proper park behaviour • Monkey-proof bins should be implemented

Pre-Construction / Construction Phase

The various options within waste management can be categorised in terms of preference from an environmental perspective. The options considered to be preferable have the least impact and are more sustainable in a long-term context. Hence, the hierarchy is as follows:

- Avoidance and minimization, i.e., not generating waste through changing or improving processes.
- Reuse or recycling of materials, thus avoiding disposal.
- Disposed in a safe and appropriate manner through licensed waste collection and disposal contractors.

The following measures are proposed to mitigate the potential waste impacts during the construction phase.

- The construction contractor should be contractually obligated to develop a Solid Waste Management (SWM) plan:
  - To manage the collection, recycling, and ultimate disposal of all generated wastes in an environmentally responsible manner.
  - To include preparation of an inventory of all anticipated waste materials to identify sources of waste that can be reduced or reused, and to formulate storage, handling and disposal procedures for each type of waste.
  - To sensitize all workers, including subcontractors handling construction and hazardous waste regarding the ecologically sensitive nature of Mandai Mangrove and Mudflat area and to train them appropriately.
  - To include emergency control measures/response plan for spillage of construction waste or hazardous materials
- Timber/wood from cut vegetation can be recovered for use in the Nature Park as far as possible.
- Surplus excavated material and inert wastes (soil, broken rock etc.) should be reused within project area as fill, landscaping, erosion control and restoration features wherever practicable.
- Scrap metals (e.g., welding rods, end caps, off-cuts etc.) can be recovered and sent for recycling as scrap.
- Other inert general waste to be collected and disposed of through licensed waste collector.
- General refuse generated on-site must be stored in enclosed bins separate from construction and hazardous waste. A licensed general waste collector shall be employed by the Contractor to remove general refuse, on a daily or every second day basis to minimise odour, pest and litter impacts.
- Chemical toilet facilities to be maintained by licensed waste collector.
- All non-hazardous waste that are generated must be handled and disposed of in accordance with the requirements of the EPHA and the EPH (General Waste Collection) Regulations.
- Any hazardous wastes that are generated must be handled and disposed of in accordance with the requirements of the EPHA and the EPH (Toxic Industrial Wastes) Regulations.
- Disposal of hazardous waste must be through a licensed waste collector for hazardous waste.

The adoption of mitigation measures and construction best practices will bring down the impact to an acceptable level.

Operation Phase

It is expected that NParks rules & regulations will be implemented to encourage users to follow proper waste disposal practices to abide by the rules to not litter and keep the environment clean. Signs and noticeboards would be put up to remind people to keep the Nature Park clean and pristine. The park visitors can be encouraged to join various activities that are organised by the Nature Groups or NParks to carry out coastal clean-up at mudflat & mangrove area to increase awareness in preserving the natural environment and removing the waste from park area.

Overall, the operation impact is assessed to be insignificant, therefore no additional mitigation measure is proposed. Should major maintenance and repair be undertaken during the operation phase, mitigation measures proposed for the construction phase will apply.

13.4 Residual Impacts

The residual impacts were evaluated using the RIAM method (Table 13.4) with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in the band of Slight Negative to No Impact.

During pre-construction phase, the main concern across most locations is disposal of materials and woody vegetation. Mitigation measures such development of solid waste management plans and usage of licensed waste collectors will help to reduce the magnitude of disturbance to shorebirds, thus reducing the environment score from Minor Negative to Slight Negative range band.

During construction phase, on top of disposal of materials and woody vegetation, other predicted impacts across many locations include disposal of hazardous waste and human-wildlife conflict. Following mitigation measures detailed in Section 13.3.2, the environment score of these predicted impacts can be reduced from Minor Negative to Slight Negative range. For example, while the environment score of human-wildlife conflict was assessed to be in Slight Negative range prior to mitigation, mitigation measures such as establishing designated areas for food and waste disposal can reduce the magnitude of impact of human-wildlife conflict such that the final residual environment score are reduced to No Impact range.

RIAM Environmental Scoring for the Residual Impacts

Table 13.4. Environmental Scores of the predicted and residual impacts on site's waste management after implementation of mitigation measures listed in Table 13.3

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	Disposal of woody vegetation	2	-1	2	2	2	-12	Slight Negative	2	-1	3	2	2	-14	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-3	3	2	1	-36	Slight Negative	2	-2	3	2	1	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		− Rain garden															
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		• Nature-based Solutions – Intertidal terrace	Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions – Intertidal terrace	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Public earth trail • Nature-based Solutions	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
		– Biodegradable coir fibre logs	Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Public Trail Boardwalk	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Public Trail (Profile B -2, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Public Trail (Profile B -2, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Geo bags	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Earth trail • Nature-based Solutions – Geo bags	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space • Hoarding	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• At-grade pedestrian connection	Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• At-grade pedestrian connection	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Disposal of vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of excavated material	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Disposal of general waste material	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Disposal of hazardous waste	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Human-wildlife conflict	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Litter and plastic pollution	2	-2	3	2	3	-32	Slight Negative	2	-1	3	2	3	-16	Slight Negative
			Human-wildlife conflict	2	-2	3	2	2	-28	Slight Negative	2	-1	3	2	2	-14	Slight Negative
Boundary markers	Pre-construction	• Markers made up of rows of Bakau poles	Disposal of woody vegetation	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Markers made up of rows of Bakau poles	Litter and plastic pollution	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

14 VECTOR CONTROL

14.1 Introduction

As Singapore has warm tropical climate, the possibility of vector borne diseases is always present. Vectors are organisms that transmit disease. According to NEA, the five main vectors in Singapore and the diseases that they could transmit are summarized in Table 14.1As most vector-borne diseases in Singapore are transmitted by mosquitoes, vector control management shall mainly focus on mosquito control during construction activities.

Table 14.1. Common vectors in Singapore

Vector	Disease
Mosquitoes	– Dengue and Dengue Hemorrhagic Fever – Chikungunya – Zika – Malaria – Japanese Encephalitis – Filariasis
Rat Flea	– Plague
Rodent	– Rat Bite Fever – Leptospirosis – Murine Typhus
Cockroach	– Cholera – Food-Borne Diseases
Fly	– Cholera – Typhoid and Para Typhoid – Salmonellosis – Dysentery

Source: https://www.nea.gov.sg/our-services/pest-control/overview

14.2 Relevant Environmental Legislation, Guidelines and Standards

The Control of Vectors and Pesticides Act, 2002 is the main legislation for control of vectors with the prime objective to prevent related diseases such as dengue fever in Singapore. It aims to prevent the propagation of vectors and stipulates the prohibition of creation of any condition favourable to the propagation and harbouring of vectors. Under Part V of the Act, only companies that are registered with NEA as vector control operators are allowed to be engaged to conduct any vector control treatment or activity. Employees of vector control operators are required to be licensed as vector control technicians or vector control workers to conduct any vector control activity. All public health pesticide/repellent products intended for use against the five vectors (namely rodents, mosquitoes, flies, cockroaches, and rat fleas) must be registered prior to local sales in Singapore as per this Act.

The Environmental Public Health Act, 2002 stipulates requirements pertaining to vector control such as public cleansing, public nuisances, and insanitary premises.
Environmental Public Health Act (Specified Construction Sites) Order 2021, and Code of Practice for Environmental Control Officers which require construction site occupiers

to employ either a part-time or full-time Environmental Control Officer, depending on the contract sum of the construction works. The Code of Practice for Environmental Control Officers sets out requirements on environmental health management of construction sites in the areas of vector control.

14.3 Impact Assessment

14.3.1 Predicted Impacts

RIAM Environmental Scoring for the Predicted Impacts

Table 14.2. Predicted vector control impacts from proposed infrastructure development and restoration works at project area

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre-construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Bird sanctuary/Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace – Rain garden	• Vegetation clearance • Land-based development with piling • Revetment • Shoreline stabilisation • Restoration of mangrove edge • Reforestation of coastal forest	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions – Interlocking rings – Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
		− Rain garden									
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Earthworks • Land-based development with piling • Vegetation clearance • Demolition of existing building	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	• Recreational visitorship • Public vehicle access • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	• Vegetation Clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Earthworks • Land-based development with piling • Demolition of existing building	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	• Recreational visitorship • Small vehicle deployment for maintenance works • Artificial light at night • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Public Trail (Profile A)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Vegetation clearance • Earthworks • Backfilling • Land and intertidal based development • Removal of PCG fence and concrete slab • Slope stablisation & erosion control	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions – Biodegradable coir fibre logs	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Public Trail (Profile B -1)	Pre-constructio	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	• Earthworks - Slope cut at gradient of 1:5 • Land and intertidal based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Public Trail Boardwalk	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Public Trail (Profile B -2, Option 1)	Pre-constructi	• Construction site access • Construction site boundary • Storage space and working space	• Earthworks • Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions − Interlocking rings	• Installation interlocking rings along mangrove edge to facilitate mangrove regeneration and slope stabilisation. • Earthworks • Backfilling • Revetment and placement of interlocking rings • Land and intertidal based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Earth trail • Nature-based Solutions − Interlocking rings	• Recreational visits • Small vehicle deployment for maintenance works	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Public Trail (Profile B -2, Option 2)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth trail • Nature-based Solutions – Geo bags	• Vegetation clearance • Earthworks • Revetment and placement of geo bags • Land and intertidal based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Geo bags	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Public Trail (Profile C)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Earthworks	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Elevated Boardwalk	• Vegetation clearance • Earthworks • Land and intertidal based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk	• Recreational visitorship • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space •	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Guided Trail (Profile D Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construc tion	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Vegetation clearance • Earthworks-backfilling • Land and intertidal based	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
			development	Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	• Recreational visits • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	• Vegetation clearance	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• At-grade pedestrian connection	• Clearance of existing path • Exotic vegetation clearance • Landscape enhancement	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• At-grade pedestrian connection	• Recreational visitorship • Small vehicle deployment for maintenance works • Generation of litter • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Planned Activities	Predicted Impacts	RIAM for Predicted Impacts						
					I	M	P	R	C	ES	ES Impact
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	• Vegetation clearance • Hoarding installation	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	• Vegetation clearance • Land based development	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative
				Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	• Recreational visits • Small vehicle deployment for maintenance works • Enhancement planting	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative
				Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative

Pre-construction and Construction Phase

The main impact is the potential to cause an increase in the vector population within project area and in surrounding areas during construction stage.

An increase in vectors may be caused by:

- Pooled water on the construction site (e.g., potholes, access roads with puddles, equipment)
- Storage of water on the construction site (e.g., water for washing)
- Storage and improper management of garbage and food waste
- Creation of stagnant conditions during drainage diversion
- Entrainment of debris, refuse and silts in stormwater run-off resulting choked drains and stagnant drainage
- Poor cleanliness and unsanitary conditions

The assessment of the potential impacts is described below.

Increase in Number of Mosquitoes

Project construction activities have the potential to create suitable breeding conditions for mosquito populations. Specifically, without control measures construction work can create pools of water due to site conditions (e.g., vehicle potholes), construction work (e.g., trenches) and storage of equipment and wastes favouring the breeding of mosquito populations. The likelihood of mosquitoes breeding without control measures in place is high.

Increase in Number of Other Vectors

During the construction, construction personnel will generate domestic waste and food waste that if not managed, can attract other vectors (e.g., rats, flies and cockroaches). A lack of correct and secure disposal of these wastes would create suitable breeding conditions for these vectors. The likelihood of rats, flies and cockroaches breeding without control measures in place is high.

Fleas require a host (e.g., rodents or other mammal) to breed and therefore fleas are considered to be directly relevant to the construction of the Project. With control of other vectors, fleas and related diseases are not likely to occur.

Increase in the Incidence of Dengue-Fever and Other Vector-related Diseases

If the number of mosquitoes increase in the construction works areas, the likelihood of a dengue outbreak occurring in the vicinity of the project can increase. Therefore, it is important to prevent mosquitoes breeding at the construction works areas. The industrial area is in the immediate surrounding of the project area. Hence occupiers of these premises can be exposed to vectors if proper control measures are not implemented.

If the number of rats, flies and cockroaches increases in the construction works areas, the likelihood of nuisance issues and vector-related diseases could increase. The impacts associated with these vectors can quickly change from nuisance to vector-disease levels. Rats can cause diseases and damage equipment.

Overall, potential impacts are expected to be of a Slight Negative nature, indirect, and local. Duration is anticipated to be short term and reversible as the impact will cease upon completion of the construction activities. As such, mitigation measures are recommended to further reduce the potential impacts.

Operation Phase

During the Operation phase of the project, pools of water may still be formed in areas where earth levels are not even. This could create potential breeding conditions for mosquito populations, leading to a high likelihood of mosquitoes breeding if there are no control measures in place.

Table 14.4 summarises the impacts with their corresponding Environmental Scores before and after the implementation of mitigation measures, which are elaborated in the following section.

Overall Impact

This section aims to assess the predicted impacts by applying the RIAM scoring of the proposed development features according to its location.

Overall, the predicted impacts are expected to be mainly Slight Negative across all locations.

During the pre-construction phase, only minor works (i.e., clearance for working space, create site access and setting up of hoardings etc) are expected. The predicted impacts from these works would be the disposal of woody vegetation from the clearance, excavated material and general waste material generated. Since the area of impact will be restricted to the boundary of the project footprint, as such there will be limited changes in baseline conditions, especially since some areas are already heavily littered in nature. Thus, the predicated impacts are Slight Negative.

During construction phase, heavy construction works (i.e., piling and demolition) will be carried out especially in the planned infrastructure areas i.e., Kranji Reservoir Park, Sungei Kranji Pavilion and Sungei Pang Sua Pavilion along the coastline. The main ecological concerns arising from these works are the increase in mosquitoes and rodent that may arise from improper disposal.

During the operation phase, no works will be carried out. Regardless, it should be noted that the litter and plastic pollution is expected to be higher than during baseline conditions given that the area will be accessible to public. Since there will be little to No Impacts towards biodiversity, the assessment is generally in the Slight Negative range.

Proposed mitigation measures will aim to lower the predicted impacts such that changes to baseline conditions will be kept to Slight Negative and below.

14.3.1 Mitigation Measures

Table 14.3. Vector control impact components and their respective mitigation measures

Phase	Impact Component	Recommended Mitigation Measures
Pre-construction	Increase in the number of mosquitoes	• Contractor to engage an NEA-registered vector control operator to prepare and implement vector management plan • An in-house vector control team to check construction sites for breeding of mosquitoes • Construction worksite to be kept free of litter; construction wastes shall be disposed promptly into bulk waste containers and the containers shall be emptied daily
	Increase in the number of other vectors (e.g. flies and rodents)	• Worksite shall be kept litter-free and refuse bins shall always be covered tightly. • Construction workers' food provisions shall be stored in rodent-proof rooms or cabinets • In-house vector control team and vector control operator to check for rodent burrows every week
Construction	Increase in the number of mosquitoes	• Contractor to engage an NEA-registered vector control operator to prepare and implement vector management plan • An in-house vector control team to check construction sites for breeding of mosquitoes • Construction worksite to be kept free of litter; construction wastes shall be disposed promptly into bulk waste containers and the containers shall be emptied daily
	Increase in the number of other vectors (e.g. flies and rodents)	• Worksite shall be kept litter-free and refuse bins shall always be covered tightly. • Construction workers' food provisions shall be stored in rodent-proof rooms or cabinets • In-house vector control team and vector control operator to check for rodent burrows every week
	Increase in incidence of dengue fever and vector-related diseases (secondary impact)	• To implement mitigation measures to control mosquito numbers and other vectors • To aid the authorities to investigate outbreaks of vector-borne diseases if required
Operation	Increase in the number of mosquitoes	• Contractor to engage an NEA-registered vector control operator to prepare and implement vector management plan • An in-house vector control team to check construction sites for breeding of mosquitoes • Construction worksite to be kept free of litter; construction wastes shall be disposed promptly into bulk waste containers and the containers shall be emptied daily
	Increase in the number of other vectors (e.g. flies and rodents)	• Worksite shall be kept litter-free and refuse bins shall always be covered tightly. • Construction workers' food provisions shall be stored in rodent-proof rooms or cabinets • In-house vector control team and vector control operator to check for rodent burrows every week

Pre-construction / Construction Phase

Increase in Number of Mosquitoes

It is essential that the construction contractor proactively implements vector control plan with appropriate requirements. Source reduction and effective drainage are proposed to be the main forms of mosquito control, with the following mitigation measures to be implemented:

- Before construction commences, the construction contractor shall engage a vector control operator registered with NEA to prepare and implement vector management plan.
- Before construction starts, a Vector Management Plan shall be submitted to NEA.
- The construction contractor shall form an in-house vector control team to check construction sites for breeding of mosquitoes.
- During the daily checks, particular attention shall be made to discarded receptacles and building wastes; building materials, canvas sheets, equipment and machinery; puddles on the ground levels; water storage drums, tanks and containers; bulk storage containers; trenches; lift wells; drains and channels temporarily constructed to drain off water; air handling units and air conditioners; and flat roofs of temporary buildings.
- Empty receptacles, pails, basins, and other containers shall be kept indoors.
- Construction worksite shall be kept free of litter; construction wastes shall be disposed promptly into bulk waste containers and the containers shall be emptied daily.
- Building materials shall be stored under shelter as far as practicable; materials shall be stored at least 60 cm above the ground to allow water collected below to be treated by the vector control operator.
- Air-handling units shall be stored under shelter or the overflow pipe shall be uncapped to allow rainwater to drain out.
- Stagnant water shall be pumped from the works areas and ground depressions shall be covered with earth.
- Anti-mosquito oil and insecticides including BTI shall be applied into stagnant water at least once a week. The application should be repeated after rain as the oil and insecticides would be washed away by the rain.
- Any significant increase in numbers of vectors shall be reported to the NEA and investigated.

Thermal fogging shall not be carried out due to the location of project area adjacent to a forested area.

Increase in Number of Other Vectors

Rats, flies and cockroaches shall also be targeted for active preventative measures to reduce their breeding habitats (waste disposal areas and wet areas). General cleanliness and waste disposal protocols will control these vector populations and worker hygiene can help reduce insect attraction. The following mitigation shall be implemented:

- The worksite shall be kept litter-free and refuse bins shall always be covered tightly.
- Construction workers' food provisions shall be stored in rodent-proof rooms or

cabinets.

- All food items shall be adequately covered and stored at least 60 cm above the ground.
- The in-house vector control team and the vector control operator should check for rodent burrows every week. Active burrows should be treated with rodenticides for three consecutive days or until the rats are all dead (i.e., no more dead rats found), and then sealed with compacted earth.
- Sanitary waste/domestic waste should be removed from the site in accordance with Singapore's legislation promptly.
- Any significant increase in numbers of vectors shall be reported to the NEA and investigated.

Increase in the Incidence of Dengue-Fever and Other Vector-related diseases

The mitigation to control mosquito numbers and other vectors will mitigate this secondary impact on increase of dengue. Additionally, the following mitigation is proposed:

- During construction, vector control shall be undertaken as per the NEA Guidebook for "Scope of Works for Mosquito Control".
- If required, assistance shall be provided to the authorities to investigate outbreaks of vector-borne diseases at the construction site.
- Weekly monitoring of the NEA's dengue cluster map shall be undertaken to determine if the workers at construction areas are at risk.

With the implementation of the mitigation measures proposed, it is expected that the impacts can be reduced along with the potential for vector borne diseases.

Operation Phase

To prevent the increase of mosquitoes, the following mitigation measures should be implemented:

- Empty receptacles, pails, basins and other containers shall be kept indoors.
- Area shall be kept free of litter; construction wastes shall be disposed promptly into bulk waste containers and the containers shall be emptied daily.
- Building materials shall be stored under shelter as far as practicable; materials shall be stored at least 60 cm above the ground to allow water collected below to be treated by the vector control operator.
- Stagnant water shall be pumped from the works areas and ground depressions shall be covered with earth.
- Anti-mosquito oil and insecticides including BTI shall be applied into stagnant water at least once a week. The application should be repeated after rain as the oil and insecticides would be washed away by the rain.
- Any significant increase in numbers of vectors shall be reported to the NEA and investigated.

Thermal fogging shall not be carried out due to the location of project area adjacent to a forested area.

14.4 Residual Impacts

The residual impacts were evaluated using the RIAM method with due consideration that the recommended mitigation measures are implemented by the Contractor. The residual impacts are likely to be in the band of Slight Negative to No Impact and considered acceptable.

During pre-construction phase, the main concern across most locations is increase of mosquitoes and other vectors. Mitigation measure such as engaging vector control operators and having in-house vector control teams will help to reduce the number of mosquitoes and other vectors, thus reducing the environment score to a lower score in the Slight Negative range band.

During construction phase, on top of the increase in number of mosquitoes and other vectors, other predicted impacts across many locations include increase in incidence of dengue fever and vector-related disease as a secondary impact. Following mitigation measures detailed in Section 14.3.1, the environment score of these predicted impacts can be reduced from Slight Negative to No Impact range. For example, while the environment score of the increase in the number of other vectors was assessed to be in Slight Negative range prior to mitigation, mitigation measures such as storing workers' food provisions properly can reduce the magnitude of impact of sediment dispersion such that the final residual environment score are reduced from Slight Negative to No Impact range.

Similar to the previous phases, during operation phase, the main concern across most locations is the increase in the number of mosquitoes and other vectors. Mitigation measures such as keeping the area litter-free can help reduce the magnitude of impact such that the residual environment score are reduced to a lower score in the Slight Negative range.

RIAM Environmental Scoring for the Residual Impacts

Table 14.4. Environmental Scores of the predicted and residual impacts on site's vector control with mitigation measures listed in Table 14.3

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Kranji Reservoir Park	Pre- construction	• Construction site access • Construction site boundary • Storage space • Temporary working space • Hoarding	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions − Interlocking rings − Intertidal terrace − Rain garden	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Bird sanctuary/ Coastal Forest • Heron rookery • Lookout shelter • Pedestrian bridge • Pedestrian path • Nature-based Solutions − Interlocking rings − Intertidal terrace − Rain garden	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
Sungei Kranji Pavilion	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• 2-storey pavilion • Public amenities • Viewing gallery • Parking lots • Coach drop-off	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Sungei Pang Sua Pavilion	Pre- construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Lookout viewing tower. • Interpretive Gallery with office • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Lookout viewing Tower. • Interactive Gallery with office. • Public amenities • Experiential walk trail • Nature-based Solutions − Intertidal terrace	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Public Trail (Profile A)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Public earth trail • Nature-based Solutions − Biodegradable coir fibre logs	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Public Trail (Profile B -1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Boardwalk (using existing PCG fence footing as foundation)	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Public Trail Boardwalk	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Public Trail (Profile B -2, Option 1)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth trail • Nature-based Solutions – Interlocking rings	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Earth trail • Nature-based Solutions – Interlocking rings	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Public Trail (Profile B -2, Option 2)	**Pre-construction**	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Earth trail • Nature-based Solutions − Geo bags	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Earth trail • Nature-based Solutions − Geo bags	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Public Trail (Profile C)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Elevated Boardwalk	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• Elevated Boardwalk	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Guided Trail (Profile D, Option 1)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Earth Trail (1.5m wide) at edge of back mangrove	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Earth Trail (1.5m wide) at edge of back mangrove	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Guided Trail (Profile D, Option 2)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Construction	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Elevated Boardwalk (1.5m wide) in back mangrove zones	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Kranji Reservoir Dam (Profile E)	Pre-construction	• Construction site boundary • Storage space and working space	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• At-grade pedestrian connection	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative

Location	Phase	Proposed Infrastructure	Impact Component	RIAM for Predicted Impacts							RIAM for Residual Impacts						
				I	M	P	R	C	ES	ES Impact	I	M	P	R	C	ES	ES Impact
	Operation	• At-grade pedestrian connection	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative
Sungei Pang Sua Trail (Profile F)	Pre-construction	• Construction site access • Construction site boundary • Storage space and working space • Hoarding	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
	Construction	• Trail (1.5m wide) 2 - 6m from back mangrove	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	2	2	2	-12	Slight Negative	1	-1	2	2	2	-6	No Impact
			Increase in incidence of dengue fever and vector-related diseases (secondary impact)	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
	Operation	• Trail (1.5m wide) 2 - 6m from back mangrove	Increase in the number of mosquitoes	2	-2	2	2	2	-24	Slight Negative	2	-1	2	2	2	-12	Slight Negative
			Increase in the number of other vectors (e.g. flies and rodents)	1	-2	3	2	2	-14	Slight Negative	1	-1	3	2	2	-7	Slight Negative

15 ENVIRONMENTAL MANAGEMENT & MONITORING PLAN FRAMEWORK

15.1 Overview

The Environmental Management and Monitoring Plan (EMMP) is a systematic approach to mitigate environmental impacts and monitor the implementation of these mitigation measures to ensure that project implementation will not cause any significant adverse impact to the site and the surrounding environment. It is also a useful tool to assess whether the mitigation measures taken are effective to reduce or mitigate the potential impacts caused by this project to minimal levels during the construction.

The EMMP framework presented in this Chapter is an outcome from the EIA process. This EMMP framework consolidates the mitigation and monitoring strategy required for this project and appointed Contractor shall adhere to this strategy, develop it further and implement throughout during the construction phase.

15.2 Construction EMMP

Before the construction works start, the appointed Contractor and Environmental Consultant will establish a detailed Construction EMMP (CEMMP) based on this EMMP framework, which is to be implemented and monitored during the construction phase. The CEMMP shall be submitted by the Contractors prior to the start of any construction activities. The Contractor shall be responsible for submitting and obtaining approval for CEMMP from NParks and other relevant Technical Agencies before commencement of works. The CEMMP shall also cover all site investigation works (e.g., soil investigation, trial trenching, etc.), and constructions works including temporary works.

The CEMMP is to include the identified mitigation measures of this EIA and shall address the methodologies of the construction works prior to their commencement. Additionally, the Wildlife Management Plan and Flora Management Plan recommended in this Chapter need to be incorporated into the CEMMP. Biodiversity specialists (if any) from the Contractor's EMMP team shall be involved to finetune and implement ecological mitigation measures recommended in this report. The CEMMP should also include waste management practices including restricting use & spillage of chemicals during construction phase into surrounding forested area.

The CEMMP shall include environmental monitoring comprising of compliance inspections for prescribed mitigation measures and ambient environmental data collection, generally requiring sample collection and analysis. The environmental monitoring activities should also ensure that the project does not cause any significant long-term environmental impacts, particularly cumulative impacts, and that the existing environmental conditions and biodiversity are maintained.

Monthly environmental monitoring reports with all monitoring results (compliance and ambient monitoring), identified problems and additional actions taken to mitigate these problems should be prepared and submitted to the relevant authorities during the construction phase. Each subsequent monthly monitoring report should report on successful or failed follow-up actions until a problem has been effectively mitigated.

Table 15.11 provides the overview of recommended EMMP measures for this project which is to be incorporated into the CEMMP by the Contractor. The environmental monitoring locations are to be finalised by the EMMP team during CEMMP formulation in consultation with relevant stakeholders.

15.2.1 EMMP Team

The contractors shall be responsible for implementing all the environmental requirements specified in this EIA report including CEMMP conditions as well as requirements mandated by the applicable regulations and relevant authorities. It is recommended that to implement the CEMMP, an EMMP team having the necessary qualifications and experience shall be available throughout the construction period up to 6 months post-construction to support the Contractor. The EMMP team should include but not limited to the following:

Table 15.1. Roles and responsibilities of EMMP team members

Role Name	Qualification	Responsibilities
Environmental Manager/ Environment Control Officer (ECO)	Valid registration with the National Environment Agency (NEA) and demonstrated previous work experience in developments of similar size or complexity.	To act as CEMMP in-charge and lead the implementation and reporting requirements of CEMMP during construction phase. Responsible for managing all environmental issues arising from the construction work which includes the monitoring and ensuring the implementation and management of change of the CEMMP, the environmental performance of the project, investigation of incidents, inspections of site and implementing corrective/ preventive measures. To coordinate with other EMMP team members for advice on specific issues related to CEMMP implementation. To prepare monthly environmental performance monitoring reports.
Qualified Erosion control Professional (QECP)	Valid registration with the Institution of Engineers Singapore (IES)	To prepare, submit, and obtain approval for Earth Control Measures (ECM) Plan from PUB prior to contractors start work. To ensure that the contractors implement the ECM in compliance with the ECM Plan.
Arborist/ Flora Specialist	Certified Arborist (CA) with an International Society of Arboriculture (ISA) certification with 5 years'	To prepare project area specific flora management plan as part of CEMMP, utilising the EMMP framework recommended in the EIA and assist contractor in obtaining authority approval. To review the flora that will be affected, and to provide monitoring and advice to the contractor on matters related to

Role Name	Qualification	Responsibilities
	experience.	transplantation and reinstatement. To visit the site regularly to oversee the implementation of flora management plan and to provide biodiversity awareness training to site personnel. To advise and implement specific measures in the case of tree pruning prior clearance, tree injury, and construction activities affecting tree roots. To provide checks on Tree Protection Zone (TPZ). To assist in reporting requirements of CEMMP during construction phase. To liaise with NParks on addressing any comments/ requirements related to flora implementation measures.
Ecologist / Wildlife Specialist	At least 5 years' experience in wildlife in Singapore and/or the region	To prepare project area specific fauna management plan as part of CEMMP, utilising the EMMP framework recommended in the EIA and assist contractor in obtaining authority approval. To conduct a pre-clearance wildlife inspection and prepare wildlife management protocols as necessary during site clearance stage. To provide advice and inspection related to wildlife throughout the construction duration and to identify, rescue & manage any trapped and/or injured wildlife at project area. To visit the site regularly to oversee the implementation of fauna management plan and to provide biodiversity awareness training to site personnel. To assist in reporting requirements of CEMMP during construction phase. To liaise with NParks on addressing any comments/ requirements related to wildlife implementation measures.
Earth Control Measures Officer (ECMO)	Valid IES registration	The ECMO is responsible to implement all ECM requirements in compliance with the ECM Plan approved by PUB.

15.2.2 Environmental Objectives

Environmental Objectives for the project are recommended below. Contractors are required to adhere to the Environmental Objectives during the entire construction stage.

- Minimise removal of conservation significant flora species at or adjacent to worksite.
- Maximise harvesting of saplings, and transplant of conservation significant flora species that will be affected.

- Prevent risk of fauna injury related to construction such as from fauna re-entry to worksite.
- Prevent human – wildlife conflicts at or near to worksite.
- Ensure retained, translocated, and planted flora's health.
- Ensure noise impacts comply with adjusted Maximum Permissible Noise Limits.
- Ensure water quality impacts comply with PUB and NEA allowable limits for trade effluent quality.
- Ensure no transmission of vector borne disease.
- Ensure no indiscriminate / illegal disposal of waste.
- Ensure no spillage / leakage of hazardous material.

15.2.3 Training Requirements

The site personnel involved in the implementation of CEMMP shall be adequately trained. Training needs assessment shall be conducted regularly and should include the concerned sub-contractors also. The contractors shall ensure that training is conducted before the starting the construction work and at a regular interval during construction phase for the site personnel. The recommended training program is provided in Table 15.2.

Table 15.2. Training Programme for Site Personnel

Training Schedule	Training Topics	Conducted by	Target Audience	Frequency
Prior to commencement of activities on site	CEMMP Requirements Biodiversity & Environmental Awareness	EMMP Consultant	Environmental Manager/ ECO/ Project Manager / Construction Manager/ Construction Engineers/ Site Supervisors/ Sub-contractors	Once
Refresher training	Biodiversity & Environmental Awareness Briefing	CEMMP In-charge/ ECO	Site Personnel including Sub-contractors	Every six months during construction phase
Toolbox meetings	Briefing to include reminders on wildlife encounters and environmental protection	CEMMP In-charge/ ECO	Construction Workers including Sub-contractors	Daily

15.2.4 Environmental Emergency Response Procedure

The regular and continual environmental monitoring may result in observations of failed or inadequate mitigation measures. Also, a public complaint/ observation may be received. Examples of environmental emergencies are described below.

- Incident related to human – wildlife conflict
- Discovery of wildlife within construction site
- Incident of injury to wildlife due to work activity
- Damage to retained/ translocated flora
- Earth control measures (i.e., silt fence, cut-off drain, treatment) are ineffective
- Discharge of ECM does not meet regulatory limits
- Illegal water discharge from construction site
- Noise levels from construction activities exceed maximum permissible limits.
- Dust event due to dry weather conditions and high winds.
- Release of hazardous materials to land and watercourse
- Illegal disposal of waste into forested area.
- Community complaint relating to pollution

In the event that a failure is discovered that failure must be reported to the CEMMP In-charge/ Project Manager within the shortest possible time. The CEMMP In-charge/ Project Manager will be responsible for ensuring adequate follow-up activities. This may include:

- Consultation with the EMMP specialists/ QECP/ VCO/ PRO.
- Arranging an immediate appropriate response on guidance of EMMP Specialists/ QECP/ VCO as necessary.
- Reporting and consultation with the relevant authorities (i.e., NEA, NParks, PUB) as required.

The emergency response flowchart in handling environmental emergency is presented in Figure 15-1. In the event of violation of relevant standards/ regulations, it is recommended that site environmental management practices are reviewed immediately, and the appropriate mitigation action taken immediately to reduce impacts to acceptable levels.

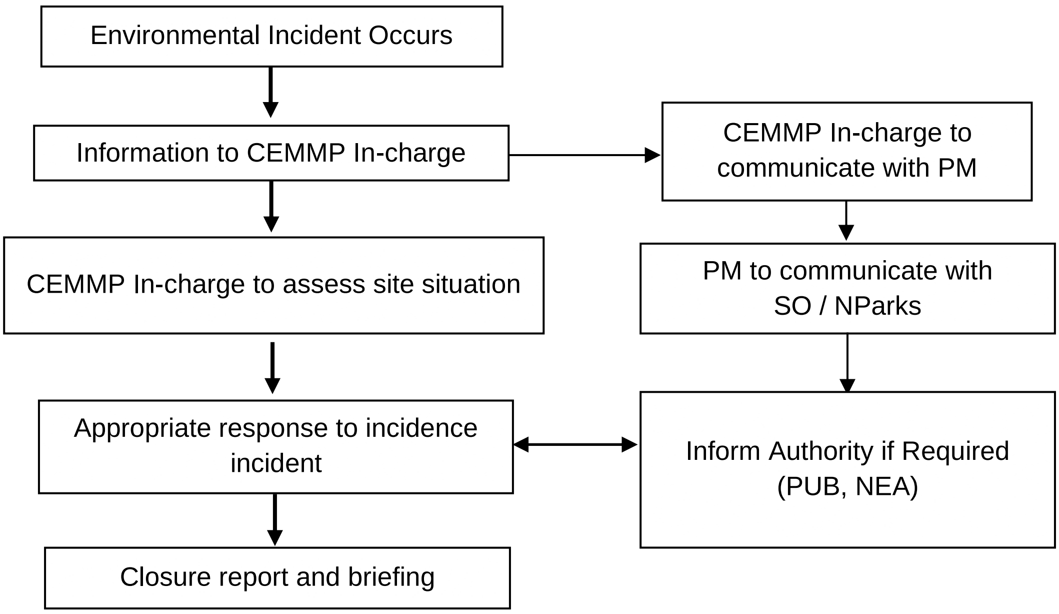

Figure 15-1. Environmental incidence reporting flowchart

15.2.5 EMMP Reporting and Documentation

Site Environmental Control Report by Environmental Control Officer

As per the Code of Practice for Environmental Control Officers for Construction Sites, ECO shall prepare the Site Environmental Control Programme before work commences at the worksite. Further, ECO shall submit the Site Environmental Control Report (SECR) to Project Manager covering assessment of the environmental efforts carried out and review the effectiveness of these measures.

The ECO shall inspect the construction activities regularly and routinely to ensure that the appropriate environmental protection and pollution control mitigation measures are properly and timely implemented based on the CEMMP's recommendations. ECO shall record all observations and actions taken to report them in the SECR. This SECR should form part of the CEMMP monthly performance report described in the next section.

Monthly Environmental Performance Report

A monthly Environmental Performance Report is to be prepared by CEMMP In-charge in assistance with EMMP Team and to be submitted to NParks project management team, NParks, and other relevant authorities. The Environmental Performance Report is to include the description of the project activities being carried out at site during the month and the status of CEMMP implementation including information on environmental incidence if any. Table 15.3 provides the monthly environmental performance reporting framework.

Table 15.3. Monthly Environmental Performance Report framework

Sr. No.	Item	Description
1.	Project Status	Update on project activities within project area
2.	CEMMP Implementation Status	Daily observations and actions taken, ECO report, ECM performance checklist, Biodiversity specialists' observations and recommendations, Physical monitoring results (Noise, Air, Surface water quality, ECM discharge) and assessment, Vector control report, Waste disposal record
3.	Environmental Awareness Training	Record of periodic biodiversity awareness training/ toolbox briefings
4.	Environmental Incidence	Environmental Incident report and corrective actions, public feedback & response
5.	Authority Inspection & Findings	Record of Authority inspection visits (i.e., NParks, NEA, PUB) and corrective actions

Environmental Close-off Report

A final environmental close-off report should be prepared after construction work is completed to confirm that no residual impacts are observed. Post-construction monitoring should be carried out for up to 6 months.

15.3 Wildlife Management Plan

Given the location of the site within forested and mudflat habitats of significant conservation value, it is necessary to minimise impacts to fauna species on the site. The development of a proper Wildlife Response and Rescue Plan will help to reduce impacts to fauna, while also reducing the risk of human-wildlife conflict, which may pose a human health and safety issue if not managed.

Wildlife management should commence prior to construction works. This is to ensure that animals within the site are safely moved outside the working boundaries, either by passive shepherding or active relocation. A Wildlife Rescue and Response Plan should then be put in place for the duration of the construction period for animals that may get trapped or injured within the construction site. Regular inspections should be conducted throughout the construction phase to ensure no fauna is trapped or injured at the worksite.

All construction personnel are to be sufficiently trained on biodiversity issues on the site and how to respond to sightings of fauna.

Additionally, the Contractor shall engage an NParks Certified Animal Management Specialist that can be mobilised immediately when the Consultant's CEMMP Ecologist recommends the relocation of fauna species at any stage during the project. The Animal Management Specialist must be a third-party contractor that has been given approval from the Director-General of Wildlife Management to conduct specific activities that are restricted by the Wildlife Act.

15.3.1 Biodiversity Awareness Training

Prior to any construction activities, all construction personnel are to attend a biodiversity awareness training by the EMMP consultant. This training should impart important information on the ecological importance of the site, and the importance of minimising impacts to the natural environment. Also, they should be trained to recognize common fauna species, and what to do should they encounter any wildlife.

After the initial training, refresher training and toolbox briefings are to be conducted as specified in Section 15.2.3.

15.3.2 Wildlife Management during Clearance

Wildlife management during tree clearance is a requirement for the project area. In areas where vegetation is relatively thick, directional clearance shall be recommended to allow for the passive shepherding of mobile fauna species. In addition, active relocation of animals found within the project area may be required for other species. This is done to:

- Minimise the risk of road hazards and kills from the terrestrial fauna that are displaced from the project area onto adjacent roads.
- Minimise the risk of human-wildlife conflict from animals remaining within the

project boundaries.
- Encourage wildlife movement into designated forested areas located outside of the project area's boundary.

Site clearance to be conducted in the following steps:
- Setting up of Tree Protection Zones (TPZs) for trees to be retained
- Trapping of wild boars at identified hotspots, if necessary
- Inspection of trees, tree holes, and burrows for fauna, and relocation by qualified agencies and/or specialists
- Clearing of undergrowth and felling of trees.

15.3.3 Target Species

A list of target fauna species has been developed based on the findings of the EIA. Besides species encountered during the baseline surveys, other probable species that exist on the site were also included. This list was developed with the following considerations:
- probable presence of species in the Project area prior to construction;
- risks to species from being in close proximity to construction activities;
- practicality of relocating species from the construction site;
- conservation significance of species; and
- risk of road kills, road hazards, and/or human-wildlife conflict arising from uncontrolled species displacement from the project area.

The target species in the list in Table 15.4 have been categorized into two groups depending on their habits, and thus the approach required for wildlife shepherding. Fauna species in the first category are in general highly mobile species in which a passive approach is recommended, while fauna species in the second category are less mobile and would require a more active approach to shepherding.

Table 15.4. List of identified target species

Category	Species	Active Hours
Passive Shepherding	Long-tailed macaque Common palm civet Smooth-coated otter	Diurnal Nocturnal Diurnal
Capture-and-release	Black spitting cobra Reticulated python Clouded monitor Malayan water monitor Other snake species	Diurnal Nocturnal Diurnal Diurnal Diurnal and nocturnal

For wild pigs found at or around the site at any time during the project, NParks is to be informed as soon as possible at nparks_wildlife_management@nparks.gov.sg for advice and subsequent action. An approved wild pig removal contractor must also be engaged to trap and remove the said animals, the process of which may take about 4 to 8 weeks.

15.3.4 Approach to Wild Pig Management

During the baseline surveys, wild pigs were observed within the project area. Wild pig management may be considered prior to the commencement of works to reduce human-wildlife conflict.

Three areas within the project boundary were identified as wild pig hotspots. These locations were identified based on the camera trapping results. While the number of sightings is not representative of the number of wild pig individuals, the higher number of wild pig sightings indicate areas where wild pigs are more likely to be present, and thus potential areas where wild pig management can be conducted.

If trapping is necessary, it must be conducted by an approved wild pigs removal contractor. The process shall also be given a period of 4 to 6 weeks prior to the commencement of tree felling.

Figure 15-2. Identified locations of wild pig hotspots

15.3.5 Methodology and Approach

Tree clearance should only be conducted during scheduled daylight hours (8am to 6pm). It may include a combination of the following activities:

- Installation of TPZs around all retained trees to clearly distinguish the trees to be felled and retained;
- Installation of hoarding along Sungei Pang Sua which would help to guide target terrestrial fauna in the intended direction of movement and as a barrier to prevent wildlife displacement onto surrounding roads;
- Careful survey to check for the presence of target fauna species and any active

nests or dens;

- Tree clearance of affected trees in the site;
- Tree clearance to be conducted in a systematic pattern along Sungei Pang Sua to encourage wildlife to move in an intended direction towards adjacent refuge habitats.

Prior to any tree felling, the site is to be inspected by an ecologist to ensure that no target fauna and active nests or dens remain. The wildlife inspection prior to tree felling and vegetation clearance will also check for any entrapped animals within the area to be cleared. This inspection will be valid for 7 days only, during which the trapped animals have to be secured away from the site and clearance must be conducted. If more than 7 days have passed and site clearance is not done yet, the inspection should be carried out again.

In the event that any target fauna listed in Table 15.4 are encountered during this process, the following actions which have been developed with the consideration of reducing stress to fauna while ensuring the effectiveness of the exercise shall be taken:

Passive Shepherding: These are highly mobile species where passive shepherding is likely to be effective. When species in this category are encountered, personnel should allow the animal to move on its own accord. If necessary, personnel may talk loudly or make some noise by clapping their hands together to encourage the animal to move. If any individual fauna does not move on its own after sufficient time (i.e., up to one hour) has passed, the EMMP team is to decide on whether to call NParks Animal Response Centre or ACRES for the appropriate removal of the animal.

Should the team encounter a visibly injured animal, NParks Animal Response Centre or ACRES should be called immediately for the next course of action.

No attempt should be made by the EMMP team, workers, or other unqualified personnel at any point to handle animals on site. Handling animals without appropriate certification is illegal under the recent Wildlife Act of June 2020.

Capture-and-release: Species in this group are less mobile and/or venomous, and a passive shepherding approach is deemed to be ineffective and/or unsafe. A capture-and-release approach will be needed to ensure safe relocation of these fauna from the site prior to construction. In the event that these species are encountered, NParks Animal Response Centre or ACRES should be called immediately for the next course of action. Capture-and release of animals encountered should be conducted by an NParks' licensed animal management company.

For trees that are subjected to removal, it is necessary to check for the presence of fauna species before each individual tree is felled.

The ecologist shall inspect the tree for the presence of fauna, including birds, bats, arboreal mammals, and herpetofauna. The ecologist should do the following:

- Check the crown of the tree for bird nests

- Check along the trunk from the bottom up for holes in which animals could be nesting
- Scan the trunk and all the branches for animals using the tree
- Scan the ground for potential nests, eggs, or burrows

Photographs of all nests, tree holes, and burrows should be taken for record purposes. In the event that the presence of birds, bats, arboreal mammals, and herpetofauna are found on the tree, tree felling, or transplanting must be postponed for further monitoring and assessment by ecologist.

Commencement of tree felling or transplanting should not occur during prime breeding season for birds in Singapore, between the months of mid-March to July. Outside these months, if active nests are detected on the tree, nests shall be left undisturbed until the young birds have fledged. When active nests are detected, the tree is to be tagged with flagging tape. Inactive nests should be removed to minimise the possibility of a new nesting attempt. Tree felling or transplanting shall occur only when no active nests are present on the tree.

Once tree felling is completed, the tree should be inspected again for any animals that were not detected earlier. Should an animal be detected after felling, NParks Animal Response Centre or ACRES should be contacted immediately, especially since the animal might be injured.

While undertaking this general approach, a register shall be maintained to record:

- the activities that were carried out,
- the species, numbers, GPS locations, dates, timings, and actions taken (if any) for each target fauna which was identified, and
- the description, GPS location, and actions taken (if any) for each burrow, inhabited tree hole and nest that was identified.

15.3.6 Spatial Visualisation of Directional Clearance

Figure 15-3 shows the trees that will likely be felled as they are located within the footprint of the development. Directional clearance should be conducted for the vegetated area along Sungei Pang Sua.

Figure 15-3. Location of trees affected by the development

The figures below illustrate the overall scheduled phasing for directional clearance. These activities should take place during daylight hours only (i.e., 8 am to 6 pm) and a minimum of one rest day (i.e., Sunday) per week should be provided to reduce disturbance to wildlife.

Along Sungei Pang Sua, there are plans for a path to be developed. It is estimated that a working area of 2 m on both sides of the path is needed, where undergrowth vegetation will need to be cleared. The indicative working area is outlined by the hoarding line in the following figures. Should the development require more working space, the hoarding line may be adjusted accordingly, and the trees affected should be considered. This plan serves as a guide and should be updated prior to actual clearance works to include a more detailed clearance regime.

Prior to clearance, permanent hoarding is to be erected at (1) the northern boundary along Kranji Loop, (2) the entire western boundary between the proposed pathway and Sungei Pang Sua, and (3) the eastern boundary from Kranji Loop to Kranji Recreation Centre.

Figure 15-4. Hoarding before directional clearance commences

As per NParks' requirements, all permanent hoarding to be fully sealed, with access gates flushed as close to the ground as possible. Permanent hoarding plans are to be approved by NParks.

The entire length of hoarding along Sungei Pang Sua is approximately 2 km, which might be arduous for fauna to be shepherded across. To shorten the distance for fauna species, directional clearance will be split into two directions starting from the middle.

Clearance is to commence next to Carros Centre (Figure 15-5) and progress in two directions – northwards and southwards. Clearance is to progress in intervals of 200 m.

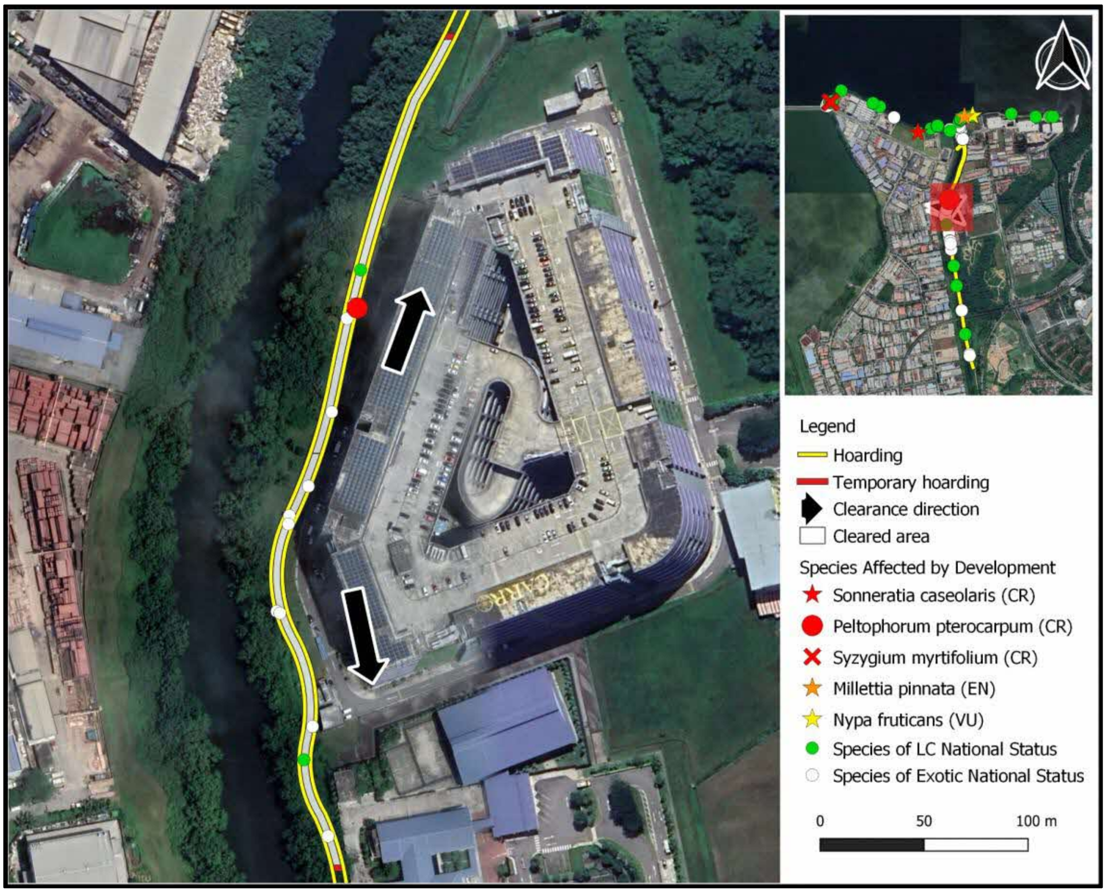

Figure 15-5. Directional Clearance 1 (Commencement)

Prior to any vegetation clearance in the first 200 m interval, all tree holes, nests, and burrows should also be inspected for wildlife. The Consultant may request for a narrow path of undergrowth to be cleared for easier access during pre-felling fauna inspection.

The first cleared areas should be temporarily hoarded up, as indicated by the red lines. Prior to any vegetation clearance in the next 200 m, all tree holes, nests, and burrows should also be inspected for wildlife. Directional clearance should take place in the direction of the black arrows, to encourage fauna to move either towards the south where there are forested areas, or towards the north where an Animal Management Specialist can assist with active relocation.

With each 200 m interval cleared, temporary hoarding should be erected to seal any gaps between the permanent hoarding. This is to prevent any fauna from entering areas that have been cleared.

After the first 200 m intervals have been cleared, all tree holes, nests, and burrows should be inspected for wildlife in the next 200 m intervals. Directional clearance can then continue in the next intervals in the direction of the black arrows to encourage fauna to move either northwards or southwards.

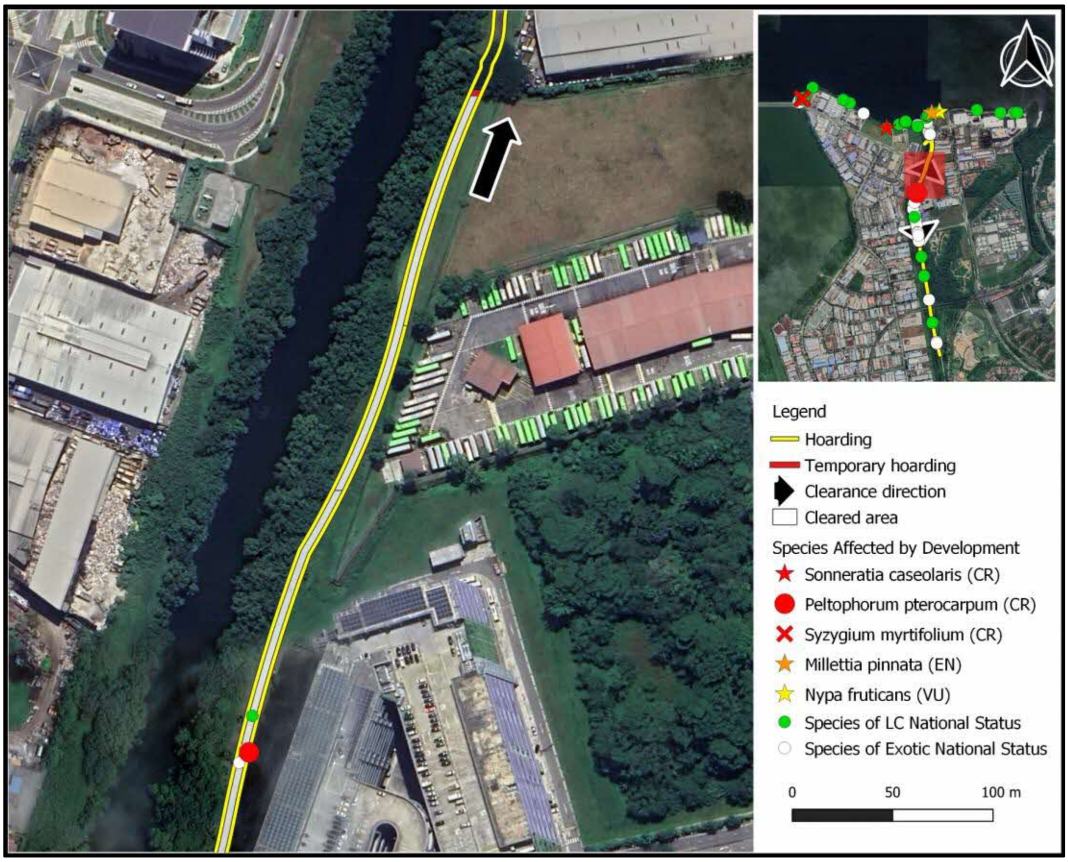

Figure 15-6. Directional Clearance 2A (north)

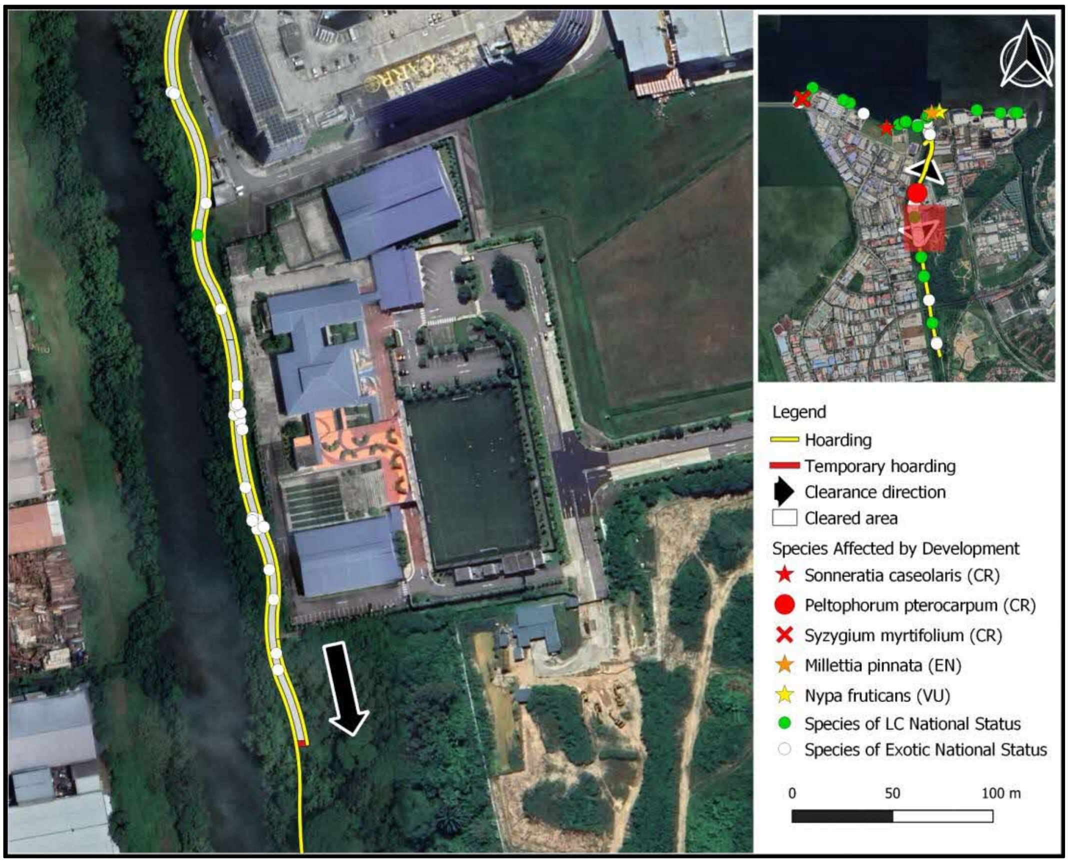

Figure 15-7. Directional Clearance 2B (south)

Prior to vegetation clearance in the next intervals, tree holes, nests, and burrows should be inspected for wildlife.

At the third and last 200 m interval leading to Kranji Loop, the working area is permanently hoarded up (Figure 15-8). During directional clearance in this interval, there should be an NParks-certified Animal Management Specialist on standby to supervise the clearance works and to ensure the safety and survival of fauna.

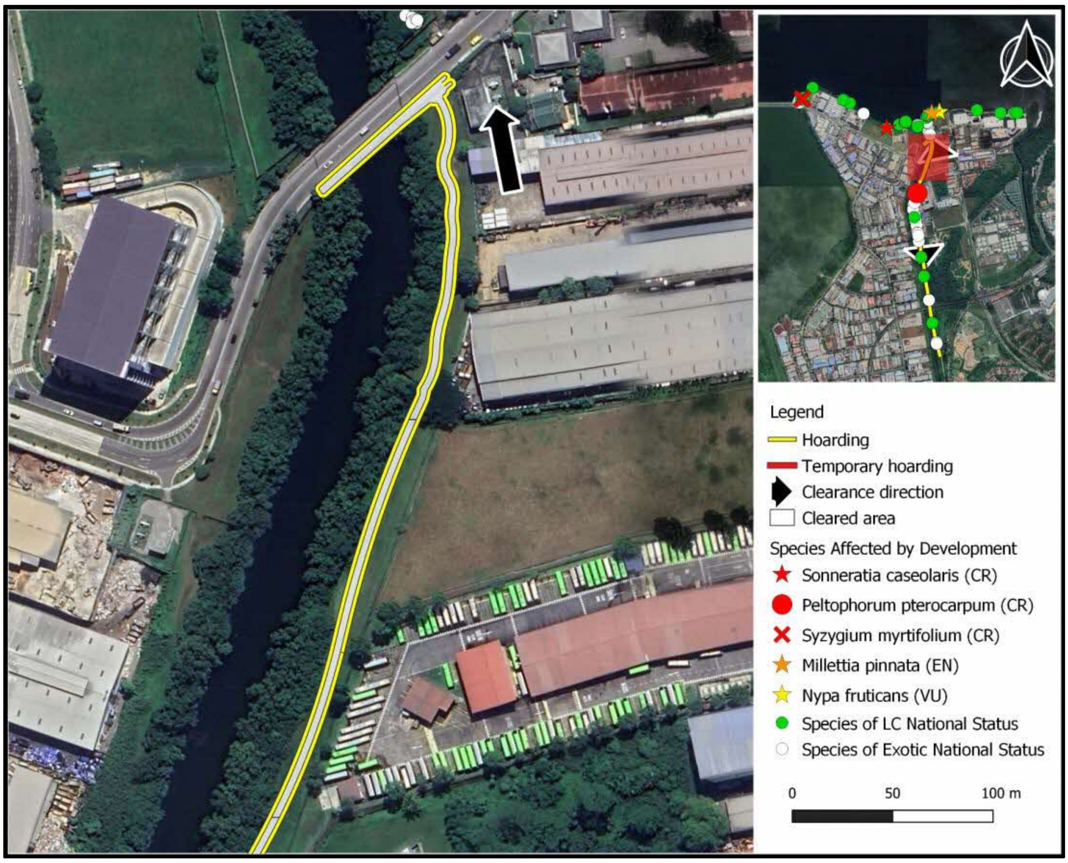

Figure 15-8 Directional Clearance 3A (north)

In the south, after each 200 m interval is cleared and temporary hoarding (red line) has been erected, the next 200 m interval should be inspected for tree holes, nests, and burrows. Permanent hoarding (yellow lines) should also be erected on the eastern boundary of the next 200 m interval prior to clearance. Directional clearance can then continue in the next 200 m interval in the direction of the black arrows to encourage fauna to move towards the forested area in the south.

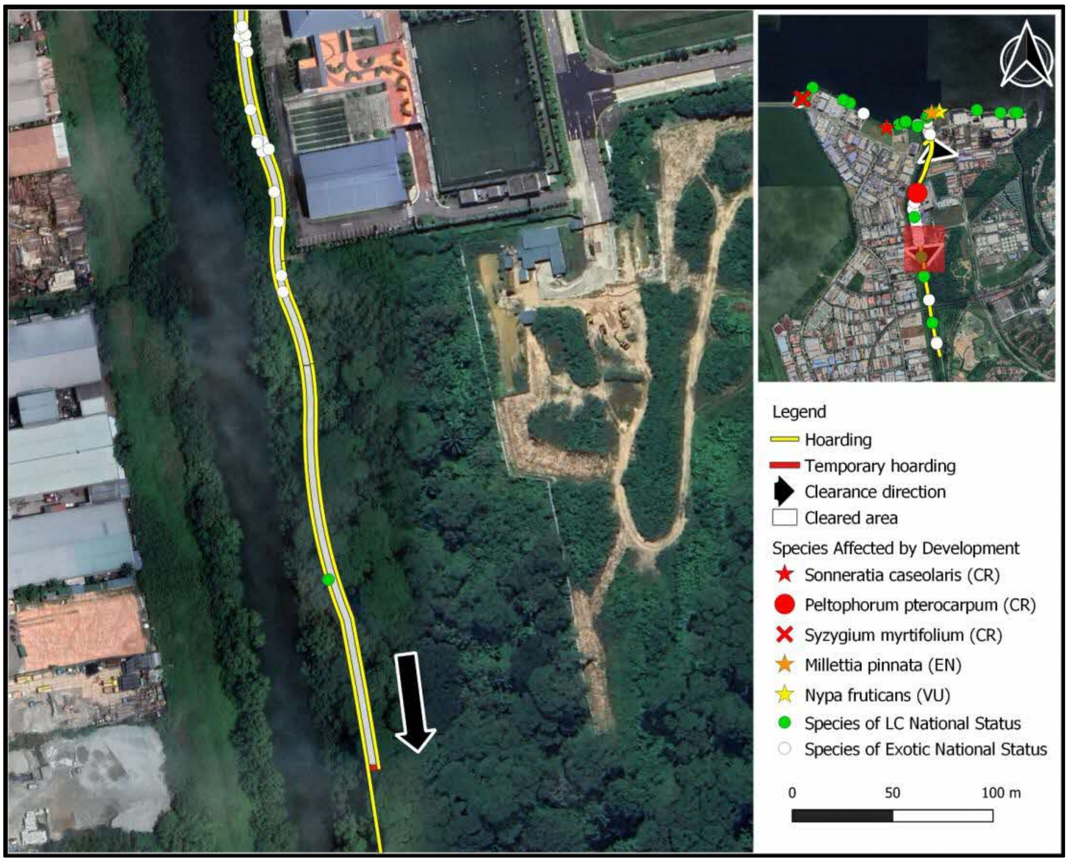

Figure 15-9. Directional Clearance 3B (south)

Directional clearance shall progress in 200 m intervals until the end of the proposed pathway. In the event of any wildlife incidences, an NParks-certified Animal Management Specialist should be engaged.

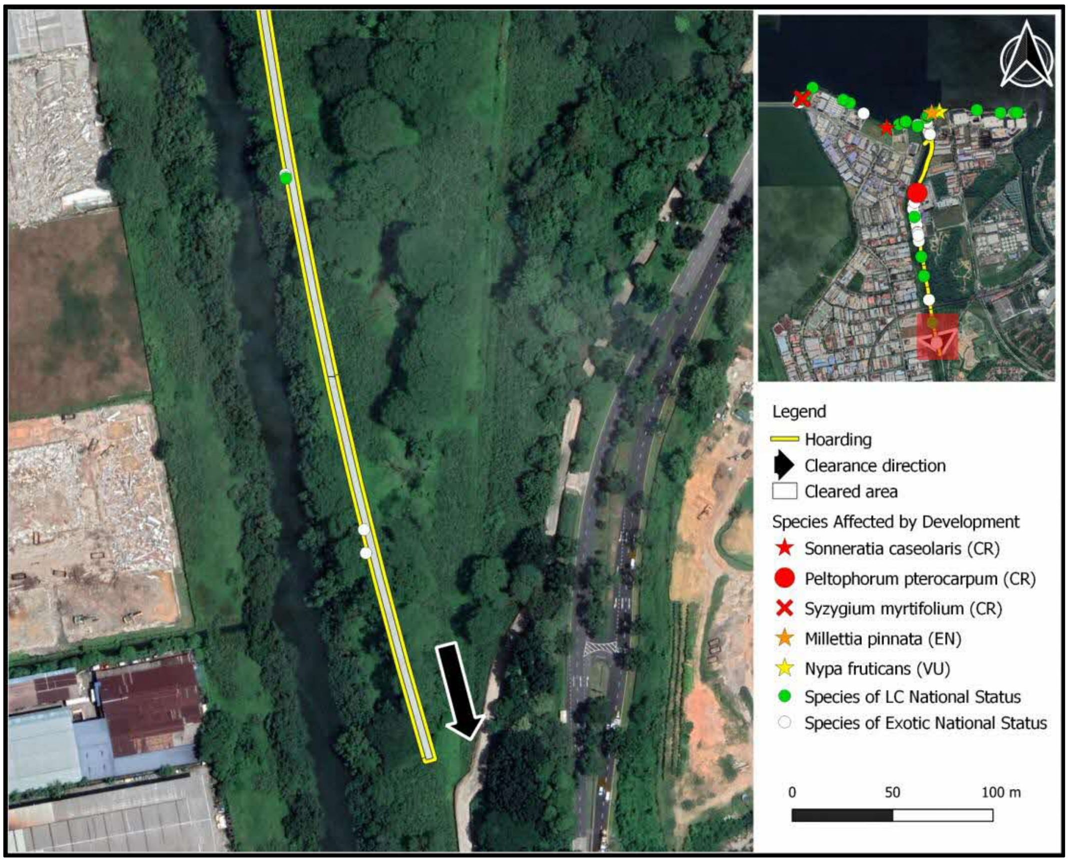

Figure 15-10. Directional Clearance in the last interval

Upon completion of directional clearance, the entire working area for the pathway along Sungei Pang Sua should be permanently hoarded up and any remaining temporary hoarding can be removed. There should be no gaps between hoarding to prevent fauna species from entering the site.

15.3.7 Wildlife Response and Rescue Protocol

Even upon the completion of wildlife shepherding works, it is highly probable that animals might be able to enter the site and get trapped, particularly burrowing or climbing animals. Whenever fauna is encountered within the working areas, all construction activities should be stopped immediately, and the Wildlife Response and Rescue Plan should be followed. Workers are to notify their supervisor, who will in turn contact the designated ecologist. The ecologist will then decide the next appropriate course of action. All documentations of wildlife are to be captured in photographs, and a Wildlife Incident Form provided in **Appendix K** is to be filled.

Table 15.5. Wildlife response and rescue plan

Particular	Within the project area						Outside project area
Timeframe	During working hours						Any time
Animal condition	Alive / Moving / Resting					Dead	Any
Animal type	Highly mobile animals (e.g., crocodile, wild pig, feral dog, smooth-coated otter, long-tailed macaque)	Venomous / poisonous (e.g., king cobra, black spitting cobra)	Non-venomous / -poisonous (e.g., Malayan water monitor)	Beehives and wasp nests	Young animals and birds (e.g., fledglings)	Any	Any
Risk To human	High	High	Low	High	Low	Low	–
Response	a. Stop work at affected area b. Report to PM c. PM to report to EMMP In-charge d. EMMP In-	a. Stop work at affected area; if possible, barricade affected area b. Maintain a safe distance to ensure the safety of	a. Stop work at affected area; if possible, barricade affected area b. Report to PM c. PM to report to	a. Stop work at affected area; if possible, barricade affected area b. Move away from the area c. Report to PM	a. Stop work at affected area b. Report to PM c. PM to report to EMMP In-charge d. EMMP In-charge to inform EMMP	a. Barricade affected area b. Report to PM c. PM to report to EMMP In-charge d. EMMP In-	a. Notify NParks Animal Response Centre/ ACRES hotline if necessary

<table>
<tr><th>Particular</th><th colspan="6">Within the project area</th><th>Outside project area</th></tr>
<tr><td></td><td>charge to inform EMMP Specialist (Fauna)
e. If required, ECO to contact NParks/ ACRES for next steps</td><td>workers on-site is not compromised
c. Report to PM
d. PM to report to EMMP In-charge
e. EMMP In-charge to inform EMMP Specialist (Fauna)
f. If required, ECO to contact NParks/ ACRES for next steps</td><td>EMMP In-charge
d. EMMP In-charge to inform EMMP Specialist (Fauna)
e. If required, ECO to contact NParks/ ACRES for next steps</td><td>d. PM to report to EMMP In-charge
e. EMMP In-charge to inform EMMP Specialist (Fauna)
f. If required, ECO to contact beehive/wasp removal specialist for next steps</td><td>Specialist (Fauna)
e. If required, ECO to contact NParks/ ACRES for next steps</td><td>charge to inform EMMP Specialist (Fauna)
e. If required, Contractor to assist with transporting of wild animal to disposal location</td><td></td></tr>
<tr><td>Remarks</td><td colspan="5">• No attempts shall be made by Contractors to handle the animal
• Contractor to take photographs of the animal if possible.
• Contractors shall allow the animal to leave the site without harassment / handling
• If animal is trapped, notify NParks Animal Response Centre or ACRES hotline</td><td rowspan="2">Contractor to take photographs of the animal.</td><td rowspan="2">• Contractor is encouraged to report
• Reports could be from public and/or Contractor’s staff
• If required, EMMP In-charge to contact PM for assistance of transferring animal carcass to disposal location</td></tr>
<tr><td>Specific Remarks</td><td>For wild pigs found at or around the site, NParks is to be informed as soon as possible at for advice and subsequent action. An approved wild pig removal contractor must also be engaged to trap and remove the</td><td>-</td><td>-</td><td>-</td><td>If the parents do not return for the young animal after 30 mins –1 hour, inform NParks / ACRES.</td></tr>
</table>

Particular	Within the project area						Outside project area
	animal.						

15.4 Flora Management Plan

It is recommended to develop a detailed flora management plan as part of CEMMP during construction stage by utilising recommended measures in this Section.

The plan should lay out details on how to set up and on how to carry out native-plant salvaging, how to maintain salvaged saplings, how to carry out tree protection works, the required components of tree assessments and monthly monitoring, etc. The responsibility of native plant salvaging process and management from this project should come under the Flora Specialist/Nursery Manager. The tree protection and assessment duties should come under an ISA Certified Arborist.

Within the project area, trees are to be identified and confirmed for suitability to retain prior to the commencement of construction. Tree Protection Zones (TPZ) should be appropriately established to protect these retained trees during the entire construction duration. At the same time, any native species found within the cleared area should be salvaged whenever possible. Proper hoardings should also be set up around the project boundary to minimize unnecessary damage to vegetation of adjacent areas or vicinity.

15.4.1 Salvaging Native Plants and Reinstatement

Plants Salvaging

Prior to any clearance or proceeding with construction works, plans should be in place to identify and salvage plants of native origin and valuable conservation status and uses them for future usage such as the reinstatement of the development site or where needed, landscaping purposes. This way, valuable or important plant species will remain within our flora diversity.

Process of Salvaging and Transplanting Native Plants (non mangroves)

Before any planned or additional/ad-hoc site clearance, the Flora Specialist, who is preferably also an ISA-certified Arborist, shall identify, take photos of, and tag native tree, shrub, climber, fern, and palm saplings with local conservation status of LC, VU, EN and CR, according to Lindsay et al. (2022), with unique tag numbers. The reason why LC species are also to be salvaged is because LC species tend to be fast growing and help to create conducive environment for growth of late-successional forest species. The tagged saplings should be in healthy and vigorous condition; have proper growth structure, free from dead wood and mechanical injuries; and be free from insect and disease.

Prior to flora salvaging works conducted by contractor, NParks should be consulted for interest in conducting salvaging of any flora species of conservation significance on site. If any fruits of species with local conservation status of EN and CR are observed during salvaging, the Flora Specialist should collect the fruits and seeds and consult with Native Plant Centre personnel (located at Pasir Panjang Nursery) if the fruits and seeds can be harvested. If Native Plant Centre does not wish to collect the fertile materials, the fruits and seeds may be released outside project area such that they do not get destroyed by ground clearance.

Unless the plant is a species of conservation significance, only saplings with a girth of 0.3m or less are to be tagged and put in plans to either be conserved or transplanted. If the species is not known, samples should be sent to the Singapore Botanic Gardens Herbarium to confirm the species. For transplanting works, the root ball size of saplings will be determined in consultation with the Arborist.

The process of transplanting begins several months with pruning of the roots. This act encourages the growth of new feeder roots (which absorb water and nutrients) closer to the tree's base to help the tree better adapt to its new location. To properly prepare the tree for pruning, water it well the day before. Watering helps ensure the soil sticks to the roots, and moist soil is easier to dig into. Water the area around the matured root ball at least 24 hours before pruning the roots.

It is vital to calculate how much of the root ball — the cluster of roots at the base of your tree — is to be pruned. As a rule of thumb, the root ball should be roughly 12 times the diameter of every unit measured in trunk thickness. For example, if the trunk is 5 cm thick, aim to prune the root ball to 60 cm in diameter by pruning in a circle about 30 cm out from the tree's main stem. Unless necessary, only minimal pruning, if not none will need to be done.

Next, cut a narrow trench (about 60 cm deep and about 30 cm wide) around the root ball with a flat spade. Place the spade straight up, perpendicular to the ground, and step on it to force the sharp point through the root. Refill the trench with the dug-up soil, carefully placing the subsoil (that from deeper within the trench) underneath the topsoil. Add a 5–8 cm layer of mulch on top of the soil above the root ball to help retain moisture. New feeder roots growing closer to the tree trunk creating a strong roots system should be seen when the soil is being removed to prepare for the tree's move.

Once the tree is ready to be transplanted, water the tree's soil one day before as moist soil is easier to dig and helps keep the root ball cohesive. There is a need to ensure that soil receives moisture around the entire circle of the trench. During the actual day of operation, start digging around the tree with a sharp, flat spade about 15 cm further out than the pruned roots. Digging 10 cm past the trench ensures that most (if not all) of the new feeder roots are included, which will help the tree adjust to its new location. After digging all the way around the circumference of the tree, start to dig under the tree to sever the roots beneath. Remember to leave the diameter of the root ball intact. If a tree trunk is 5 cm in diameter, then dig a little more than 30 cm down to get the full root ball.

Gently shaking the root ball within the hole can help determine whether any roots undetected remain attached. Carefully remove loose soil from around the root ball. Once the tree is completely free of the ground in the hole, place a sheet of natural burlap in the hole and coax the tree roots over it. Heavier root balls might need to be gently rolled out of the hole and onto the burlap. Be sure the burlap will cover the entire root ball. Secure the burlap together with twine to keep the soil together and carry the tree to set into a fresh hole in its new location. Do add any soil necessary to achieve the proper height. Once it is properly set in the hole, remove the burlap and twine. After transplanting, ensure the tree gets enough watering in relation to the environment climate, soil type and rainfall. In event the saplings are to be kept temporarily at an interim holding area, especially if it's an offsite one, saplings should be unloaded from the transport vehicle, lifting the sapling from the secure root ball. The saplings should be placed into the bags or containers in the nursery site. After placing the tree sapling into the polythene bag, remove the geotextile/polythene wraps and backfill the space/gaps with clean approved soil. Staking support shall be provided when necessary to keep the plant upright and placed with adequate spacing from one another. Operationally, the saplings will need to be salvaged, transported, and replanted within a day. In the case of climbers, cuttings shall be dipped into growth hormone and inserted into a container with a mixture of sand and soil.

If a plant (e.g., climber) cannot be transplanted in full, cuttings of 1–1.2 m should be made and propagated. The cuttings shall be placed in a sealed plastic bag with water to maintain humidity. Epiphytes and ferns can be collected and tied to a fern slab or, in cases where the epiphyte or fern is attached to fallen branches or log, the epiphyte or ferns can be collected with the branch or log. Transportation of transplanted epiphyte or ferns need to be done with proper care to reduce transportation shock to the saplings/plants. It would be acceptable to mount the epiphytic ferns to bark of a mature healthy tree if suitable trees can be found in vicinity of project area. It is important to ensure that epiphytic ferns are relocated to trees or areas (if the fern is attached to fallen branch or log) of similar microclimates with where such ferns were collected.

The Flora Specialist shall tally the total number of salvaged saplings and provide an inventory list consisting at least the tag number, photo, and species of each salvaged sapling.

Figure 15-11. Example of a tagged tree / sapling

Figure 15-12. Examples of temporary plants holding area

Growth and Maintenance of Salvaged Native Plants

For the well – being of the salvaged plants, it is vital for the Flora Specialist to follow a general maintenance regime, outlined in Table 16.6 to upkeep their general condition and therefore increasing their opportunities to be replanted where needed.

To ensure good form and structure of the harvested tree saplings, it is recommended to carry out regular formative pruning in accordance with ANSI A-300 pruning standards (ISA). Manual weeding should be carried out regularly for all the harvested saplings, be it trees or shrubs. All weeds should be removed before mulching. Regular mulching should be applied to all harvested saplings at the receiving site. The mulch used should be friable, odour-free high grade mature composts.

Table 15.6. Maintenance regimes for salvaged plants

Regime	Frequency	Material
Watering	Daily, except for the rainy days	Non potable water 5L for trees <0.1m in girth and at least 30L for trees >0.3m in girth
Fertilisation	As and when necessary i.e. when deterioration occurs	E.g., Fish kelp, humic acid, high EC molasses
Pesticide	As and when required	Pesticide should be avoided whenever possible. Use organic certified solutions instead
Mulching	Once a month	Mulch should have a minimum thickness of 20 mm, should be an approved friable, odour-free high grade mature compost or an approved mix, with C:N ratio between 12:1 and 25:1. Mulch pH must be between 5.5 to 7.
Weeding	Once a week	Weeding should be done manually and before mulching
Pruning	As and when necessary	Clean cutters. Cutters must be wiped clean in between cuts.

Relandscaping Works Using Salvaged Native Plants

Three months after the translocation of the salvaged saplings, the Flora Specialist shall consolidate the quantities of the surviving saplings and using this number as a guide, to conclude and document the survival rate of specific species, particularly that of native ones. This will be useful in transferring and sharing of knowledge across the industry. With reference to the final list of the surviving saplings and their quantities, the Flora Specialist / Arborist can liaise with the Contractor of their respective availability and suitability for inclusion into the relandscaping plans of the new development, wherever need be.

After all the remaining salvaged plants have been used / planted, the following ISA Best Management Practices (BMP) are to be implemented, including watering for at least eight weeks to ensure survival and establishment.

The criteria of satisfactory saplings include (but are not limited to):

- Saplings are in good health and free from injury, diseases and pests with satisfactory form and structure.
- Except for climbers and shrubs, saplings of tree species shall be self-supporting and planted without staking, unless necessary.
- Saplings of excurrent species should have a defined central leader with apical bud intact.
- Visible trunk flare slightly above or along the soil surface
- The root ball should remain intact and will not break up when transferring / planting the saplings into the tree hole.
- No girdling roots. If any are seen, it shall be pruned or removed.

Process of Salvaging and Transplanting Mangroves

In general, SBWR should be consulted for interest in conducting salvaging of their own for true mangrove species, and Native Plant Centre consulted for interest in conducting transplanting mangrove associate species such as back mangrove climbers.

After NParks conduct mangrove salvaging, subject to project requirements, we recommend different salvaging methods for mangroves of different sizes conducted by contractor’s team. The recommendations below are based on a combination of field observations, IUCN Best Practice Guidelines on Mangrove Restoration (IUCN Sri Lanka Country Office, 2007), Guidelines on Mangrove Ecosystem Restoration for Western Indian Ocean Region (UNEP-Nairobi Convention/USAID/WIOMSA, 2020) and Florida Marine Research Publications (Pulver, 1976).

1. Propagules

Mangrove propagules present in vicinity of building footprints should be collected and planted in areas with stable sediments; indicators of stable sediments include fine muddy substrate, scattered mangroves and established seedlings. Areas for planting should ideally be sheltered from high waves and frequent boat activity to minimize the risk of propagules being washed away.

To help in selection of mature propagules of seedlings, one can refer to the indicators below:

Table 15.7 Maturity indicators of mangrove propagules/seedlings (based on West Indian Ocean regional data)

Species	Planting Material	Indicator of Maturity
Avicennia marina	Seedling	Seed-coat turns light yellow, wrinkly
Bruguiera gymnorhiza	Propagule	Reddish brown body
Ceriops tagal	Propagule	Light yellow collar, brown/green body
Rhizophora mucronata	Propagule	Yellow collar, green body
Sonneratia alba	Fruit	Dark green, float in water
Xylocarpus granatum	Fruit	Dark brown, float in water
Xylocarpus moluccensis	Fruit	Dark green
Lumnitzera racemosa	Seed	Dark green dry style
Heritiera littoralis	Fruit	Dark brown

The mature propagules should be packed in plastic bags to be transported to the planting site. Depending on species, the propagules can be stored in plastic bag under moist conditions for 4-6 days for *Avicennia marina*, 15 days for *Aegiceras corniculatum*, 40-45 days for *Rhizophora* sp based on data collected in Sri Lanka. To facilitate germination, one can store *Sonneratia sp.* and *Lumnitzera sp.* propagules in containers with high moisture for more than three days under natural shade, soak *Xylocarpus sp.* seeds in water for one week, and manually remove seed coat of *Aegiceras sp.* The germination time ranges from one week for *Avicennia sp.*, two weeks for *Sonneratia sp.* and *Rhizophora sp.*, four weeks for *Aegiceras sp.*, *Lumnitzera sp.* and *Heritiera sp.*, to eight weeks for *Xylocarpus sp*.

2. Saplings (0.5-1.5m height)

Mangrove saplings can be transplanted by digging up rootball that is approximately depth of 25cm and diameter about half of the original tree height. Proproots from *Rhizophora sp*. should be included in rootball if possible; if the prop roots are severed, the severed proproots should be left on the sapling for possible regeneration. The rootball should be wrapped in a gunny bag or a polythene bag.

Suitable transplanting locations will be identified based on the presence of stable sediments; indicators of stable sediments include fine muddy substrate, scattered mangroves and established seedlings. Areas for planting should ideally be sheltered from constant waves to minimize the risk of sapling mortality due to shifting substrate, and sheltered from frequent boat activity to prevent damages by boats. The holes appropriate for the root ball size should be dug in the mud during low tide. Saplings should be transplanted at roughly same level in the destination ground as they were in original habitats.

During the transplanting process, the sapling with rootball should be watered and stamped down to improve contact between the rootball and the side of planting hole. Pneumatophores and proproots should not be covered to allow aeration of subterranean roots and potentially faster recovery of the transplanted sapling. Mixed species can be transplanted together to help prevent complete mortality of a site due to the single transplanted species being incompatible with the transplanting destination.

3. Larger mangrove trees (<5m height)

Similar transplanting techniques outlined above can be used for larger mangrove trees, with deeper root zones and larger rootball diameter (e.g. same with tree height) due to larger root system.

4. Mature mangrove trees

Whenever possible, development should avoid mature mangrove trees. Mangroves to be retained on site should have tree protection zone that include all visible pneumatophores with additional 2m radius to prevent damage to root zones of mangroves, especially for older mature mangrove trees.

5. Mangrove associates

The salvaging methods of mangrove associates generally follow that listed for the non-mangrove species above.

15.4.2 Assessment and Monitoring of Trees to be Protected.

Before any construction activity begins (including both planned and ad-hoc site clearance), the Arborist shall perform pre-construction tree assessment for trees at proposed development site. The Arborist should utilise Site Layout Plan and Topography Plan to determine extent of tree roots and tree crown affected by the development. Based on site observation, construction drawing and design, estimated work area boundary, the Arborist shall produce tree assessment report recording tree information such as condition of site, tree photos, species, height, girth, crown spread, tree health, form, structure. He / She will conclude on whether the tree will be affected by proposed development footprint and if so, what are the perceived construction impacts and recommended mitigation measures to mitigate these impacts. This tree assessment report will then serve as a record of pre-development tree conditions, and the Arborist will refer to this report as a benchmark when performing monthly monitoring for trees.

Mitigation actions such as crown cleaning to remove damaged and dead branches, applying appropriate pest and disease control should be the first line of measures. Tree Support Systems such as Tree Guying and Root Anchoring must be considered if the tree is deemed to be susceptible to wind throw. Furthermore, regular monitoring of defects such cavity with wounded wood development by the CA will also be useful in detecting hazardous trees.

15.4.3 Tree Protection Zones

It is possible to retain large and significant trees within the construction footprint with thorough pre-construction plans such as re-routing underground pipelines, altering footpath directional design and repositing hardscapes (e.g., pumphouses) to avoid a native / mature tree within or at the border of such site. However, if these measures prove to be impossible to put into place around a large, retained tree, a minimal Tree Protection Zone (TPZ) need to be demarcated to protect individual trees, to minimize the impacts of construction activities (including root damage, mechanical trunk damage, branches breakages, damage due to soil compaction, etc.) on the tree. NParks (2018) has included some guidelines on Tree Protection Zones in their Guidelines on Greenery Provision and Tree Conservation for Developments. It is to be noted that this subjected development may affect mangrove habitats, and therefore another approach, which differs from the protection of terrestrial trees species needs to be adopted. This may be in the form of protected area which shall be further established with inputs from relevant specialists including marine ecologists, engineers and certified arborists.

TPZ size varies depending on tree size (Table 15.8). In general, the remaining space should be sufficient for implementation of design and required infrastructures. While there are no established or published standards for mangrove TPZ, for large mangrove trees that are difficult to transplant and not directly affected by development footprint, we recommend the TPZ to include all visible pneumatophores in vicinity of each large mangrove tree plus two meters radius to minimize damage to extensive root system of mature mangrove trees. In the event the Contractor require extra spacing during the construction period for necessary works, the adjacent areas should be surveyed for native species / trees to be retained and possibly salvaged before any clearance. If any materials spill into TPZ, the spillage should be cleaned up immediately and the Arborist must be informed. The Contractor is also required to notify the Arborist immediately if retained trees are observed to be damaged. If the tree suffers from substantial damage and in a state of irreversible deterioration as determined by the Arborist, the Contractor should replace the tree of the same species at a minimum girth size of 0.2m with the defaulted replacement ratio (Table 15.9).

Table 15.8. TPZ size required for different girth ranges

Girth	Recommended TPZ (radius)
<0.5m	1 m
>0.5m but less than 1m	2 m
>1m but less than 1.5m	3 m
>1.5m but less than 2m	4 m
>2m	5 m
Fig trees and Trees with Critically Endangered status	Prescribed individually by Arborist on a case-by-case basis

Girth	Recommended TPZ (radius)
Mangrove trees	Visible pneumatophores in vicinity of each tree plus 2m radius

Table 15.9. Tree Replacement Ratio

Girth of Trees to be Replaced	Recommended Replacement (NO)
<0.4m	1
≥0.4m but ≤ 2m	3
>4m	5

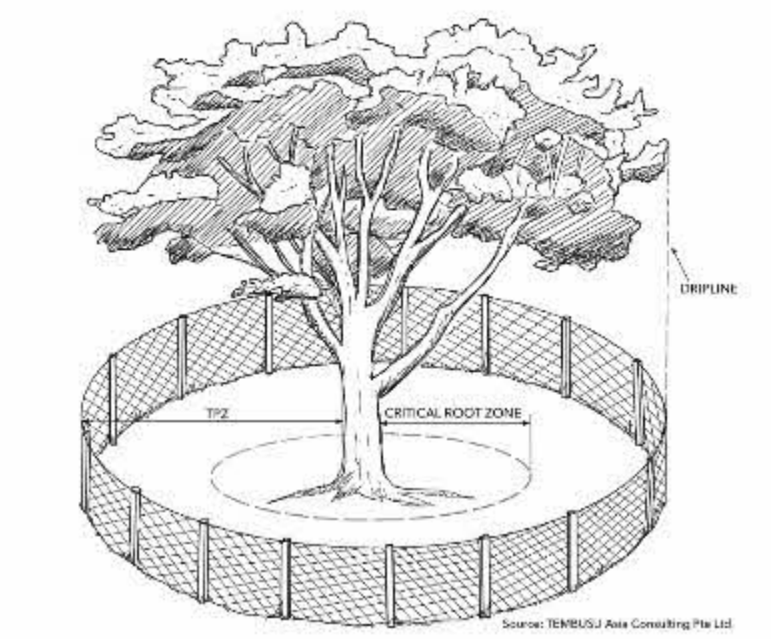

Figure 15-13. Tree Protection Zone Diagram

The following specifies guidelines for construction activities within and outside the TPZ, extracted from NParks (2018).

Inside TPZ

- There must be no excavation, raising or lowering of soil level, compaction or any form of construction activities including temporary works within the hoarded area.
- Dumping of debris, excavated materials and/or storage of construction materials and equipment are not allowed within the TPZ.
- The demolition of drains and structures within the TPZ should be carried out manually and backfilled with Approved Soil Mixture (ASM) immediately.
- Trees are to be watered regularly if rainfall is inadequate.
- Trees are to be fertilised if soil tests or deficiency symptoms indicate they are nutrient stressed.

Outside TPZ

- If major roots are encountered during excavation, the applicant may like to seek advice from a Certified Arborist, as cutting of major roots may affect the stability of the tree. Where possible, alternative proposals should be explored to avoid the need to cut the roots.
- In cases where the trees are managed by NParks (e.g., trees within the park connector planting verge), or are required by NParks to be conserved (e.g., trees with girth >1.0m within TCA or vacant land), approval from NParks must be obtained before the major root can be cut. If approval is granted by NParks to cut the roots, this must be done with a clean cut using a chainsaw.
- All building debris and chemical waste should not be burned or buried within green verges on the site.

15.4.4 Tree Felling Within Forested Areas

Before felling trees, the Arborist must ensure the identified and / or tagged native saplings have already been transplanted to interim nursery. The Arborist must also survey, identify, and confirm the trees to be protected in the surrounding areas have the necessary protection measures put in place as well as establishing a tree felling / drop zone based on site condition and tree crown spread.

The trees to be felled shall be inspected for any fauna as per guidelines provided in wildlife management plan (Section 15.3). Such trees will be marked with red & white tape and no tree felling operation shall be carried out within 5 m from the said tree until further instruction.

Before commencing tree felling works, personnel forming the tree felling team shall scout the area a final time to ensure that the tree felling / drop zone is clear of all activities, while fauna specialist will inspect zone and to ensure that the site is free of wildlife activities. Once the areas are cleared, the banksman should signal the excavator operator to commence work for trees felling. The excavator operator should first clear off the shrubs and small trees (<5 m height) to create a clear line of sight for the whole area and to keep away blind spot areas which are blocked by small trees or tall shrubs. The excavator operator shall operate cautiously and fell all small trees and shrubs in a controlled manner, aware of the location of protected trees.

When opening is completed, the excavator operator should clear off small trees and shrubs along the path into the site to demark the area that they are supposed to work within. When the paths are cleared, the operator should then move inward to fell trees within the area. If the operator faces a tree with height between 5 and 7 m, they should clear off shrubs in the surrounding area so that the foreman can move closer to the tree. The recommended tree cutting method should be the notch cut (Figure 15-14). The foreman shall determine the direction of falling and ensure the tree does not land on any property, cause injury, or damage nearby Trees to be Protected. To avoid trees leaning in an unintended direction when performing a third cut, the excavator should assist to prevent fall back and guide the tree to fall into the intended direction. Once the tree has been felled, the tree cutter shall cut the tree trunk into shorter lengths for easier loading during clearing of the debris from site.

If the tree has a height greater than 7 m, the tree height must be reduced with a lorry crane or manual tree climbers first, depending on site accessibility. Before the lorry crane can enter the site, the Contractor must prepare proper access for the lorry crane to enter the site and access the tree location. The Contractor must ensure that the access ground is firm and stable enough to allow the lorry crane to deploy its outrigger to carry out the works safely. When the access is ready, the Contractor will then mobilize the lorry crane to enter the site to reduce tree height to 7 m to adopt the notch cut method for trees less than 7 m in height.

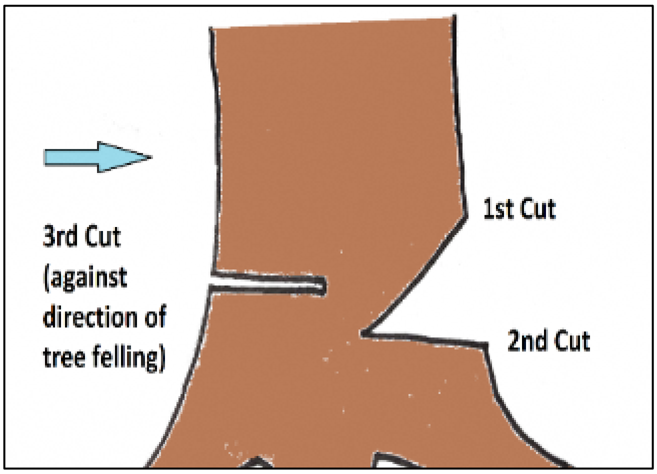

Figure 15-14. Illustration of a notch cut

15.5 Lighting Management Plan (LMP)

Although no night works are currently being planned, a Lighting Management Plan (LMP) is developed as part of the Construction EMMP, in the event that any artificial lighting is to be used. This section provides items to be covered in the LMP.

15.5.1 Purpose

The purpose of LMP shall be:

- Provide guidance for construction lighting to reduce impacts of artificial lighting at night (ALAN) on the natural environment;
- Provide details on light utilisation on site, including the approximate location and specification of each lighting unit; and
- Recommend light mitigation measures that are to be implemented on the site.

15.5.2 General Lighting Management Principles

Based on the international practices, the following four lighting management principles are to be taken into consideration while formulating the LMP during construction phase.

1. Additional lighting is to be installed only when it is needed

Given the proximity of the project area to forested areas, all ALAN are to be installed only when it is determined that potential safety hazards from the project activities can be mitigated with the use of ALAN.

2. ***Leverage adaptive controls to minimise lighting usage for specific tasks***
In light of the schedule of project activities, ALAN usage must be planned in advance to minimise the lighting duration (i.e., minimum number of nights/hours required) and intensity required to complete the works in an area. Adaptive controls (e.g., automatic switches, motion sensors, timers) are to be deployed where appropriate and feasible to limit the ALAN's duration, intensity, and/or extent.

3. ***Additional lighting is to be designed to reduce beam spread***
ALAN are to be directed inward the project area and downward so that only the objects or areas intended are lighted. The lighting is to be shielded and installed at the appropriate height to avoid any spills into the surroundings.

4. ***Use appropriate lightings and equipment in the project area***
ALAN with long wavelength (defined as above 580 nm, e.g., amber/orange light) must be used wherever possible to reduce disturbance to sensitive animals. Usage of lighting with short wavelength (defined as below 500 nm, e.g., blue and ultra-violet light) has to be reduced with the sources filtered as much as feasible when used. Moreover, the construction equipment deployed in the project area must have a non-reflective, dark-coloured surface as far as practicable.

15.5.3 Lighting Control Measures

The LMP shall include following lighting control measures to be implanted at the project area:

- Spatial layout of lighting to be utilised in project area
- Designs of lighting utilised – including height and shielding design
- Specifications of lighting utilised – lighting colour, spectrum, and brightness level
- Additional measures in place in the event that white or non-shielded lighting is required
- Implementation monitoring of mitigation measures
- The colour temperature of the lights used for night works shall not be more than 3000K.

15.6 Biodiversity Monitoring Requirements

Specific monitoring requirements for biodiversity are detailed in this section. The other monitoring requirements for physical parameters are presented in Table 15.11.

15.6.1 Fauna Monitoring

There should be regular checks to ensure that the implementation of mitigation measures for fauna protection are in place and effective in the mitigation of impacts. Sensitive biodiversity should also be monitored to ensure that their presence has not been adversely affected by the works. The following section outlines visual site inspection and aquatic monitoring recommendations.

Visual Site Inspection

Monthly inspections of hoarding surrounding the worksite:

- There should be no clearance of vegetation outside the hoarding boundary. Additionally, there should be no gaps between the hoarding to ensure that animals are not able to enter the site. Specifications for hoarding should also follow directives from NParks.

Monthly inspections of habitats:

- Besides immediate forested areas surrounding the hoarding, visual inspections should also be carried out at nearby sensitive habitats. There should be no visible impacts to the stream, including, but not limited to, loss of vegetation, siltation, visible increased sedimentation or erosion, presence of oil, etc.

Aquatic Fauna Monitoring

Due to the importance of the streams as habitat for rare aquatic fauna, monthly aquatic fauna surveys are recommended. The surveys should target fish, decapod crustaceans, and molluscs. The points and methodology should closely follow the baseline surveys, so that data can be comparable to the baseline. Additionally, monthly odonate surveys along the stream should also be carried out. The data collected should be compared on a monthly basis, which can provide an indication on any major changes in aquatic fauna diversity

15.6.2 Flora Monitoring

Due to the presence of many plant species of conservation value within and around the project area, periodical checks should be conducted by qualified persons (e.g., Flora specialist and / or Certified Arborist) to ensure that the implementation of all mitigation measures are put in place and are effective in protecting these plants during the construction phase. The following section outlines the monitoring recommendation for flora protection.

For the monitoring of flora, the flora specialist and arborist should have access to the documents listed in Section 15.4.2.

Monitoring of Retained Trees

During the construction stage, the Arborist shall conduct visual tree inspection (level 2) of trees to be protected, conducted once every 6 to 24 months depending on the requirements. The inspection report will cover 2 main aspects: (i) Current tree health observations and (ii) The TPZ condition. Table 15.10 below presents criteria to be reflected in the inspection report. Photos of each tree are to be included in the inspection report. In addition, past or current maintenance activities will be reflected in the monthly inspection report (such as Last Tree Pruning Date) during the development period.

Table 15.10. Parameters to take note of during tree inspections.

Tree Health	TPZ Condition
• Foliage colour (Normal, Chlorotic, Necrotic)	• TPZ barriers installed/good condition • Evidence of illegal encroachment

• Foliage density (Normal, Sparse, Dense) • Leaf size (Normal, Small) • Vigour (Good, Average, Poor) • Lean (Self corrected, Unnatural) • Diebacks and Dead branches (%) • Cracks • Cavities / Conks / Fungi • Roots collar buried / not visible • Pest / Disease Infestation • Damaged / Cut roots • Root plate lifting • Site Changes (None, Grade change, Site Clearing) • Soil Condition (Limited volume, Saturated, Compacted, Pavement over roots) • Wind Exposure (Protected, Partial, Full, Funnelling)	• Evidence of damage to tree • Evidence of toxic splash • Evidence of illegal compaction • Evidence of materials storage • Evidence of machinery, equipment and vehicle storage

It is critical for the certified arborist to ensure that protected trees are not gravely affected by construction activities. The trees' conditions should be documented in the report and provide useful preventive recommendations to manage the trees' well-being, preventing them from possible failures. Periodical pruning such as deadwooding, formative pruning should also be conducted regularly to keep the trees structurally safe and sound.

Monitoring of Salvaged Plants

Regular monitoring of plants that were salvaged is important to ensure a high rate of survivability and therefore suitability to reinstate any site locations, where necessary. Monitoring for tree species health should follow the parameters indicated in Table 15.10. It is also necessary to ensure that the regime presented in Table 15.6 have been effectively implemented.

15.6.3 Water Quality Monitoring

Given the importance of good water quality in the maintenance of healthy aquatic habitats, in-situ and ex-situ surveys of water quality along Pang Sua River should be conducted. The points, methods used, and parameters measured, should closely follow what was studied in this EIA, and monitoring should take place on a fortnightly basis during the construction phase. Water quality parameters should be compared to the baseline to ensure that there are no major changes in water quality.

15.7 Environmental Monitoring Plan

Table 15.11 provides the overview of recommended environmental monitoring plan and EMMP measures for this project which is to be incorporated into the CEMMP by the Contractor. The environmental monitoring locations are to be finalised by EMMP team during CEMMP formulation in consultation with relevant stakeholders. In the case of non-compliance, the EMMP team will provide recommendations in the monthly Environment Performance Report, and if necessary, serious non-compliance instances will be highlighted and forward to relevant agencies for follow-up and advice.

Table 15.11. Recommended Environmental Monitoring Plan for construction phase

Monitoring Category	Impact	Monitoring Parameters	Monitoring Method	Location	Standards / Criteria	Time / Duration / Frequency	Reporting	Implementation	Supervision
Biodiversity Monitoring • Avoiding clearance of vegetation outside working boundaries • Minimisation of disturbance to sensitive species • Minimisation of disturbance to sensitive habitats • Avoiding human wildlife conflict	On-site Visual and Compliance Monitoring								
	Habitat Loss and Degradation	• Hoarding to be erected prior to vegetation clearance along Sungei Pang Sua to demarcate working boundaries • Properly designated Tree Protection Zones (TPZ) prior to construction	• Visual monitoring • Compliance check	Entire project area (near / within forested area)	• Proper hoarding installation • Proper TPZ installation • Absence of vegetation clearance outside working boundaries	• During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • Ecologist • Arborist	NParks / TAC
	Species Mortality	• Visual inspection of trees and holes for nesting birds prior to felling • Directional clearance of vegetation • Translocation of identified plant species • Translocation of targeted animal species • Daily checks of ECM nets for entrapped fauna	• Visual monitoring • Compliance check	Entire project area (near / within forested area)	• Retention of tree health • Absence of mechanical damage on trees • Absence of nesting birds • Absence of large mammal species • Absence of entrapped fauna	• During entire construction phase • Daily checks for fauna entrapment • Prior to vegetation clearance (for wildlife translocation and fauna inspection)	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • Ecologist • Arborist	NParks / TAC
	Human-wildlife Conflict	• Briefing to on-site workers on dos and don’ts, as well as notes on safety. • Areas are to be demarcated for food consumption and storage. • Trapping of wild boars, if necessary	• Visual monitoring • Compliance check	Entire project area	• No injuries due to wild animals	• Weekly during construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • Ecologist	NParks / TAC

Monitoring Category	Impact	Monitoring Parameters	Monitoring Method	Location	Standards / Criteria	Time / Duration / Frequency	Reporting	Implementation	Supervision
Noise Monitoring • Minimisation of biodiversity disturbance due to construction noise • Minimisation of nuisances to human due to construction noise	On-site Visual and Compliance Monitoring								
	Disturbance to biodiversity and human due to construction noise	• Noise barriers around construction work areas • Utilisation of quieter equipment and vehicles with low noise levels • PPE use by construction personnel at all times while on the construction site	• Visual monitoring • Compliance check	Entire project area	• Environmental Protection and Management (Control of Noise at Construction Sites) 2008	• Monthly during entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC
	On-site Noise Monitoring								
	Noise generated from construction work	• Leq 12 hrs • Leq 1 hr • Leq 5 mins	• Sound level meter	Entire project area	• Environmental Protection and Management (Control of Noise at Construction Sites) 2008	• Continuous (24x7) boundary noise monitoring • During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC
Water Quality Monitoring • Minimisation of impact to waterbodies due to contaminated site run-off • Minimisation of impact to terrestrial habitats due to erosion of topsoil	On-site Visual and Compliance Monitoring								
	ECM non-compliance	• Verify implementation of ECM Plan • Perimeter cut-off drains, perimeter silt fence, silt traps, sedimentation basin and silt treatment system	• Visual monitoring • Compliance check • ECM checklist	Construction area with earthworks	• ECM Plan designed by a Qualified Erosion Control Professional (QECP)	• Daily compliance monitoring • During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO • QECP	NParks / TAC
	On-site Water Quality Monitoring								
	ECM discharge (sediment runoff)	• Total Suspended Solids (TSS)	• Implementation of TSS monitor and CCTV including a Silty Imagery	• Final ECM discharge points	• Less than 50 mg/L for TSS • Sewerage and Drainage (Surface Water	• Real-time continuous during entire construction phase	• TSS report • Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC

Monitoring Category	Impact	Monitoring Parameters	Monitoring Method	Location	Standards / Criteria	Time / Duration / Frequency	Reporting	Implementation	Supervision
			Detection System (SIDS)		Drainage) Regulation 2007				
	Contamination of water resources through trade effluent discharge	• All parameters identified in EPM (Trade Effluent) Regulations for Controlled Watercourse • Additional parameters: Aluminium, Conductivity, Turbidity, Total nitrogen, Total phosphorous, Total organic carbon, Ammonia as NH3-N, Enterococcus, Mercury	• Ex-situ monitoring	• At every discharge outlet	• EPM (Trade Effluent) Regulations for Controlled Watercourse	• Once a month • During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC
	Degradation of Sungei Pang Sua habitat (Construction stage monitoring)	• All parameters identified in EPM (Trade Effluent) Regulations for Controlled Watercourse • Flow velocity	• In-situ and ex-situ monitoring	• Same locations as per baseline surveys at Pang Sua River during constructi on phase	• EPM (Trade Effluent) Regulations for Controlled Watercourse • Baseline results	• Monthly during construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC
Air Quality Monitoring • Minimisation of human health & biodiversity impacts due to dust pollution • Minimisation of human health impacts due to	On-site Visual and Compliance Monitoring								
	Fugitive dust emissions	• Verify implementation of dust suppression plan • Watering to reduce dust emissions from exposed areas • Washing bay • Implementation of vehicular speed limit • Covered stockpiles • Use of PPE (face mask) by construction personnel	• Visual monitoring • Compliance check	All construction areas	• Approved dust suppression plan	• During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge	NParks / TAC

Monitoring Category	Impact	Monitoring Parameters	Monitoring Method	Location	Standards / Criteria	Time / Duration / Frequency	Reporting	Implementation	Supervision
exhaust emissions	Exhaust emission from construction machineries operations	• Maintenance frequency of vehicles and machineries	• Visual monitoring • Compliance check	All construction areas	• No visible exhaust plume, dark smoke etc.	• During entire construction phase	• Monthly Environmental Performance Report •	• Contractor/ CEMMP In-charge	NParks / TAC
	On-site Air Quality Monitoring								
	Particulate matter emission from construction activities	• $PM_{2.5}$ and PM_{10}	• Dust sampler	• Entire project area	• Singapore Ambient Air Quality Targets	• 24hr (1 day) continuous monitoring • Once a Month	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge	NParks / TAC
Light Impact Monitoring • Minimisation of light pollution impacts on ecological processes	On-site Visual and Compliance Monitoring								
	Light pollution affecting sensitive species	• Appropriate positioning of lights • Scheduling of activity during nightworks • Turn off all unnecessary lights outside working hours	• Visual monitoring • Compliance check	Entire project area (near forested area)	• Absence of heavy nightworks • All artificial lights to be downward facing, turned away from forested areas	• During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • Ecologist	NParks / TAC
Vector Monitoring • Minimising the impacts due to increase in vector related diseases	On-site Visual and Compliance Monitoring								
	Increase in the Incidence of vectors & related diseases	• Verify implementation of vector control management plan • Engagement of NEA registered vector control operator • Appointment of an in-house vector control team	• Visual monitoring • Compliance check	Entire project area	• Vector control management plan • Control of Vectors and Pesticides Act, 2002	• During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC
Waste	On-site Visual and Compliance Monitoring								

Monitoring Category	Impact	Monitoring Parameters	Monitoring Method	Location	Standards / Criteria	Time / Duration / Frequency	Reporting	Implementation	Supervision
Management Monitoring • Minimising the impacts due to improper disposal of hazardous and general waste	Improper disposal of hazardous waste leading to land pollution	• Engagement of NEA licensed waste collector for hazardous waste • Record of waste disposal	• Visual monitoring • Compliance check	Entire project area	• Environmental Public Health (Toxic Industrial Wastes) Regulation, 2000	• During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO • QECP	NParks / TAC
	Improper disposal of construction waste leading to land pollution	• Verify implementation of solid waste management plan • Engagement of NEA licensed general waste collector • Record of waste disposal	• Visual monitoring • Compliance check	• Construction waste storage location • General waste storage location	• Environmental Public Health (General Waste Collection) Regulation, 2000	• During entire construction phase	• Monthly Environmental Performance Report	• Contractor/ CEMMP In-charge • ECO	NParks / TAC

16 CONCLUSION

Through the collection of data via environmental baseline field surveys, this EIA has described the environmental baseline conditions at the site. Environmental baseline parameters assessed in this EIA considered seasonal variations, and include:

- Biodiversity;
- Hydrology and water quality;
- Coastal hydraulics;
- Sediment quality and dynamics;
- Noise;
- Ambient air quality; and
- Ground-borne vibration.

Based on these parameters, this EIA has identified potential environmental impacts brought about by infrastructure works during the pre-construction, construction, and operation phases of the upcoming MMM Nature Park development on the environment. Although no baseline levels were assessed for these environmental parameters, the EIA also included predicted impacts for:

- Light;
- Waste management; and
- Vector control.

Using the RIAM method, the EIA assessed and quantified these predicted impacts and recommended mitigation measures to reduce the residual impact levels of each environmental impact. The overall impact assessments for each environmental parameter can be found below:

Table 16.1. Summary of overall assessed impacts

Environmental Parameter	RIAM for Predicted Impacts	RIAM for Residual Impacts
Biodiversity	Minor Negative	Slight Negative
Water Quality	Slight Negative	Slight Negative to No Impact
Sediment Quality	Minor Negative	Slight Negative
Noise	Minor Negative	Slight Negative
Air Quality	Slight Negative	No Impact
Vibration	Minor Negative	Slight Negative
Light	Slight Negative	No Impact
Coastal Hydraulics	No Impact	No Impact
Waste	Minor Negative to Slight Negative	Slight Negative to No Impact
Vector	Slight Negative	Slight Negative to No Impact

The environmental impact of the proposed infrastructure development of future Mandai Mangrove & Mudflat Nature Park has been assessed as Slight Negative or No Impact. As the main development footprints are confined to specific nodes at Kranji Reservoir Park, Sungei Kranji Pavilion, Sungei Pang Sua Pavilion and the coastal trails, assessed impacts are manageable by the proposed environmental mitigation measures and monitoring plans.
Coastal trails and slope enhancement works shall be constructed in sections and phases with the considerations of bird migratory seasons and low impact construction methodologies.

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